# Factors related to resting energy expenditure and physical activity of 6–9-year old children in two primary schools in the City of Tshwane metropolitan area

by

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## DECLARATION AND ETHICS STATEMENT

**Declaration:**

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I, Adeline Pretorius, declare that the thesis, which I hereby submit for the degree PhD Dietetics at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature: Date: 11 December 2020

Adeline Pretorius

**Ethics statement:**

The author, Adeline Pretorius, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the Policy guidelines for responsible research.

Signature: Date: 11 December 2020

Adeline Pretorius

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# ABSTRACT

**Factors related to resting energy expenditure and physical activity of 6–9-year-old children in two primary schools in the City of Tshwane metropolitan area**



by

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## Background

A lower resting energy expenditure (REE) has been suggested to partially explain the disproportionate prevalence of overweight/obesity among black African women, yet no studies have investigated the REE of South African (SA) children. Similarly, physical activity (PA) as a modifiable factor related to childhood energy expenditure is under-researched in the local context.

## Aim

To determine the relationship between sex and population group (determinant factors), on the one hand, and REE and PA (outcomes) of 6–9-year-old SA children attending two primary schools in the City of Tshwane metropolitan area, on the other, taking phenotypic characteristics as confounders (mediating factors) and the study context into account.

## Methods

In a cross-sectional study with quota sampling, the REE of 6–9-year-old children attending two urban schools in SA was measured with indirect calorimetry (IC), and PA with a pedometer. Multifrequency bioelectrical impedance analysis was used to assess body composition (BC) (fat-free mass [FFM], FFM index, fat mass [FM] and FM index). Multivariate regression was used to calculate REE and PA adjusted for phenotypic confounders (z-scores of weight-for-age, height-for-age and body mass index-for-age, and BC). Sex and population differences in REE and PA (measured and adjusted) were determined with two-way ANOVA.

**Results**

Ninety-four healthy children (59.6% girls; 52.1% black African) with similar socio-economic status and access to PA participated in the study. Despite variations in BC, sex differences in REE were not significant (41 kcal/day ≈ 172 kJ/day; $P = 0.375$). The REE in black African participants was significantly lower than in their white counterparts (146 kcal/day ≈ 613 kJ/day; $P = 0.002$). When adjusting for BC, population differences in REE declined, especially after adjustment for FFM (91 kcal/day ≈ 382 kJ/day; $P = 0.039$), but remained clinically significant. Average steps/day in girls (10212 [9519;10906]) was lower than in boys (11433 [10588;12277]) ($P = 0.029$), and lower in black African (9280 [8538;10022]) than in white (12258 [11483;13033]) ($P < 0.001$) participants. No significant relationship ($r = 0.05$; $P = 0.651$) was observed between REE and PA.

**Conclusion**

Within the context of a similar SES and PA environment, the REE and PA of black African children was lower than white. Differences in REE between sexes were not significant, but girls had a lower PA than boys.

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# LIST OF ABBREVIATIONS

| Abbreviation | Meaning |
|---|---|
| AEE | Activity-related energy expenditure |
| ANOVA | Analysis of variance |
| ATP | Adenosine Triphosphate |
| BC | Body composition |
| BIA | Bioelectrical impedance analysis |
| BIVA | Bioelectrical impedance vector analysis |
| BMI | Body mass index |
| BMI-FA | BMI-for-age |
| BMR | Basal metabolic rate |
| $CO_2$ | Carbon dioxide |
| CSHQ | Community Survey Household Questionnaire |
| CV | Coefficient of variation |
| DEXA | Dual-energy X-ray absorptiometry |
| DLW | Doubly labelled water |
| EPOC | Excess post-exercise oxygen consumption |
| FAO | Food and Agriculture Organization |
| FFM | Fat-free mass |
| FFMI | Fat-free mass index |
| FM | Fat mass |
| FMI | Fat mass index |
| HFA | Height-for-age |
| IC | Indirect open-circuit calorimetry |
| LOA | Limits of agreement |
| ISAT | The international study of childhood obesity, lifestyle and environment school audit tool |
| LMIC | Low- and middle-income country |
| mBCA | Medical Body Composition Analyzer |
| MVPA | Moderate- to vigorous-intensity physical activity |
| NCD | Noncommunicable disease |
| NFCS-FB-1 | South African National Food Consumption Survey Fortification Baseline |
| $O_2$ | Oxygen |
| PA | Physical activity |

| Abbreviation | Meaning |
|---|---|
| PAQ | Physical activity questionnaire |
| PAQ-C | Physical activity questionnaire for older children |
| REE | Resting energy expenditure |
| RER | Respiratory exchange ratio |
| RMR | Resting metabolic rate |
| RQ | Respiratory quotient |
| SA | South/Southern Africa(n) |
| SANHANES-1 | First South African National Health and Nutrition Examination Survey |
| SD | Standard deviation |
| SDQ | Sociodemographic questionnaire |
| SES | Socio-economic status |
| SMS | Short message service |
| SS | Steady state |
| Stat SA | Statistics South Africa |
| TBW | Total body water |
| TEE | Total energy expenditure |
| TEF | Thermic effect of food |
| TV | Television |
| UNU | United Nations University |
| $VO_2$ | Oxygen consumption/uptake |
| $VCO_2$ | Carbon dioxide production/release |
| WFA | Weight-for-age |
| WHO | World Health Organization |

# CHAPTER 1: BACKGROUND AND OVERVIEW OF THE STUDY

## 1.1 INTRODUCTION

Overweight and obesity is a form of malnutrition caused by imbalances in a person's intake and energy expenditure.(1) For young children, being overweight or obese can have direct physical and mental health effects and is considered a major risk factor for diet-related noncommunicable diseases (NCDs) during adulthood.(2) Overnutrition is a rising epidemic worldwide, particularly in urban settings, and children are increasingly affected.(1) Although overweight and obesity affect all populations, it is evident that some population groups, e.g. black Africans and African Americans, are disproportionally affected.(3, 4) There is a great need in South Africa (SA) to better understand overweight, obesity and NCDs and the related risk factors and to transform this information into effective healthcare policies, programmes and services.(5) Many studies(6-11) suggest that lower resting energy expenditure (REE) may be a contributing factor for the higher prevalence of overweight and obesity in black African/African American individuals. Additionally, the degree of African versus European ancestry may have an amplified effect on REE, meaning that black African groups from Sub-Saharan countries may have an even lower REE than African American groups, thereby increasing their risk of overweight and obesity.(12, 13)

Dietary energy recommendation is based on determining the energy required from food intake that corresponds with energy expenditure to reach an energy balance and maintain growth in children.(14, 15) Although the direct measurement of energy expenditure is the most accurate method to determine energy requirements, the equipment required is costly, time-consuming and often unavailable, especially in low- and middle-income countries (LMIC), including SA. Subsequently, prediction equations based on variables such as weight, height and body composition (BC) have been developed to determine REE and can be used with activity-related energy expenditure (AEE) to estimate an individual's total daily energy expenditure (TEE). Prediction equations were derived by assessing the REE of mainly the white American population, and population group was not taken into consideration.(15, 16) Many international studies(16-18) have confirmed that these prediction equations may not be accurate in estimating the REE of all population groups, and there is a need to develop equations that can accurately predict REE for various populations, thereby improving population-specific nutritional intervention. Extension of research to investigate the REE in Sub-Saharan population groups is limited.[12] In SA, two recent studies in the Department of Human Nutrition at the University of Pretoria found lower REE in black African adults compared to their white counterparts and identified that the most generally used prediction equations do not provide satisfactory results across these population groups.[19, 20] Studies to determine differences in REE between children of various population groups are also limited to the African American and white populations and have resulted in varied outcomes.[6, 7, 9, 10, 21-23] There are no known studies that have investigated the REE of Sub-Saharan African children. There is a need for further research to investigate REE and the importance of factors related to REE as variables to adequately predict the energy requirements of children in SA and provide a preliminary indication of whether differences in REE "acquired" later in life (during adulthood) are due to socio-economic status (SES) or whether they already exist at a relatively young age.

Apart from REE, physical inactivity also tracks to obesity[24] and the World Health Organization (WHO) therefore declared action to reduce malnutrition in all its forms through nutrition and physical activity (PA).[25] In SA, at least 50% of children are not meeting the recommended levels of PA,[26] and children from various population and socio-economic groups appear to have different PA levels with inter-population differences.[27-29] Since obesity originates in childhood and presents differently in various populations,[3] the understanding of PA patterns and the related effects on energy expenditure in children from different population groups is important for effective population-specific PA intervention.[2, 24, 26, 27] The direct measurement of AEE would provide the most accurate information when determining energy requirements for PA and the effect on energy balance, but these measurements are often impractical, costly and not always available, especially when assessing children. Cost-effective tools such as pedometers and PA questionnaires (PAQs) are increasingly being used as alternatives to assess PA patterns and rank PA levels of groups but cannot be used to assess AEE.[30] Pedometers measure ambulatory PA in terms of step counts. Since the majority of PA includes walking or running, it is often used to represent habitual PA. Recent interest has emerged in the use of pedometers and steps/day indices associated with health outcomes.[30-32] However, further population-specific research and refinement is required before these recommendations can be widely applied.[32] In SA, many studies have used PAQs to determine the PA of children.[29, 33, 34] However, PAQs may include a high degree of error and the use of complementary methods, especially for children, is advised.[30, 35, 36]

Theoretical arguments exist that exercise regimens do not sufficiently increase TEE to reverse obesity. However, practical experience indicates that increased PA is successful in achieving and sustaining weight reduction.[37] This suggests that there are additional metabolic effects of PA on energy balance that may magnify the effects of the energy expended on PA alone. A suggested mechanism may be a positive effect of PA on REE that may increase the energy imbalance above that generated by PA alone.[11, 12, 37, 38] Some evidence exists[8] that habitual PA may independently influence REE and that the population group may be an independent predictor of these effects. Overall, there is inconclusive research on the relationship between PA and REE.[8, 38]

## 1.2 PROBLEM STATEMENT

Overweight, obesity and NCDs may originate in childhood. Since children are the future generation, population-specific and timely nutrition and PA intervention will contribute to the future health of all population groups.[2] A lower REE has been identified as a possible reason for the higher incidence of obesity among black African/African American adults.[11] However, it is unclear whether differences in REE originate in childhood since studies investigating REE among children are limited, have delivered varied results and are mainly restricted to African American and white populations.[6, 7, 9, 10, 21-23] Accurate determination of REE serves as the foundation for effective nutrition intervention, but the available REE equations have been developed mainly for white populations and may not be applicable to all population groups.[16-18]

Resting energy expenditure and AEE are major determinants of TEE. To effectively provide nutritional and PA interventions, AEE cannot be separated from REE.[14]

Physical activity is associated with an increase in AEE and evidence suggests an additional metabolic effect of PA on REE that may increase the energy balance; however, a limited number of studies have investigated this relationship, with none performed in SA.[11, 12, 37, 38] There is a need to further investigate the relationship between PA measurements on REE and the effects of sex, population groups, SES, BC and body weight categories on these measurements and their interrelationship, to provide insight into the energy expenditure of SA children.

## 1.3 RESEARCH AIM AND OBJECTIVES

Aligned to Figure 1-1, the study has the following aim and objectives:

**Aim**:

To determine the relationship between sex and population group (determinant factors), on the one hand, and REE and PA (outcomes) of 6–9-year-old SA children attending two primary schools in the City of Tshwane metropolitan area, on the other, taking phenotypic characteristics as confounders (mediating factors) and the study context into account.

**Primary objectives:**

To describe (by sex and population group) in 6–9-year-old SA children attending two primary schools in the City of Tshwane metropolitan area the

- REE measured with indirect open-circuit calorimetry (IC)
- REE predicted with equations
- number of steps per day measured with a pedometer (objective PA)
- "physical activity questionnaire for older children" (PAQ-C) activity score before and after pedometer measurement (subjective PA)
- relationship between measured REE and objectively measured PA (number of steps per day)

**Secondary objectives:**

For 6–9-year-old SA children attending two primary schools in the City of Tshwane metropolitan area:

- To describe the contextual factors:

- Age
- School built environment
- SES

- To describe (by sex and population group) the phenotypic mediating factors:

  - Anthropometric measures (weight-for-age [WFA] z-score; height-for-age [HFA] z-score and body mass index-for-age [BMI-FA] z-score)
  - Weight categories (healthy, overweight and obese)
  - BC (Fat-free mass [FFM], Fat-free mass index [FFMI], Fat mass [FM], Fat mass index [FMI])

- To determine the relationship between each phenotypic characteristic and

  - REE
  - PA

- To analyse the diagnostic accuracy of REE prediction equations.

Figure 1-1 illustrates the outline of the study, with the grey shaded areas indicating the objective measurements used to determine the relationship expressed in the study aim.

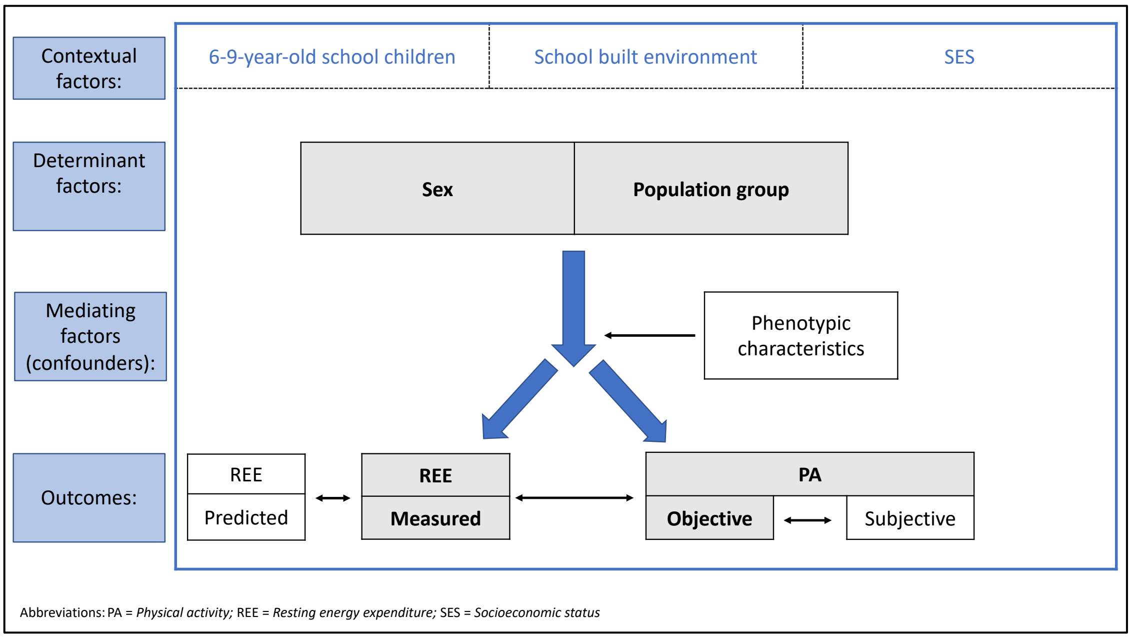


**Figure 1-1:** Study outline

## 1.4 IMPORTANCE AND BENEFITS OF THE STUDY

- This is the first known study to investigate the REE of children in SA.
- Measuring and comparing the REE and PA measurements between SA children of different sex categories and population groups will contribute to an understanding of the problem of overweight and obesity that disproportionally affects black African groups in SA.
- Investigating REE of SA children of different sex categories and population groups may contribute to the need to develop sex- and population-specific prediction equations to accurately determine REE for effective nutrition intervention.
- Establishing PA profiles of SA children of different sex categories and population groups by means of replicable cost-effective measurements, and investigating the relationship between REE and PA measurements, will provide insight into the energy expenditure of the study population. This can serve as a foundation for clinicians and dietitians to determine population-specific PA recommendations to plan effective nutritional and PA intervention strategies.

## 1.5 DELIMITATIONS AND ASSUMPTIONS

Delimitations and assumptions for the study are summarised below.

### 1.5.1 Delimitations

- 6–9-year-old SA children, i.e. born during 2010, 2011 or 2012 and attending the two selected primary schools in the City of Tshwane metropolitan area.
- PA was determined with an objective and subjective tool, i.e. Yamax Digi-Walker spring-levered pedometer and the PAQ-C.
- REE was measured with IC.
- BC, including FFM and FM was determined with prediction equations using bioelectrical impedance analysis (BIA).

### 1.5.2 Assumptions

- The onset of puberty has not yet occurred for participants aged 6–9 years.
- Prediction equations to determine FFM developed for African American and white American children between the ages of 6 and 9 years can be used to determine the FFM of black African and white children in SA.
- SA as a LMIC relies on cost-effective tools and methods for the assessment of REE, BC and PA in most clinical settings.
- White population groups in SA are of European descent.
- Parental report of population group can be used as good approximations of ancestral origin.

## 1.6 DEFINITION OF KEY TERMS

**Table 1-1:** Definition of key terms

| Key concept | Definition |
|---|---|
| Body composition (BC) | Body composition refers to an individual's body weight compartments, including (in the context of the two-compartment model) that of FM (fat from brain tissue, skeletal fat and adipose tissue) and FFM (water, protein and mineral components).[14]<br>In this study, BC was determined with BIA measurements at 50 kHz to obtain total body resistance (R) (Ω). The R values were used to calculate FFM with Horlick's[39] prediction equation. FM was calculated by subtracting the FFM from total body weight. |
| Contextual factors | Contextual factors refer to the setting in which the study was undertaken including the age range of participants (6–9 years), the school built environment and the SES of participating households. |
| Determinants factors | Determinant factors refer to the sex categories and population groups (black African and white SA boys and girls); both considered as possible determinants of REE and PA. |
| Mediating factors | Mediating factors refer to confounding factors, including phenotypic characteristics, that typically influence REE and PA of children and were taken into consideration when comparing the PA and REE between sex categories and between population groups. |
| Physical activity (PA) | Any bodily movements, both voluntary and involuntary, produced by the contraction of muscles causing an increased energy expenditure.[40] In this study PA refers to all physical activities that may cause an increase in energy expenditure as determined by the number of steps per day via a pedometer and the PAQ-C activity score. |

Table 1-1: Definition of key terms (cont'd)

| Key concept | Definition |
|---|---|
| Population group:<br>- Black African<br>- African American<br>- White | In health-related research the term "race" is often used to group populations according to shared biological characteristics, including genes, skin colour and observable features. The term "ethnicity" is typically used to describe cultural and social aspects rather than biological features. However, both race and ethnicity include a mix of interrelated social and biological constructs and classification of groups are challenging.(3, 41)<br>In SA, Statistics SA (Stats SA) categorise people based on self-report in terms of five "population groups" as black African, white, Indian or Asian, Coloured or Other.(42) Self-identification of race and population categories by subjects can be used as good approximations of ancestral origin.(3)<br>For this study, the term "population group" is used and refers to categories used by Stats SA(42), based on parental report of black African, White, Indian or Asian, Coloured or Other .<br>Based on Stats SA classification,(42) "black African" refers to individuals of Southern African descent.<br>"African American" refers to American individuals of African descent. The term is generally used in international studies. (The term is added for informational purposes; this population group is not included in the study.)<br>The term "white" population group refers to white-skinned individuals of European descent and is used interchangeably with the term Caucasian in international studies. For this study, the term "white" is used, consistent with the Stats SA classification.(42) |
| Resting energy expenditure (REE) | The rate of energy expenditure when a person is at rest, i.e. awake in a post-absorptive, thermoneutral state, and have abstained from exercise for typically 12 hours; expressed as kcal or kJ per 24 hours.(14)<br>In this study, IC is used to measure REE. |
| School built environment | Children spend a great amount of time at school and the school built environment and surrounding areas are often used as the primary environmental determinant to describe access and opportunities that may influence their PA.(43)<br>The international study of childhood obesity, lifestyle and environment(44) school audit tool (ISAT)(45) was used in this study to collect information regarding the school built environment. |
| Socio-economic status (SES) | A combined economic and sociological measure of an individual or groups. Stats SA uses the Community Survey Household Questionnaire (CSHQ) to collect SES information regarding a household's social profile, household characteristics, housing conditions, access to basic services, economic participation and income, health and wellbeing and education and skills, and to categorise SES based on income.(46) For this study, SES classification will be an educational- and income-based indicator as used by Stats SA as a proxy for SES. |
| Southern African | Southern African refers to an individual with a nationality from a country that lies south of the equator, including Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, SA, Swaziland, Zambia and Zimbabwe.(47) |

Table 1-1: Definition of key terms (cont'd)

| Key concept | Definition |
|---|---|
| Steady state (SS) | The concept of steady state (SS) was introduced to improve the accuracy of REE measurements with IC.[48]<br>In this study, a machine-indicated SS was used, which refers to the SS displayed by the Quark RMR software and defined by Cosmed[49] as a time period when the average minute oxygen consumption ($VO_2$) and carbon dioxide production ($VCO_2$) changes by less than 10% and the average respiratory quotient (RQ) changes by less than 5%.[48, 49] |
| Weight categories | BMI-FA z-scores were used to categorise participants into weight categories based on the 2007 WHO growth reference data.[50] Participants were classified as:<br>- Thin when BMI-FA < -2 SD (standard deviation) of the median<br>- Healthy when BMI-FA ≥ -2 and ≤ 1 SD of the median<br>- Overweight when their BMI-FA is > 1 SD and ≤ 2 SD of the median<br>- Obese when their BMI-FA is > 2 SD of the median. |

# CHAPTER 2: LITERATURE REVIEW

A comprehensive review of the literature is presented in this chapter and follows the outline as shown in Figure 2-1.

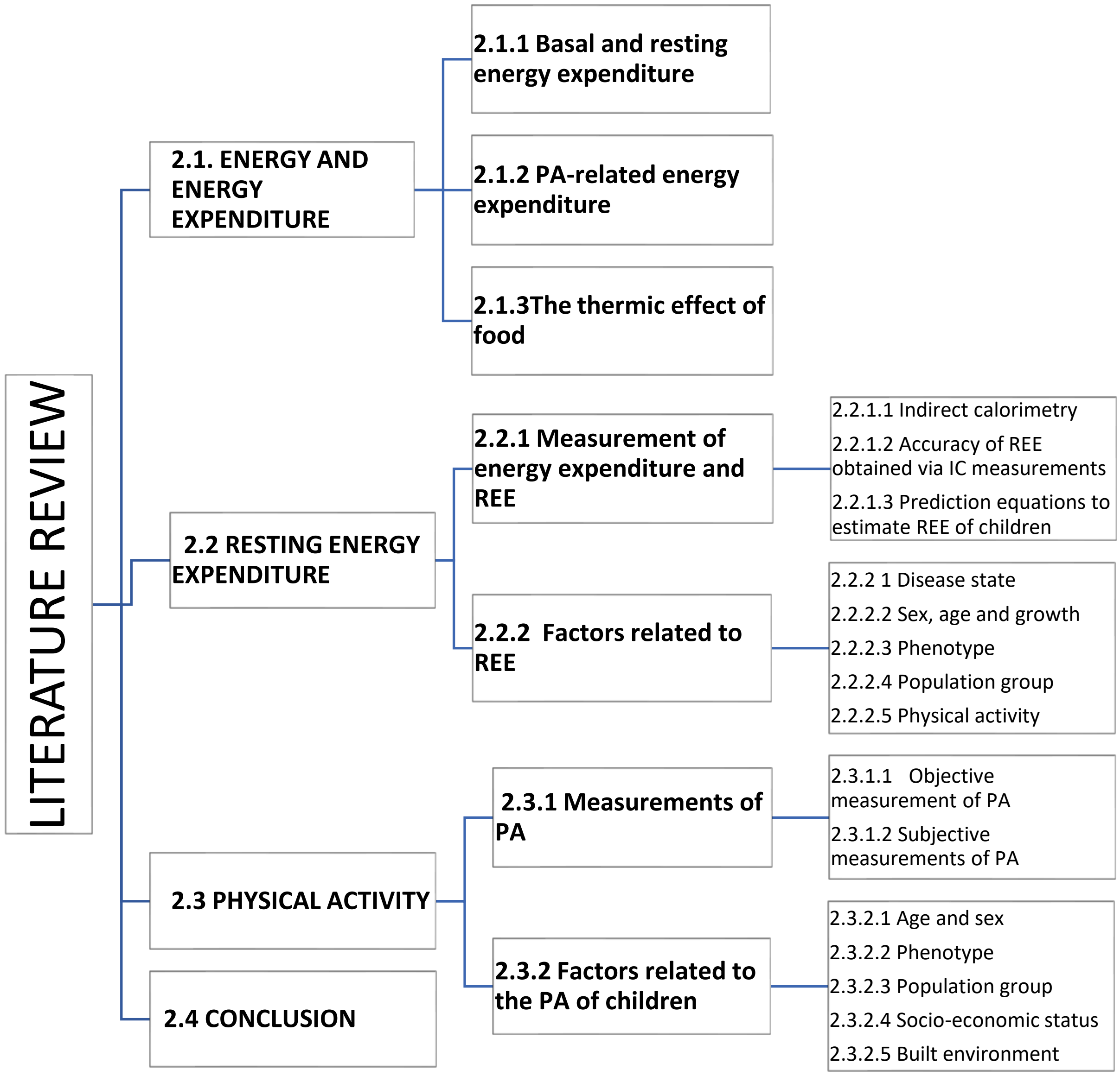


**Figure 2-1:** Outline of chapter 2

## 2.1 ENERGY AND ENERGY EXPENDITURE

Energy is required by the body to perform physical actions and to sustain the body's functions. This energy is supplied by macronutrients in the diet, including carbohydrates and alcohol, fats and proteins. The process of converting food into energy is referred to as the body's energy metabolism.[14, 43]

Energy metabolism involves a variety of complex biochemical pathways that enable the body to use or store energy. The determination of whether the energy in foods is used for fuel or stored for later use comes down to the balance between energy intake and energy expenditure. When energy intake exceeds expenditure, a positive energy balance occurs, causing an increase in body weight. In contrast, when energy expenditure exceeds intake, a negative energy balance occurs that may lead to weight loss. Consequently, dietary energy recommendation is based on the accurate determination of energy required from food intake that corresponds with energy expenditure to achieve an energy balance in adults and to maintain growth in children.[14, 40]

To predict energy requirements for weight maintenance and growth, the reported energy intake could, in principle, be used. However, it is widely recognised that energy intake assessed via dietary surveys underestimates usual energy intake,[51] and it is therefore not appropriate to base energy requirements on self-reported food consumption data. Alternatively, measurements of energy expenditure are generally used to determine energy requirements.[40]

Energy is mainly released in the body by the process of oxidation (combining organic nutrients with oxygen [$O_2$], while releasing carbon dioxide [$CO_2$] and water) to maintain a steady supply of chemical energy in the form of adenosine triphosphate (ATP). Adenosine triphosphate is a high-energy compound used to fuel the body's functions while at the same time producing heat. The production of heat, known as thermogenesis, can be measured to establish the amount of energy expended.[14]

Total energy expenditure refers to anything that requires the body to expend energy such as physiological functions, depositing new tissue, thermoregulation, voluntary and involuntary muscular contraction (e.g. peristalsis, maintaining posture) and movement (e.g. sports, walking).[14] Total energy expenditure can be divided into three main categories:

### 2.1.1 Basal and resting energy expenditure

The basal metabolic rate (BMR) refers to energy expended to sustain the body's life functions such as breathing, circulation, nerve function and muscle tone. Basal metabolic rate is usually expressed as kilocalories or kilojoules per kilogram body weight per hour (kcal/kg/hr or kJ/kg/hr; 1 kcal ≈ 4.2kJ) when an individual is at complete digestive, physical and emotional rest.[14] The accurate measurement of BMR is challenging since individuals are rarely in a state of complete rest. Consequently, the resting metabolic rate (RMR), approximately 10 – 20% higher than the BMR, is often used and indicates the rate of energy expenditure when a person is at rest in a comfortable setting, i.e. awake in a post-absorptive, thermoneutral state, and have abstained from exercise for about 12 hours. Resting energy expenditure (kcal/day) refers to RMR extrapolated to 24 hours and is the dominant source of energy expenditure contributing to more than 50 – 70% of TEE. In clinical practice, measurement or prediction of REE is generally used as the baseline to determine energy requirements.[14, 40, 52]

### 2.1.2 PA-related energy expenditure

Physical activity-related energy expenditure (AEE) is defined as the increase in metabolic rate that results from using skeletal muscle for any type of voluntary and involuntary bodily movement. Activity-related energy expenditure is the second-largest and most variable component of TEE and is affected by many factors, including muscle mass, body weight and the duration, frequency, intensity and type of activity.[14]

### 2.1.3 The thermic effect of food

When a person eats, the activity of the digestive and absorptive systems accelerates and elicits an increase in energy expenditure, referred to as the thermic effect of food (TEF).[14] For most purposes, the TEF is considered a constant 10% of TEE or is often even disregarded when assessing energy expenditure because its influence on TEE is smaller than the typical errors involved in estimating energy requirements especially in a fasted state.[14]

## 2.2 RESTING ENERGY EXPENDITURE

### 2.2.1 Measurements of energy expenditure and REE

2.2.1.1 Indirect calorimetry

For measurements of energy expenditure to be meaningful in practice, energy expenditure needs to be stated as a unit of energy. Since energy expenditure encompasses thermogenesis, the amount of heat is generally measured to determine the amount of energy expended and is often expressed as calories, a heat unit that refers to the amount of heat energy required to raise the temperature of 1 L of water by 1°C.[14] Direct calorimetry measures the total heat released by the body as a result of energy metabolism. Although highly accurate, this measurement is technically challenging, high in cost, impractical and rarely used currently. Subsequently, indirect calorimetry was developed. All energy-releasing reactions in the body depend on $O_2$. Because a direct relationship exists between $O_2$ consumed and the amount of heat released by the body, the measurements of $VO_2$ can provide an indirect, yet highly accurate, estimation of energy expenditure.[52, 54] The gold standard is the doubly labelled water (DLW) technique that uses isotopes for the measurement of $VCO_2$ to calculate TEE in a free-living environment. However, DLW requires sophisticated laboratory analysis and is very costly.[52, 55]

Indirect open-circuit calorimetry is the most practical and widely employed method used to determine REE.[55] In an open-circuit system, the subject inhales air, and the exhaled gases are then analysed. Ventilated open-circuit systems allow for the least complex approach to collecting expired gas by using a ventilated mouthpiece, mask or transparent hood connected to an $O_2$ and $CO_2$ analyser mounted on a mobile cart. Through a unidirectional valve situated in the ventilated canopy/mask, the calorimeter collects and quantifies the volume and concentration of $O_2$ inhaled and $CO_2$ exhaled by the subject to determine the respiratory exchange ratio (RER; also referred to as the RQ for individuals at rest). The RER allows for the quantification of $VO_2$ and $VCO_2$ to determine the heat production of the energy-yielding macronutrients using Weir's equation.[56] Results are displayed in a software program attached to the system.[52, 57] These devices, known as metabolic carts, are non-invasive, relatively low in cost and easy to operate. The gaseous sampling attachment/mixing chamber however, limits movement and restricts study duration to just a few hours and is therefore most appropriately used to determine REE.[52, 58]

More recent IC makes use of advanced technology with micro-mixing chambers and high precision gas analysers. The devices involved are portable and more convenient due to larger mixing chambers being eliminated. Additionally, a shorter measurement time is required, and the devices can be used without warm-up time or regular calibration. Developments are still underway, but devices could potentially be used to measure energy expenditure accurately in various clinical and research settings.[55, 59]

#### 2.2.1.2 Accuracy of REE obtained via IC measurements

Determining REE utilising IC metabolic carts involves the measurement of RMR over a short period (generally less than 60 min) extrapolated to represent the 24-hour REE, which may introduce significant error.[52] To improve the degree to which the shorter measurement accurately represents REE, the concept of steady state (SS) was introduced. Steady state represents a state of complete rest. It is defined as a period during which average minute $VO_2$ (ml/min), $VCO_2$ (ml/min) and the RQ ($VO_2/VCO_2$) change by less than a predetermined percentage range (generally between a 4 and 25 min interval during which the average minute $VO_2$, $VCO_2$ or RQ changes by less than 5 – 10%).[48, 55, 60-62] Achieving SS during IC is recommended to improve validity and reduce error from artefactual influences. Evidence-based measurement protocols are therefore advised to ensure the individual has reached a resting state.[48] Currently, although graded as weak evidence, the Evidence Analysis Library of the Academy of Nutrition and Dietetics recommends IC measurement in adults involving a 30-min rest period before IC, discarding the first 5 min of the measurement and achieving a period of 5 min with a coefficient of variation (CV) ≤ 10% for gas exchange. These measurement periods may continue for 20 min or beyond.[48] In contrast, although weak, evidence exists[62] that an extended SS interval of 5 min may unnecessarily prolong the duration of IC testing, without significantly improving the overall validity of the test. Furthermore, a recent review[55] suggested that if an SS is obtained after 15 min of measurement, there is no need to prolong the test. Alternatively, a pre-set period between 3–4 min has been reported to be accurate, especially in research settings, when the effect of random measurement error is reduced with larger samples.[61, 62]

At present, the Evidence Analysis Library of the Academy of Nutrition and Dietetics recommends the following guidelines for IC measurements of healthy adults to achieve an SS and improve measurement accuracy:[48]

- Rest quietly for 30 min prior to measurement:
    - When subjects enter the assessment unit, it is essential to return to a resting level before taking the measurements. Studies investigating the length of the rest period required before taking REE measurements, identified that a resting condition can occur within 20 min in many adults if they remain still. No significant differences in mean REE were found between adults who slept at the facility and those sleeping at home and commuting to the facility.
    - Activities during the rest period, including laughing, reading and listening to music, may increase REE and should be avoided.
- Subjects should maintain a supine position and avoid fidgeting. Sitting, standing or even lying in an elevated position may increase REE.
- More evidence is required to compare gas-collection devices, but a ventilated hood/canopy appears to result in a lower REE. This may be due to increased subject comfort.
- The time of day does not appear to affect the measurement. No significant difference was detected between morning and afternoon measurements, but further studies are required.
- Lower room temperature ≤ 20°C is associated with a higher REE, and cold indoor room temperature may increase REE during winter compared to summer. A thermoneutral environment between 22 – 25°C has less effect on REE. No evidence exists regarding room conditions, including humidity, light and noise.

- The TEF on REE is complex. Additional research is required to determine the optimal fasting period before measurements to eliminate the TEF. A seven-hour fasting period is generally desirable, but if this cannot be achieved, researchers suggest a small meal (≤300kcal) can be ingested two hours before the measurement.
- Caffeine is known to increase REE, but the effects may vary and are likely to be dose- and product-dependent. Based on evidence, REE remains elevated for at least four hours after caffeine consumption; however, the length of time the REE remains elevated beyond this period remains unclear.
- Type and intensity of exercise may affect REE, but limited research has investigated the effect of light-intensity PA or moderate- to vigorous-intensity PA (MVPA) on REE. It is common practice to instruct individuals to refrain from exercise 12 – 24 hours before an REE measurement.
- RQ is often used to evaluate feeding protocol violation (i.e. not fasting) but has poor accuracy. The physiological range of RQ reflects cellular metabolism across the fed and fasted state at 0.67 to 1.3. If the RQ falls outside this range (<0.67 or >1.3), an error can be suspected and it is advised to repeat the measurement. Measurements between 0.68 and 0.90 can be expected for an individual who has fasted. If the RQ is between 0.91 and 1.3 in a healthy individual who has fasted, a problem with the measurement may be expected resulting from an error in calibration, a leak in the calorimeter, a ventilation problem or some other artefact or protocol violation.

Research on the best procedures in children is very limited[48] and consensus on a standardised protocol has not been reached.[48, 63] Measuring REE in young children presents an additional challenge because many children cannot rest quietly for the required time while the measurement is being taken. Although a longer measurement period is currently recommended for adults, prolonged measurements have been shown to increase restlessness in children. Shorter REE protocols of 20 min appear to be more suitable for children and have shown to be more accurate due to a reduction in boredom and consequent fidgeting.[48, 63]

### 2.2.1.3 Prediction equations to estimate REE in children

The actual measurement of energy expenditure is not feasible in most clinical settings, consequently predictive equations, usually based on age, sex, body weight and height, are used to calculate REE. The REE can then be used to estimate TEE when a person's AEE is known.[64, 65] The first prediction equations to estimate BMR were developed almost a century ago.[66] Although REE is considered a better indicator of daily energy expenditure, these pioneer studies often incorrectly referred to BMR to describe the amount of energy required to maintain bodily functions (hence the term BMR displayed in Table 2-1). Consequently, more recent studies refer to REE and BMR interchangeably.[67]

The development of the initial Harris and Benedict equations was based on IC-derived measurements only on white population groups and under stringent experimental conditions, which resulted in overestimating the BMR of free-living individuals. Despite its limitations, a simplified version[68] is still widely applied in clinical settings.[69] As development of various equations continued, the inaccuracy of these became more apparent, especially when applied to individuals of various characteristics and populations. Consequently, the Schofield[15, 70] and Oxford[16] equations (Table 2-1) were developed. These equations were age- and sex-specific and based on anthropometric measurements, including body weight and height. The Schofield equation was developed using a database of previous publications based on BMR measurements of European, especially Italian, and North American individuals. The Schofield analysis was later extended and adopted by the FAO (Food and Agricultural Organization)/WHO (World Health Organization)/UNU (United Nations University) expert consultation on Energy and Protein Requirements.[71] However, it was recognised that they generally overestimated the BMR of non-white populations. Considering this limitation, the Oxford equation was developed with the inclusion of a larger population range, including individuals from tropical regions.[16] Although the generalisation of these has since also been found to be limited, they are still primarily used by clinicians to estimate REE.[64, 72]

More recently, the use of BC has been suggested to improve the accuracy of REE prediction equations.[18, 64, 65, 72] Corresponding with this recommendation, Maffeis et al.[73] developed new prediction equations specifically for prepubertal children. Even though FFM was measured and considered the main predictor of REE, they concluded that their equations based on FFM along with age and gender, did not improve the accuracy of estimating REE.

**Table 2-1:** Prediction equations for estimating BMR of children aged 3–10 years

| Prediction equation: Name and reference | Sex and age category | Prediction equation |
|---|---|---|
| Harris-Benedict 1919[66] | Males | BMR (kcal/day) = (kg x 13.7516)+ (cm x 5.0033) – (yr x 6.755) + 66.475 |
| | Females | BMR (kcal/day) = (kg x 9.5634) + (cm x 1.8496) – (yr x 4.6756) + 655.0955 |
| Harris-Benedict 1984[68] | Males | BMR (kcal/day) = (kg x 13.397) + (cm x 4.799) – (yr x 5.677) + 88.362 |
| | Females | BMR (kcal/day) = (kg x 9.247) + (cm x 3.098) – (yr x 4.330) + 477.593 |
| Schofield (weight and height)[15, 70] | Males 3–10 years | BMR (MJ/day) = 0.082 x kg + 0.545 x m + 1.736 |
| | Females 3–10 years | BMR (MJ/day) = 0.071 x kg + 0.677 x m + 1.553 |
| Schofield (weight)[70] | Males 3–10 years | BMR (MJ/day) = 0.095 x kg + 2.110 |
| | Females 3–10 years | BMR(MJ/day) = 0.085 x kg + 2.033 |
| FAO/WHO/UNU[71] | Males 3–10 years | BMR (MJ/day) = 0.0949 x kg + 2.07 |
| | Females 3–10 years | BMR (MJ/day) = 0.0941 x kg + 2.09 |
| Oxford (weight)[16] | Males 3–10 years | BMR (MJ/day) = 0.0937 x kg + 2.15<br>BMR (kcal/day) = 23.3 x kg + 514 |
| | Females 3–10 years | BMR (MJ/day) = 0.0842 x kg + 2.12<br>BMR (kcal/day) = 20.1 x kg + 507 |
| Oxford (weight and height)[16] | Males 3–10 years | BMR (MJ/day) = 0.0632 x kg + 1.31 x m + 1.28<br>BMR (kcal/day) = 15.1 x kg + 74.2 x m + 306 |
| | Females 3–10 years | BMR (MJ/day) = 0.0666 x kg + 0.878 x m + 1.46<br>BMR (kcal/day) = 15.9 x kg + 210 x m + 349 |
| Maffeis[73] | Males | REE (kJ/day) = 28.6 x kg + 23.6 x cm – 69.1 x yr + 1287 |
| | Females | REE (kJ/day) = 35.8 x kg + 15.6 X cm – 36.3 x yr + 1552 |

BMR = *Basal metabolic rate*; cm = *centimetre*; kcal = *kilocalories*; kg = *kilogram*; MJ = *megajoules*; m = *meter*; REE = *Resting energy expenditure;* yr = *years*

It is difficult to establish the best formula for calculating BMR or REE because of contradictory results. It has been suggested that additional factors such as BC, metabolic stress, muscle tone, medication, body temperature and population may influence REE, and predictive equations should be applied to meet the characteristics of the target group.[10, 18, 64, 65] Despite the recommendation that a single prediction equation cannot be used across various groups and populations, there are no known prediction equations available to determine the REE of black African populations.

### 2.2.2 Factors related to REE

Resting energy expenditure primarily depends on disease state, sex, age and growth, as well as BC, particularly FFM and FM. Protein-energy status and PA are modifiable factors that may affect REE, and several studies investigated population group as an additional factor.[6, 7, 74-76] To accurately determine REE, it is essential to consider the factors that may influence REE in children and to facilitate intergroup comparison. Consequently, these factors will be discussed in more detail.

#### 2.2.2.1 Disease state

Conditions that can lead to changes in muscle mass, e.g. chronic illness, anorexia nervosa, or other factors associated with illness such as inflammation, malignancies, neurological impairments and medication (e.g. medication to treat attention deficit disorder, epilepsy, asthma, cardiac conditions, diabetes, medication that contains caffeine or stimulants etc.), may increase REE. [63, 64]

#### 2.2.2.2 Sex, age and growth

Goran et al.[74] performed one of the first studies to examine a large sample of factors affecting REE in young children and found a significantly higher REE in boys compared to girls. Many subsequent studies have confirmed these findings, and added that the REE of boys remained significantly higher than in girls, even after adjustments were made for differences in body size and BC.[75, 76] A meta-analysis by Hermann et al.[76] further reported that the absolute and relative REE for boys remains higher than for girls at any specific age, with a linear increase in absolute REE as the child ages. However, in contrast with their findings, many studies focusing only on prepubertal children did not identify age as the strongest predictor of REE before the onset of puberty.[73-75]

### 2.2.2.3 Phenotype

Phenotype refers to the observable features, including physical appearance or symptoms, of a disease or condition caused by the interaction between genes and the environment.(77) Although research is still ongoing, it has been recognised that weight status and BC may be determined by the interaction of various genetic, metabolic, environmental and behavioural factors and are therefore often referred to as phenotypic characteristics in health and nutrition-related research.(78, 79) For this study, body weight and size (anthropometric measures) and BC are collectively referred to as phenotypic characteristics.

Phenotype has repeatedly been identified as a major determinant of REE.(52, 76, 80) Initial pioneer studies focused mainly on the influence of external anthropometric features, including weight and height, but with the development of BC measurements, research extended to the effect of body compartments such as FM and FFM on REE.(80)

**Anthropometry**

Anthropometry refers to the measurement of body size, weight and proportions and is often used as an indicator of an individual's weight status that may be related to health outcomes.(81) However, since absolute weight measurements are influenced by height, body mass index (BMI) (body weight in kg divided by height in metres squares = kg/m$^2$) has been introduced as an index of weight status minimally affected by height. A BMI between 20–25 kg/m$^2$ is considered a healthy weight for adults.(1)

For children, age and age-related growth need to be considered when assessing protein-energy status and defining body weight categories. Consequently, age-specific WHO growth reference data were developed for the interpretation of weight and height measurements and to categorise BMI.(82) Measurements are compared to the median of the WHO child growth reference and expressed as a z-score or SD of the median. The z-score of most children is expected to be between -1 and 1 SD, with cut-off values set at less than -2 SD and at 2 SD or greater.(50)

For children aged 5–10 years, a set of reference data for a WFA z-score is available and can be used to identify under- and overnutrition. Beyond the age of 10 years, the pubertal growth spurt occurs and WFA cannot distinguish between the effect of height and weight on growth. Reference data are therefore not available beyond this age. A set of HFA reference data is available for children aged 5–19 years. It can be used to identify stunting (z-score < -2), whereas the BMI-FA reference data set can be used to identify malnutrition, overweight or obesity. Although the WHO does not define a healthy BMI, a BMI-FA greater than -2 SD of the median, and 2 SD or less of the median, is associated with a lower health risk.[2]

Although body size and BMI are related to REE, it is specifically the FFM component of body weight that has repeatedly been identified as the strongest predictor of REE.[9, 74] Since body weight and BMI measurements cannot distinguish between the weight of FM or FFM,[83] BC analysis is advised when investigating factors related to REE.[11, 64, 75, 76]

**Body composition**

Body composition refers to an individual's body weight compartments, including (in the context of a two-compartment model) that of FM (fat from brain tissue, skeletal fat and adipose tissue) and FFM (water, protein and mineral components).[14] It is generally accepted that BC is a major determinant of REE, with the size of the metabolically active FFM being the most significant.[11, 75, 76] Fat-free mass refers to total body weight, including tissues and organs, excluding the weight of its fat mass.[14] Although organs account for only about 7% of body weight, they contribute to approximately 60% of TEE. Therefore, the organs are more metabolically active, i.e. the largest consumers of energy at rest with the liver expending approximately 29% of TEE, followed by the brain at 19% and skeletal muscle consuming approximately 18%. Skeletal muscle and FM account for 35–40% of total body weight, while contributing approximately 18–20% and 3–4% respectively to REE.[40, 75] Several studies[40, 75, 76, 84, 85] have confirmed that REE is related to FFM, with some[74-76, 86] indicating that FM or the distribution of FM may influence REE. However, investigations on the distribution of FM have been mainly performed on adults.

Although it is generally accepted that a correlation exists between FFM and REE, the relationship is not stable and the REE per unit of FFM is not constant over the whole range of FFM.[11, 87, 88] This may be explained by the composition of FFM. Skeletal muscle and organ mass differ substantially with respect to their masses and growth rates, especially during childhood, as well as in their individual rate of energy expenditure. Therefore, body size variations in REE are considered to be caused by the proportional contribution of different organ mass and FFM and variations in organ metabolic rate, i.e. diverse metabolically active organs within FFM.[18, 87] Additionally, growth affects FFM composition (i.e. the metabolically active organs within FFM) and further adds to variation in the REE-BC relationship.[11]

These results confirm the importance of careful interpretation of REE measurement results and suggest compartmentalisation of FFM when designing or interpreting studies. Although in practice REE needs to be related to FFM in general for appropriate interpretation, it is recommended that when REE is outside a population-specific ±10% prediction range (e.g. during malnutrition, obesity, acute or chronic disease states) the REE should be related to a measure for distinguishing metabolically active FFM.[87]

The gold standard method for determining BC is the four-compartment model, which uses body weight, total body volume, total body water (TBW) and bone mineral content. These measurements require costly, specialised equipment, however, and are not feasible in many settings. Alternatively, various laboratory methods based on two- or three-compartment models have been developed to measure BC in adults and children, such as dual-energy X-ray absorptiometry (DEXA), hydrodensitometry (underwater weighing), air-displacement plethysmography, and single- and multifrequency BIA. These methods provide an indirect measure of BC based on assumptions that convert raw data into measures of TBW, FFM, FM or body fat percentage. Measurements needed for these calculations may vary greatly depending on the method and the subject's age, gender, race and health condition.[89] Bioelectrical impedance analysis has gained popularity as a practical measure of BC in field studies involving children, but the research area, especially for children, is still evolving. Although BIA is susceptible to imprecision compared with the four-compartment model, it is relatively inexpensive, simple, quick and non-invasive and it is the method most generally used to determine BC in children and adults.[89-91]

With the BIA methods, a low-level, harmless alternating electrical current is passed through the human body, and the impedance (Z), or opposition to the flow of current, is measured with a BIA analyser. In the human body, lean tissue is a good electrical conductor because it contains large amounts of water and electrolytes. Fat is anhydrous and therefore a poor conductor. Electrodes are placed or held on the body, spanning a region for measurement. The BIA device measures the impedance to the flow of the current as it passes through the body. The opposition (impedance) to the flow of the current varies from tissue to tissue. When the volume of water and electrolytes is large, the current flows more easily through the body with less resistance, i.e. low impedance. Fat and bone provide more resistance (R), i.e. high impedance. Based on these measurements, BIA can provide estimates of BC parameters by using prediction equations.(90, 91)

The use of different frequencies during BIA measurement allows for the division of the estimated TBW into intra- and extracellular fluid, thereby improving the accuracy of measurements. However, a systematic review by Chula de Castro et al.(93) reported that most of the BC equations available for children and adolescents were based on the use of a single 50 kHz frequency. Consequently, most studies have used equipment delivering a single-frequency alternating electrical current (50 kHz) to enable the calculation of BC for children. Although it was reported that octa-polar multifrequency BIA was superior to single-frequency BIA for the prediction of FFM in children,(92) only 5 of the reviewed studies used multifrequency BIA and the algorithms used were not disclosed, thereby limiting the use of multifrequency BIA in subsequent studies.

To date, although restricted to single-frequency, various validated equations are available for the estimation of TBW, FFM, FM and body fat percentage among children. However, these equations were developed based mainly on white population groups and were less accurate when applied for different populations, ages and sex groups.(91) One known South African study(182) on prepubertal black African children was recently undertaken to determine the agreement between FFM measured by DEXA and FFM calculated from prediction equations published in the literature. No published equation was identified as being suitable to accurately estimate the FFM of this population group, and consequently an equation, based on BIA at 50 kHz, was developed specifically for this population group. However, this SA equation was not validated for use in the white population group. The systematic review by Chula de Castro et al.[93] and a study by Wang et al.[91] to assess the validity of BIA estimation in children, identified only two equations suitable for determining FFM in both African American and white American children aged 6–9 years. These equations, provided in Table 2-2, were also developed by using equipment delivering a single-frequency alternating electrical current at 50 kHz. The FM can then be calculated by subtracting FFM from total body mass. The equation developed by Morrison et al.[22] was restricted for use in girls. Consequently, the equation by Horlick et al.[39] is the only known equation suitable to calculate FFM of boys and girls of African American and white population groups.

**Table 2-2:** Prediction equations to calculate FFM of African American and white children aged 6-9 years

| **Equation** | **Population characteristics** | **Equation for FFM** | **Correlation between predicted and measured values** |
|---|---|---|---|
| Horlick et al.[39] | 4-18 years, African American, white | [(0.459 x $H^2$/R) + (0.064 x W) + 3.474] / [(0.769 – (0.009 x age) – (0.016 x sex)]<br>Sex: Male = 1; Female = 0 | Regression coefficient = 0.99 |
| Morrrison et al.[22] | 6–17 years African American females | (0.78 x $H^2$/R) + (0.1 x X) + (0.18 x W) – 8.78 | Regression coefficient = 0.99 |
| | 6–17-years white females | (0.56 x $H^2$/R) + (0.06 x X) + (0.34 x W) – 6.41 | Regression coefficient = 0.99 |

H = *body height in cm*; R = *resistance in Ω*; W = *body weight in kg*; X = *reactance in Ω*

Traditionally, FM has been expressed as a percentage of body weight, while FFM was referred to as an absolute weight, unadjusted for size. Percentage FM and the weight of FFM were then interpreted within the context of age or weight.[94-96] It was soon realised, however, that this approach was inappropriate. Fat mass expressed as a proportion of body weight may not distinguish between an individual with a higher body weight and more FM versus a low body weight and less FM. Additionally, absolute FFM did not allow for between-subject comparison. Consequently, the concepts of FMI (FM[kg]/height[$m^2$]) and FFMI (FFM[kg]/height[$m^2$]) was introduced to express fat and lean components relative to an individual's height. This approach not only allows for the evaluation of FM and FFM relative to body size, but also enables comparison between individuals or groups.[95] Therefore, using FMI and FFMI may provide a better indication of the effect of BC components relative to body size on REE.

Age-based reference standards for FFMI and FMI have been developed for American[94, 97] and European children.[98] However, reference data differ considerably. This may partly be due to the complexity of accurately measuring BC in children as well as methodological differences in determining BC. Additionally, population variability in body size and BC may affect indices and, thus, the development of population-specific reference standards have been proposed.[98]

#### 2.2.2.4 Population group

The use of the terminology "race" versus "ethnicity" in health research has been an ongoing debate.[3, 41, 99] The concept of race is often used to represent social, biological and genetic differences. Therefore, classification based on race generally refers to characteristics such as genes, skin colour and other observable features, but is not independent from social aspects.[3, 41] Many social scientists oppose this classification of people based on physical characteristics or ancestral origins, since the concept is historically variable and depend on a multitude of economic, political, social and cultural practices. Scientists therefore often prefer the use of the term "ethnicity" over "race". Ethnicity refers to a self-consciously selected grouping based on shared cultural practices, including language, diet, religion, values and norms. In health research, this concept captures environmental, cultural, behavioural and socio-political experiences that may affect disease aetiology and response to interventions.[41] However, it is argued that there are genetic variations that overlap with ancestral origin that may not be reflected by the definition of ethnicity.[3, 41] Although the classification of race and ethnicity can be deceptive, these definitions have great potential value in healthcare, especially in multi-ethnic societies, to reveal and resolve inequities that involve different population groups.[3, 100]

In nutrition research, historical and persistent differences in food systems have contributed to inequalities that resulted in variations in protein-energy status. Many studies have indicated differences in body size and composition, reflecting racial or ethnic disparities.[94, 101] However, the fact that interconnected biological and sociological pathways may affect nutritional outcomes often presents a dilemma when it comes to referring to either race or ethnicity.(101)

In SA, the apartheid regime resulted in numerous racial or ethnic disparities, with many black Africans having insufficient access to public services such as healthcare or other economic activities. Since race and ethnic groups originally clustered together, it is difficult to distinguish between the contributory role of genetic versus the social, cultural, economic and political factors that led to these disparities.(102-104)

The term “population health” has been suggested to describe the health outcomes of populations as influenced by a combination of interrelated factors, including the social, economic and physical environment, individual practices, biology, childhood development and health services.(99) In SA, the term “population groups” is also often used to describe race and ethnic groups,(105) and this term will therefore be used throughout this study to describe and classify participants.

It has been identified by many studies over the past few decades that population group (mainly determined by self-report or parental report) may influence REE.(7, 19-21, 106, 107) These investigations initiated in North America and have to date focused primarily on African American and white American adults. Accordingly, there is sufficient data to conclude that the REE of African American populations is lower compared to white Americans. Adjustments for body size, BC and environmental factors such as SES do not completely explain these findings.(7, 21, 106, 107) However, some researchers are of the opinion that this conclusion arose from inappropriate study designs with incomplete models of BC, suggesting that the lower REE observed among African American individuals may be mediated by a relatively smaller volume of metabolically active organs.(18, 38, 86, 107) The primary cause of differences in REE may therefore be due to differences in compartments of FFM with varying metabolic rates.

More recently, investigations expanded to Sub-Saharan Africans have indicated a significantly lower REE in black African than white adults. Sub-Saharan black Africans are expected to have a lower degree of European ancestry than African Americans, and it is hypothesised that individuals with a higher degree of African descent may have lower REE even when adjusted for differences in body size and BC.(12, 13) The study undertaken by Manini et al.(13) examined the REE of older African Americans and determined the contribution of European ancestry through single nucleotide polymorphisms. They concluded that European ancestry was significantly related to a higher REE. They predicted that every percentage increase in European ancestry would increase the mean REE by 1.6kcal (6.7 kJ) per day and that those with pure African ancestry could have a lower REE of 160 kcal/day (672 kJ/day), when compared to pure European ancestry. Similarly, Adzika(12) found that the REE of Sub-Saharan black Africans was significantly lower when both adjusted and unadjusted for BC compartments. Another study conducted in SA by Olivier et al.,(19) also indicated that black African overweight women had a significantly lower REE than white overweight women (generally accepted as European ancestry) by as much as 585 and 860 kJ/day (139 and 205 kcal/day) when adjusted for FFM and BMI, and FFMI respectively. In contrast, Dugas et al.(108) conducted a study on 44 black African and white SA women who were lean and obese and found no significant difference in REE, but they stated that a small sample size may have affected their results.

Studies that performed investigations on children to determine differences in REE between population groups are restricted to the African American and white populations and have delivered mixed results. Although many studies identified a lower REE in African American than white children,(6, 9, 21, 22) some studies found no significant difference.(23, 85) Broadney et al.(21) indicated that the REE of African American children was lower than white Americans when adjusted for total lean mass (skeletal muscle and organ mass). However, they argued that specific compartments of lean mass may account for these differences. When adjusted for compartment-specific lean mass (by controlling for trunk lean mass or appendicular lean mass), the differences in REE were no longer statistically significant. Another study by Tershakovec et al.(109) found that after accounting for total FFM (as well as age, sex and FM), African American children demonstrated a 111.2 kcal/day lower REE than white American children, but after accounting for trunk lean mass, the difference declined to 76.6 kcal/day. However, it is important to recognise that even small differences in REE, may lead to inaccurate estimation of dietary requirements, thereby increasing long-term accrual of energy stores and obesity or vice versa.(13, 110)

No known studies have been undertaken to determine REE in children in Sub-Saharan Africa and whether this differs between population groups. Many discrepancies in findings regarding population and racial differences in REE, especially for children, still exist and necessitate further investigation.[109]

#### 2.2.2.5 Physical activity

Physical activity is a modifiable component of TEE that can greatly affect energy balance and consequently the health of an individual. Over the past decades, there has been a rapid decline in PA associated with modernisation. A behavioural shift has occurred from traditionally active lifestyles to more industrialised sedentary lifestyles, often referred to as the "PA transition".[111] The WHO classifies physical inactivity as the fourth largest cause of global mortality and a major determinant of chronic diseases.[15] In SA, there is currently a concern for the health and wellbeing of children, in part due to habits of physical inactivity and sedentary behaviour. Fifty percent or more of SA children are not meeting recommended PA levels,[26] with children from black African population groups having lower PA levels than white children.[27-29]

Physical activity refers to any bodily movements, both voluntary and involuntary, produced by the contraction of muscles resulting in increased energy expenditure. Exercise is considered a component of PA and refers to a voluntary and more vigorous type of PA with a greater effect on energy expenditure than lower intensity PA. Energy expenditure can rise many times over REE during PA and exercise, and the effects of an exercise bout on REE can last for hours or days.[40] A systematic literature review by Speakman and Selman[37] reported that PA may have two distinct effects on REE: Firstly, PA training may result in muscle growth and increased FFM that will result in a higher REE. A second effect may result from the influence of PA on metabolic processes that may influence REE. These metabolic effects may occur both over shorter periods following single bouts of exercise and in the long term due to physiological changes as a result of prolonged periods of exercise. The short-term effects would change REE immediately following a bout of PA over a time period too short to involve alteration in lean muscle tissue. Typically, this effect lasts 10–90 min after an exercise bout.[48] Such changes in REE following single exercise bouts have been termed the excess post-exercise $O_2$ consumption (EPOC).[37] The second phase is called slow or long-term EPOC, which is a slight elevation in $VO_2$ that can last up to

48 hours.[48] The magnitude of the long-term effect appears to be approximately 5–10% of the REE. Although the percentage may appear small, the effect can be long-lasting and consequently be a significant percentage of the total energy cost of the exercise bout. Therefore, more energy can be expended following the exercise than during the exercise event itself.[37]

Some evidence[112] indicates a relationship between exercise intensity and frequency, and the effect on EPOC. Higher intensity exercise at greater than 50–60% of maximum capacity could stimulate a linear increase in EPOC as exercise duration increases, resulting in a prolonged EPOC (3–24 hours). The exercise and related EPOC effect should therefore be considered during the measurements of REE. Frankenfield and Coleman[113] evaluated the immediate effect of very-light-intensity PA on REE and concluded that 30 min of rest is required for REE to return to baseline after very-light-intensity PA, such as walking a distance of 300 metres. However, there are no known studies that have evaluated the effect and duration of increased REE after light-intensity PA and MVPA.[48] More research is required on the type and duration of activities prior to REE measurements.[48]

The effect of PA on energy expenditure, i.e. the direct effect on AEE, is relatively small in relation to total daily energy demands. In theory, exercise interventions do not sufficiently increase TEE to alter the energy balance and reverse obesity,[37] however, practical experience suggests that exercise programmes are successful at producing and sustaining weight loss. This suggests that there are additional effects of exercise on energy balance that amplify the effects of the energy expended on the exercise alone. A suggested mechanism may be a lasting positive effect of PA on REE that may increase the energy imbalance above that generated by exercise alone.[37] Research on the lasting effect of PA on REE is very limited. Nevertheless, it has been identified that habitual PA, including habitual aerobic and resistance training, may influence REE independent of differences in FFM, even when the effect of EPOC is excluded.[37] Gilliat-Wimberly et al.[114] investigated the effects of habitual PA on the REE of women and concluded that REE adjusted for FFM was significantly higher in active women compared with sedentary controls.

Shook et al.[38] investigated the differences in REE between African American and white women, adjusting for differences in BC and levels of fitness and MVPA. The study concluded that African American women spent significantly more time in sedentary and light activity and less in MVPA. A lower REE was observed among African American women, which may partially be explained by a lower fitness level. While fitness may be associated with increased PA,[8] no association was found between MVPA and REE. Although these studies suggest a relationship between fitness and REE, there is limited research on the relationship between PA and REE, and further research may be required to better understand the influence of PA on REE.[38]

## 2.3 PHYSICAL ACTIVITY

### 2.3.1 Measurements of PA

An increase in the energy expended during PA (AEE) is an imperative factor to consider when determining the energy required to achieve energy balance and support healthy growth and development in children.[15, 40] However, the accurate measurement of PA and the related energy expenditure is challenging. Doubly labelled water and IC can be used to determine AEE, but measurements are expensive and are confined to the limited space of metabolic chambers that does not represent an individual's PA in a free-living environment.[30] Consequently, it became increasingly popular to measure involvement in PA, as instruments are markedly cheaper, unobtrusive and allow investigators to categorise the intensity of the activity. Although these PA measurements do not measure actual energy expended (the AEE), they can determine PA habits and trends related to health maintenance or disease. A variety of measurement instruments such as motion sensors (e.g. accelerometers and pedometers), observation booths, heart rate monitors, questionnaires and activity diaries are available to capture current and past activity, steps, frequencies, accelerations or counts. Yet, PA is a complex and multi-faceted construct, and there is no recognised "gold standard" technique for accurate measurements.[115] Furthermore, the limitations concerning measurement accuracy are often amplified in children due to the cognitive, physiological and biochemical changes that occur during growth and development, along with their more intermittent activity patterns.[30, 115] In children, up to 96% of activity bouts are shorter than 10 seconds, with the majority lasting between 3 and 22 seconds. This has numerous implications for all aspect of measurements, processing and interpretation of PA data in youth, including data sampling, frequency and length of measurements and where to place activity monitors. The choice of the most accurate and suitable instrument therefore depends on numerous factors such as affordability, sample size and age of participants.[115]

Since no single method is able to quantify all aspects of PA under free-living conditions, the use of multiple complementary methods with a combination of an objective and subjective approach, is recommended.[30, 115]

#### 2.3.1.1 Objective measurements of PA

Motion sensors are movement-based techniques that present a good, inexpensive objective method for measuring PA. The two most commonly used movement-based devices are accelerometers and pedometers.[30, 116]

An accelerometer is an electromechanical device that detects acceleration forces of the body, generally worn on the waist or upper arm for a number of days. Acceleration forces may be static, such as the constant force of gravity, or they could be dynamic, caused by movement or vibration of the accelerometer. By measuring the amount of static acceleration forces due to gravity, it can be determined at what angle the device is tilted. At the same time, the dynamic acceleration forces can be measured to determine the way the device is moving. These acceleration forces can indicate the rate of change in velocity over a given time, expressed as multiples of gravitational force and can be used to determine frequency, intensity and duration of PA over an extended period of days or weeks. Accelerometers generate an output in the form of “counts” per unit of time. These counts can be converted to AEE units with the use of prediction equations.[30, 116] Technological advancement in accelerometers has increased the popularity and accessibility of this method, and it is often the preferred objective approach for assessing PA volume and intensity with minimal discomfort.[30] Although accelerometery has enabled PA to be measured more accurately than subjective methods in both adults and children, it has some limitations. A review by Sardinha and Júdice[116] on the validity of different motion sensors to estimate AEE and TEE compared to DLW in adults and children concluded that motion sensors may be a valid method to determine AEE and TEE at group level, but individual bias is very high. Although less expensive than DLW and calorimetry, accelerometer devices are costly (approximately R40 000 [$2 650] per unit and an additional R20 000 [$4 000] for software) and may often not be feasible for assessing the PA and AEE of large numbers of participants, especially in resource-limited settings.

Alternatively, pedometers are increasingly being used as an objective tool to assess PA in children.(117) Pedometers are typically worn on the hip or ankle and devices are small, easy to use, unobtrusive and relatively low in cost at approximately R800–R3000 (± $50–$200) per unit. Although pedometers cannot differentiate PA intensity and therefore cannot be used to determine AEE,(115, 118) they can provide a simple means of tracking PA by registering the number of steps during walking or running. This standardised steps/day unit of measurement allows universal interpretation and facilitates reliable cross-population comparisons. Pedometers measure vertical displacement only from ambulation, thus some types of activities such as bicycling and swimming or sedentary activities such as the playing of computer games are missed.(30, 118) However, walking is the most commonly reported PA and steps/day indices are considered an effective and accurate measure of habitual PA.(32)

A large and increasing number of pedometers are available and devices may vary greatly in accuracy. Many research-grade pedometers use either spring-levered or piezoelectrical accelerometer mechanisms. Spring-levered pedometers are most commonly used and contain a spring-suspended horizontal lever arm that moves up and down in response to vertical acceleration of the hip during ambulation. This movement opens and closes an electrical circuit; when the lever arm moves with sufficient force, above the sensitivity threshold of the pedometer, the lever arm causes electrical contact and a step is registered. Piezoelectric pedometers contain a horizontal cantilevered beam with a small weight on one end. When subjected to acceleration above the sensitivity threshold, the weight compresses a piezoelectric crystal; this generates a voltage proportional to the acceleration and the voltage oscillations are used to record steps. This type of pedometer is not affected by pedometer tilt, and therefore may be less prone to error than lever arm pedometers.

They are also more sensitive to vertical accelerations, meaning that they can record steps more accurately in slow walking than spring-levered pedometers.[118]

Several studies have assessed the accuracy of pedometer measurements in children.[118, 119] Although some evidence suggests that pedometers with a piezoelectric mechanism are more accurate, the majority of pedometer validation studies in children aged 5–12 years were undertaken on the spring-levered Yamax pedometer (Yamasa, Japan). This is considered the gold standard in the literature and has been used in many large-scale studies to assess activity in children.[118, 120-122] The accuracy of the Yamax pedometer has been measured at many walking speeds, against ascending and descending stair climbing and bench stepping, and has been found to be a reliable and accurate tool with a correlation coefficient of 0.85 and 0.80 for boys and girls respectively when compared with accelerometery.[118]

A general problem with all pedometers is the underestimation of steps taken when moving very slowly (< 60m/min), or due to the tilting of the pedometer by the stomach when worn by adults with obesity.[30] The practical significance of this finding when measuring step-count in children has been questioned since children tend to walk faster, and speed-related pedometer error may therefore not be relevant for children. It was also found that the style of waistband on their clothing is likely to be the largest determinant of pedometer tilt, and children with loose-fitting clothing may experience a reduction in pedometer accuracy, especially when spring-levered pedometers are used. Securing the pedometer to a belt could minimise errors associated with pedometer tilt.[118] Additionally, the number of steps taken can be manipulated, especially by young children who may regularly look at the number of steps and try to alter the "typical" pattern. To avoid or discourage such manipulation, researchers often tape over the device to reduce any feedback based on step count.[30] Another issue with pedometers is that many devices do not have the ability to store time, thus duration and intensity of a discrete activity at a specific time cannot be identified, making it nearly impossible to extrapolate or convert steps into energy expenditure. It is recommended that output should therefore be expressed only as steps/day and further inference of distance or energy expenditure may not be appropriate.[115, 118]

Recent interest in the use of pedometers includes the relevance of cut-points, in particular their equivalence to activity recommendations and energy expenditure in populations. Since walking is the most commonly reported PA, step-count can provide a simple and affordable means of tracking daily PA and the need arose to express public health recommendations in terms of steps/day.[32] Although this field is still developing, many studies have explored the PA and steps/day indices associated with health outcomes.[30-32, 119, 123-125] Tudor-Locke et al.[32] used data from a range of studies to categorise PA levels based on step-count. They acknowledged that although pedometers cannot discriminate PA intensity on their own, they do provide a simple, affordable and reliable means of tracking PA expressed as a summary output of steps/day. Consequently, preliminary pedometer-based steps/day guidelines related to a healthy body weight in American children were developed.[32] Qualitative descriptors varying between “copper” and “platinum” were used instead of “sedentary” to “highly active”, in an attempt to differentiate between adult and youth recommendations (Table 2-3).

**Table 2-3:** Potential steps/day youth indices[32]

| Qualitative descriptor | Girls 6–12 years: Steps/day | Boys 6–12 years: Steps/day |
|---|---|---|
| Minimum level; Copper | < 7000 | < 10 000 |
| Bronze | 7000–9499 | 10 000–12 499 |
| Silver | 9500–11 999 | 12 500–14 999 |
| Gold | 12 000–14 499 | 15 000–17 499 |
| Platinum | ≥ 14 500 | ≥ 17 500 |

Tudor-Locke at al.[32] further identified the need to refine guidelines, since step-count may be influenced by population group, age, sex, geographic location, climate, season, to name but a few. Vincent et al.[125] reported step-count data on children aged 6–12 years in Australia and Sweden. Results showed that mean values ranged from 15 673–18 346 and 13 864–15 023 steps/day for boys in Sweden and Australia respectively. Girls averaged between 12 041 and 14 825 and 11 221 and 12 322 steps/day in Sweden and Australia respectively. American boys averaged between 12 554 and 13 872 and girls between 10 661 and 11 383. A SA study[33] reported an average number of steps per day of 7988 for girls and 10 504 for boys in an urban setting. The Canadian Physical Activity Level Among Youth (CANPLAY) developed a unique database for step-defined PA, based on pedometer data of over 43 300 children and adolescents collected between 2005 and 2014. Based on their data of average daily step-count, 13 000–15 000 steps/day for boys, and 11 000–12 000 steps/day for girls aged 6–11 years are recommended to meet the equivalent of the WHO recommendations of approximately 60 min per day of MVPA.(31, 119)

Evidently, there is still much need for additional research to ensure widespread acceptance of pedometers for PA measurements and for population-specific evidence-based steps/day indices associated with important health-related outcomes. Nevertheless, pedometers may often be the only reasonable tool to employ in larger studies and evidence suggests that in children above the age of 5 years, pedometers provide a valid and reliable objective measure of ambulatory activity.(30)

The optimal monitoring frames to detect habitual activity with pedometers in youth have yet to be determined. The most common monitoring frame used in surveillance studies has been seven consecutive days, thereby capturing both weekdays and weekend days in the monitoring period.(118)

#### 2.3.1.2 Subjective measurement of PA

Subjective measures are considered indirect methods to assess PA and are often used due to their relatively low cost and low participant burden.(30, 36) Subjective methods may include a range of approaches that usually involve the individual recording their own activity. Typical subjective methods may include PAQs, interviews, surveys and activity diaries. Each approach may assess different dimensions of PA with a variety of outcome measures and are associated with their unique strengths and limitations.(30, 36) It is well recognised that subjective assessments may include a relatively high degree of error since several factors can affect reported PA, including bias, error and the age and functional status of an individual. Common challenges with subjective methods include the cognitive tasks associated with recall, participant burden and lack of compliance in the completion of diaries, the inability to distinguish between intensity levels of PA and dependence on response rate, to name a few.(30, 36, 126) In children, the use of subjective methods may hold the extra limitation that a child may be less able to recall their PA, possibly due to their intermittent and variable activity patterns that may be harder to remember and their differences in cognitive and linguistic ability by age may also play a role. Furthermore, children find the task of capturing activities very complex, making the use of activity diaries inappropriate. The validity of self-administered methods in children can be increased by interviewer-administered methods or having an adult check the completion of a self-report questionnaire, however overall the validity of these methods to determine AEE remains poor. Subjective methods are therefore more valuable for monitoring activity levels, or assessing the activity settings and activity behaviours and their determinants, which cannot always be determined with objective methods.(30, 115)

Physical activity questionnaires are the most widely used subjective approach to monitor PA levels and behaviour. A variety of PAQs have been designed to capture various activity parameters with varying degrees of reliability and validity.(30) Many studies(36, 117, 127-129) have identified the PAQ-C as a reliable tool for children aged 6–12 years. The PAQ-C has also been successfully used in SA studies to investigate PA in urban-based SA primary school learners.(29, 33) The PAQ-C has demonstrated good test-retest reliability and internal consistency, including internal consistency among ethnic groups (ICC = 0.96).(127) However, due to the poor validity when compared with accelerometery ($r = 0.311$, $p < 0.01$),(127) it is advised that the PAQ-C should be used in conjunction with an objective movement-based device.(127, 129, 130)

### 2.3.2 Factors related to the PA of children

The PA of children is a complex behaviour influenced by a variety of interrelated multifactorial environmental, demographic, biological, social and psychological influences that may include both modifiable and non-modifiable elements. Several studies and systematic reviews have been conducted to determine correlates associated with young children's PA as discussed below, however, it is often difficult to discern specific influences.(111, 131, 132)

#### 2.3.2.1 Age and sex

Several studies have identified differences in PA between prepubertal boys and girls. A systematic review by Muthuri et al.(111) identified higher levels of PA in Sub-Saharan black African boys than girls between the ages of 5–17 years, irrespective of age. Likewise, the SA study by McVeigh and Meiring[27] concluded that time spent on PA was consistently lower for girls than boys aged 6–18 years. Van Biljon et al.[29] investigated the PA of primary school learners across SA and also identified that boys had higher PA levels than girls and PA levels declined with age from 11 years. A similar effect of age on PA was identified by the review of Sallis et al.[132] who concluded that age was not related to PA in younger children between the ages of 3 and 12 years and that age-related differences in PA emerged during the adolescent years.

#### 2.3.2.2 Phenotype

Overweight children are less likely to engage in PA and exercise than their non-overweight peers.[27, 133, 134] The study by McVeigh and Meiring[27] on SA children during the 12 years of schooling (aged 6–18 years) identified that time spent in sedentary activities was significantly and positively correlated with body weight across all race groups (white: $r = 0.22$, $p<0.001$; black African: $r = 0.37$; $p=0.001$) and the strength of the association was similar between boys and girls. Similar findings were reported for African American and white children.[134] Generally, hindrances to PA among children with a higher body weight may include lack of access to resources, social constraints, low fitness levels and body-related barriers associated with a higher body weight such as self-consciousness when being active, body dissatisfaction or having lower self-efficacy. Other aspects could include victimisation, less substantive peer networks for overweight children and bullying leading to isolated sedentary activities.[27, 133, 134]

#### 2.3.2.3 Population group

Many studies, including SA studies have identified that children from white population groups engage in more regular PA and less sedentary activity than children from other populations, including black African groups.[24, 28] Sallis et al.[132] found no significant difference in PA between population groups at a younger preadolescent age, but during the adolescent years the PA of white population groups was consistently higher than for other population groups.

It has repeatedly been identified that the variations in PA between population groups may be caused by a variety of interrelated factors. The review by Eyre et al.[24]

identified that factors such as SES and phenotype may cause variations in the PA of population groups. The study by McVeigh and Meiring[27] reported that both cultural and biological factors may be a cause for variations in PA levels of various population groups in SA. Population groups are social constructs and groups tend to cluster in similar sociodemographic regions. Behavioural and SES factors may influence PA and it may be difficult to determine the independent effect of population groups in itself.[3, 29, 30] Additionally, in many black African communities, obesity and overweight may still be considered a sign of good health, beauty and wealth and PA may not be considered a priority.[135] The level of PA in these communities may therefore be more of a cultural determinant associated with SES, rather than population group.[29] Caprio et al.[3] also explained in their consensus statement that cultural perceptions of obesity and perceived ideal body weight may affect PA habits. African Americans generally have a higher ideal body weight than white populations and this perception of mothers may affect diet and PA behaviour in their children. Changing cultures associated with urbanisation, along with changes in preferences and exposure to food and PA or other leisure activities (exposure to television [TV]) may further influence engagement in PA.[3, 27]

#### 2.3.2.4 Socio-economic status

In LMICs, children from a higher SES are usually engaged in lower levels of PA and display more sedentary behaviour.[28, 111] Higher activity levels in children from lower SES are associated with the demands of informal, survival activities such as household chores and walking from place to place (i.e. lower access to motorised transport) with less access to sedentary activities such as TV and computer activities, whereas their more privileged peers may have access to formal, organised sporting activities, but also more motorised transport, TV watching and screen games.[111, 135] Higher SES in LMICs is generally positively related to parental education. Parental education level can be categorised as a higher education qualification including any college degree, a bachelor or postgraduate degree, whereas a lower education level may include high school completed, some high school completed or less than high school.[111] In contrast, the study by McVeigh[28] found that SA children falling into the highest SES quartile had mothers with the highest educational levels, were highly physically active and were less engaged in sedentary activities. There were higher levels of low activity and high TV watching time among lower SES groups. These findings are in line with reports from studies in high-income countries where children of a higher SES generally have the highest levels of PA. These differences are often attributed to parental education and influence since parents with a higher level of education and health awareness act as role models and are responsible for instilling the value of PA in their children.[27, 131]

When considering these variations in the effect of SES on PA, it is important to acknowledge that various levels of SES, including maternal, household and community levels, may influence the health-related behaviour of children in various ways.[135] SES-related factors are often difficult to identify and may permeate every aspect of life. Data on household SES are often limited to self-reported parental education and income levels. These indices of parental education and income levels may fail to fully convey the complexities of SES and social class. One definition of social stratification is the unequal distribution of privileges among population subgroups. The focus on income and education can therefore mask major underlying disparities in material resources, e.g. a car and a house and accumulated wealth. Furthermore, access to resources and services may not be equivalent for a given level of education and income. Differences in neighbourhood may influence PA due to varied access to PA, the lower perceived safety of the surroundings or the quality of local schools, which affect access to physical education classes, sports facilities and extramural sports activities.[135]

#### 2.3.2.5 Built environment

Worldwide, the obesity epidemic has been closely linked to an obesogenic environment in which labour-saving technologies and leisure options promote an inactive lifestyle.[43, 111] Sub-Saharan Africa, including SA, is still undergoing rapid urbanisation, which has led to the replacement of an economy based on physical labour, with one dominated by industry and mechanised manufacturing. This has resulted in shifts in habitual and work-related PA from high-energy expenditure activities such as active transport and manual labour, to low-energy expenditure activities or sedentary behaviour e.g. motorised transport and desk work. Both subjective and objective measures of PA have found that rural children are more active than urban.[111, 135]

Additionally, the school environment is considered a significant factor that may influence the health-related behaviour, including PA involvement, of young children.[43, 141, 142] Children spend a great amount of time at school and the school built environment is therefore often used to describe access to PA facilties and opportunities that may enhance the PA of children.[43] The school built environment refers to anything external to the individual and man-made, such as buildings, amenities, areas or equipment within the school's boundaries.[45, 141, 142] Although not part of the school environment, additional environmental components in the school's surrounding neighbourhood, such as threatened personal and road safety, higher traffic density or urbanised communities may further affect the PA levels of school children due to inactive commuting, leading to a reduction in PA.[142]

## 2.4 CONCLUSION

To determine the relationship between the REE and PA of different sex categories and population groups, it is essential to measure of REE and PA accurately. Indirect open-circuit calorimetry is a practical, relatively affordable and the most widely employed method used to determine REE in adults and children. An evidence-based protocol, including measurement prerequisites is required to ensure participants can achieve a resting state to reflect an accurate REE. Since IC is not feasible in all practical settings, prediction equations are used as an alternative method to determine REE; however, the accuracy of these equations varies across population groups and further population-specific research is required for the development of appropriate prediction equations.

The accurate measurement of PA can be challenging, since PA is a complex construct and there is no recognised "gold standard" technique for measuring it. Children have erratic PA patterns, contributing to the complexity of measuring PA during childhood. Nevertheless, a worldwide PA transition exists and understanding the PA levels of children is important to ensure appropriate interventions to improve the health of future generations. Pedometers are generally accepted as a relatively accurate and cost-effective way to objectively determine PA in children, especially when the PA of larger groups needs to be assessed. However, the use of subjective methods along with objective measures of PA is advised to add insight into PA level. Although PAQs may involve many limitations, the PAQ-C is accepted as a reliable tool to subjectively assess the PA of young children that was successfully implemented in previous SA studies.

When studying the REE and PA of different sexes and population groups, it is further important to consider influencing confounding factors such as age, the environment, SES and phenotypic characteristics to allow for objective and appropriate intergroup comparisons.

# CHAPTER 3: RESEARCH DESIGN AND METHODS

A description of the research design, a detailed explanation of the research methodology and a summary of ethical and financial considerations will be provided in this chapter, as shown in Figure 3-1.

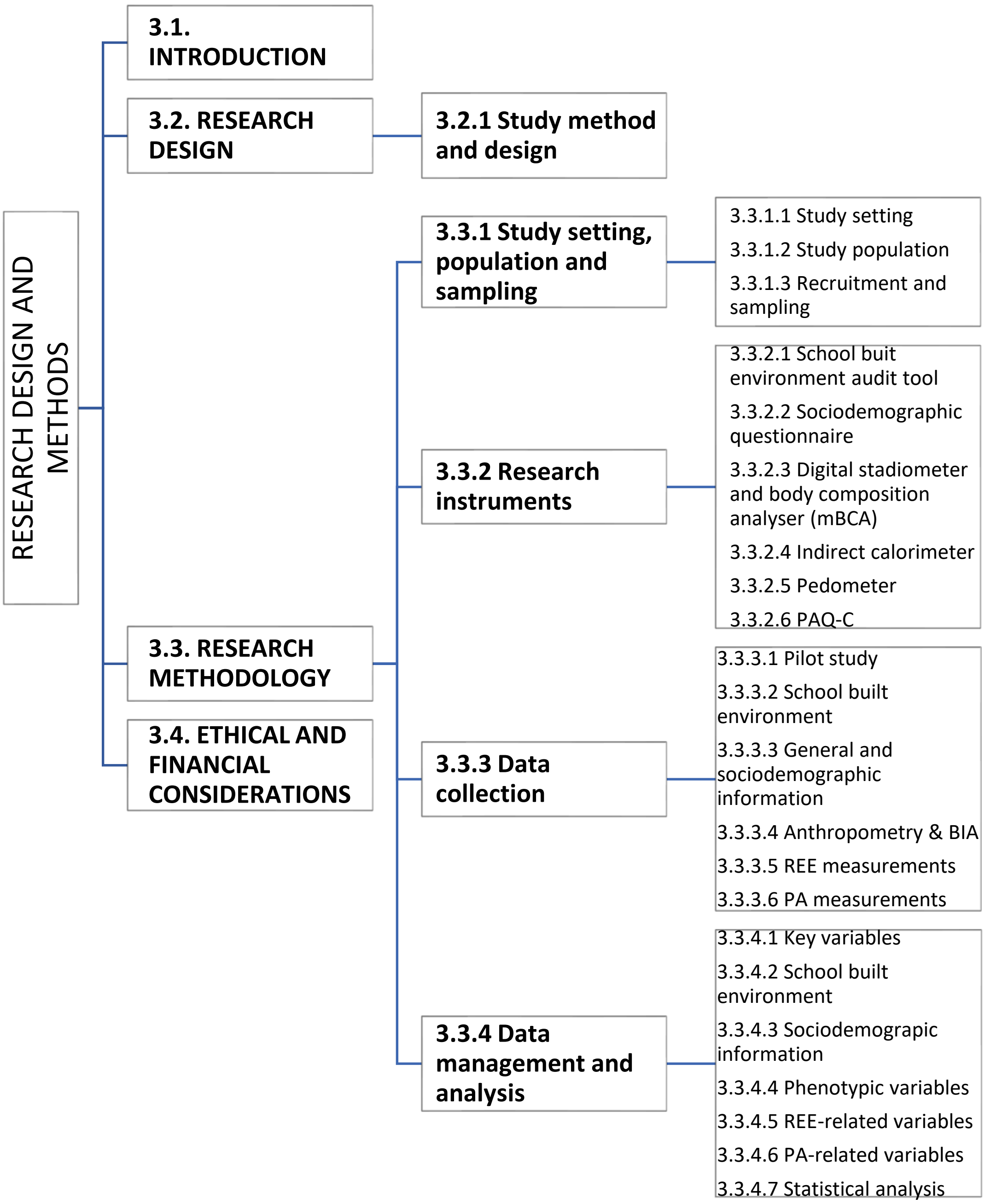


**Figure 3-1:** Outline of chapter 3

## 3.1 INTRODUCTION

This chapter will discuss and explain the methodological approach of the research project. It assists in "setting the scene" for the research study, including the study setting, description of the population and the sampling procedure. The chapter further provides an overview of each measurement instrument and how it was used during fieldwork for the collection of accurate, reliable data to meet the study objectives. Key variables that were measured included contextual factors, i.e. the school built environment and SES of participating households and phenotypic mediating factors i.e. anthropometric measurements and BC, all of which were expected to influence the outcome variables, i.e. the REE and PA of participants. Furthermore, the procedures followed for data management and statistical analysis will be explained, and ethical considerations will be presented.

## 3.2 RESEARCH DESIGN

### 3.2.1 Study method and design

The study was observational in nature with no intervention, thereby providing the best possible scientific evidence to gain an understanding of the factors related to REE in young SA children of different populations. A cross-sectional, analytical design incorporating quantitative research methods to permit statistical analyses of the data was used to examine, describe and compare the following in 6–9-year old black African and white SA children attending two primary schools in the City of Tshwane metropolitan area:

- Contextual factors including school built environment and SES
- Phenotypic mediating factors:
    - Anthropometric data including WFA z-score, HFA z-score, BMI-FA z-score
    - Weight categories according to WHO classification[50]
    - BC measured with BIA to calculate FFM with a prediction equation; and calculations of FFMI, FM, FMI

- REE
  - Measured with IC
  - Predicted with equations
  - Agreement between measured and predicted REE to describe the appropriateness of prediction equations
- PA
  - Average steps/day (objective) measured with pedometers
  - PAQ-C activity score (subjective) before (PAQ-C-before) and after (PAQ-C-after) objective PA measurement; and average (PAQ-C average) calculated from PAQ-C-before and PAQ-C-after
  - Relationship between the average steps/day and PAQ-C average score to describe the accuracy of objectively measured PA
- The relationship between each phenotypic variable and:
  - measured REE
  - average steps/day
- Relationship between measured REE and average steps/day

The observational, cross-sectional research design permitted the measurement of multiple outcomes of individuals, the comparison of outcomes (REE and PA) between groups (sex categories and population groups) an exploration of the relationship between mediating factors and outcomes in a cost-effective way, within a limited time frame in the study context.(136, 137) Although cross-sectional studies are generally considered economical and useful for exploring public health needs, they have the potential to include measurement error and bias.(137) Consequently, careful consideration was given to ensure the use of standardised procedures and instruments to improve the accuracy of measurements, which will be discussed in more detail later in this chapter.

## 3.3 RESEARCH METHODOLOGY

### 3.3.1 Study setting, population and sampling

3.3.1.1 Study setting

The participants for the study were recruited from two primary schools in the City of Tshwane metropolitan area. Children in SA attend primary school at the age of 6–13 years, with Grades 1–3 including children mainly between the ages of 6 and 9 years. The two schools were purposively selected based on their attendance of mainly black African and white SA children, their urban location, their similar access to PA opportunities during and after school and the predominantly homogenous SES of the schools and of families who generally enrol their children at these schools. School A accommodates approximately 260 learners in Grades 1–3 with mainly, but not exclusively, white SA children attending the school (based on communication received from the school administration: > 85% white, ±10 % black African; ± 5% other population groups). School B accommodates approximately 190 learners in Grades 1–3 with mainly, but not exclusively, black African SA children attending the school (based on communication received from the school administrator: 88% black African; 7% white; 5% other population groups). School A is a quintile 5 government school, i.e. considered among the upper 20% in the City of Tshwane in terms of economic affluence.[(138)] School B is a private school. In SA, private schools do not normally receive financial support from the government. School fees are consequently higher and therefore typically attract families from a higher SES.[(139)] Children attending school A or B could therefore be expected to have a similar socio-economic background.

Both schools are situated in the urbanised region of the City of Tshwane metropolitan area, east of the central business district, in Gauteng, SA, approximately 2km apart and within close proximity to the University of Pretoria, thereby allowing convenient access for both the researcher/assistants and participants (Figure 3-2).

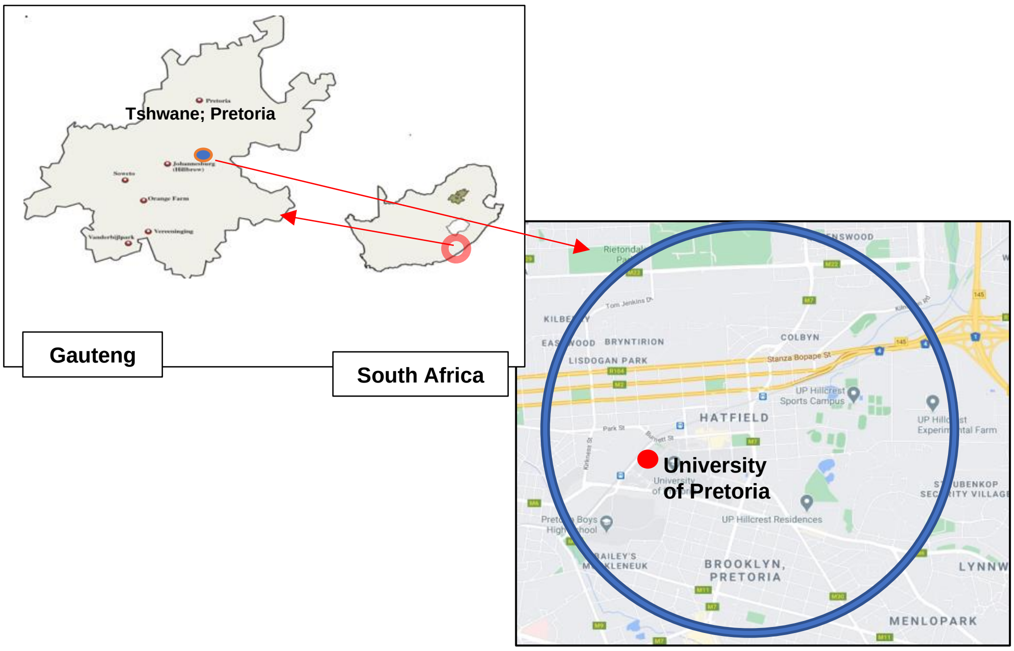


**Figure 3-2:** Location perspective of the University of Pretoria and the two selected schools in Tshwane, Gauteng, SA[(140)]

A suitable venue (Figure 3-3), where equipment could safely be stored, was used in the Department of Consumer and Food Sciences at the University of Pretoria where the researcher was based.

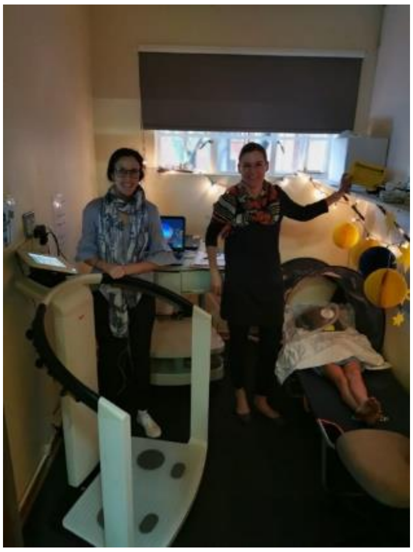

**Figure 3-3:** Venue at the University of Pretoria Old Agricultural Building (Research assistant left; researcher right)

Measurements (including PAQ-C-before, anthropometric measures, BIA and REE) for children who attended School A were taken before school at this venue. Follow-up measurements i.e. monitoring of step-count and completion of the PAQ-C-after, were taken after school on the premises of the aftercare centre of school A.

All measurements of children attending school B were taken on the premises of the school. The school provided their boardroom where measurements were taken before school and where equipment could be stored (Figure 3-4). The monitoring of step-count and the completion of the PAQ-C-after were performed after school on the premises of the school, mainly at the aftercare centre or on the sports fields where children spent their afternoons.

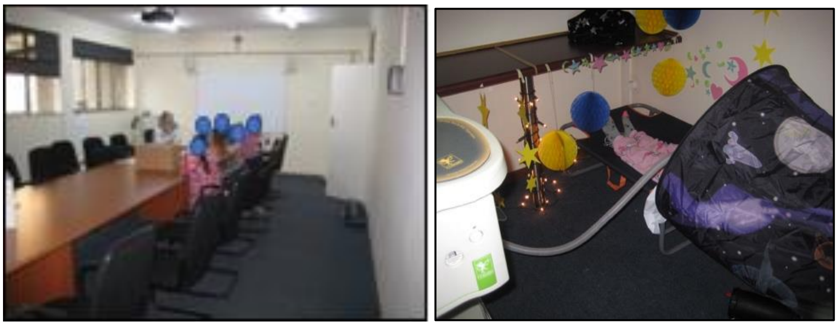

**Figure 3-4:** Venue at school B boardroom

### 3.3.1.2 Study population

The study included SA children aged 6 to 9 years, i.e. who were born during 2010, 2011 or 2012 and enrolled for Grades 1, 2 or 3 at the two selected schools during the 2019 academic year. The majority of the children who attend the two selected schools are either black African or white children. Representation of other population groups at these schools is small and the study population was therefore restricted to black African and white SA children. Classification of population groups based on self-identification of population is considered a good approximation of ancestral origin and has repeatedly been used in research.[41] Children were therefore classified as SA based on parental report (via the parental questionnaire in Annexure A-1) of the country of birth of both parents and the nationality of the child. Nationalities from Southern African countries, i.e. all countries lying south of the equator, including

Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, SA, Swaziland, Zambia and Zimbabwe,[47] were included.

Children who were injured, ill or taking chronic medication (determined via the parental questionnaire, Annexure A-1) or those who did not want to take part or whose parents refused consent were excluded.

#### 3.3.1.3 Recruitment and sampling

The internal statistical services at the Research Office of the Faculty of Health Sciences, University of Pretoria assisted in calculating the sample size prior to the study. Comparison of population groups with respect to REE, overall and within sex categories, were considered for sample size calculations. Resting energy expenditure data for children of different populations are limited and could not be used to facilitate sample size estimation of SA children of different populations. Based on the results of previous REE-related research of SA adults[19, 20] and children of American populations[9], the REE parameters for adults were halved. To detect a clinically relevant difference of 75 kcal/day (315 kJ/day) between groups and assuming a common SD of 84 kcal/day (354 kJ/day),[19, 20] a sample of 28 participants per group was calculated to have 90% power when using a two-sided two-group Student's paired t-test at the 0.05 level of significance. Since two subgroup analyses were of interest, i.e. for boys and for girls, 60 participants from each population group were enrolled into the study for a total sample size of 120 participants. However, accurate calculations of a sample size prior to this study, and the estimation of oversampling requirements to overcome anticipated sampling challenges and non-compliance, were not possible since REE research in SA children was not available. Consequently, the power of the sample was recalculated after data collection to ensure the power of the sample remained at least 90%.

A total of 120 participants, 60 black African (32 girls and 28 boys) and 60 white (37 girls and 23 boys) were recruited and measured at the two schools between 13 April and 22 October 2019 (Table 3-1). Since REE measurements had to be taken in a fasting state, participants needed to be measured before the school started at 07h30. Appointments were scheduled from 06h20 in the morning and took approximately 45 min to complete. Consequently, only two children could be measured per day i.e. a maximum of 10 per week.

Recruitment at school A commenced in April 2019. Many of the parents with children attending the school were known to the researcher and were contacted in person to enquire if they, and their child, would agree to take part in the study. In addition, a parental invitation letter (Annexure B-1) was distributed at the aftercare centre and the researcher and assistant personally approached parents at the aftercare centre to invite their children to participate. Sixty-five children from school A were recruited and measured during the first eight weeks from 13 April to 8 June 2019, i.e. an average of 8 children per week. Recruitment and data collection were discontinued during the school holiday and resumed on 23 July 2019 to measure another 9 participants (4–5/week). A total of 74 children (14 black African: 8 girls and 6 boys; 60 white: 37 girls and 23 boys) were measured at school A before the equipment was moved to school B on 8 August 2019 (Table 3-1).

Recruitment at school B started in August 2019. Participants were recruited via the parental invitation letter (Annexure B-1) that was distributed to all the Grade 1–3 learners. Additionaly, similar to the procedure at school A, the researcher and assistant approached parents at the school during drop-off and pick-up time to invite their children to participate. Thirty-three children were measured during the 5 weeks (i.e. 6–7 children/week) from 13 August until the start of the school holiday on 20 September when measurements were discontinued. Data collection resumed on 8 October and continued until 22 October when another 13 children were measured. A total of 46 children (black African: 24 girls and 22 boys) were measured at school B (Table 3-1).

**Table 3-1:** Participants recruited from participating schools (N=120)

| School A<br>13 Apr – 6 Jun; 23 Jul – 8 Aug 2019<br>n = 74 | | | | School B<br>13 Aug – 20 Sept; 8 – 22 Oct 2019<br>n = 46 | |
|---|---|---|---|---|---|
| Black African = 14 | | White = 60 | | Black African = 46 | |
| Girls = 8 | Boys = 6 | Girls = 37 | Boys = 23 | Girls = 24 | Boys = 22 |

| TOTAL = 60 black African + 60 white = 120 | | | |
|---|---|---|---|
| Total black African girls = 32 | Total white girls = 37 | Total black African boys = 28 | Total white boys = 23 |
| TOTAL GIRLS = 69 | | TOTAL BOYS = 51 | |

### 3.3.2 Research instruments

#### 3.3.2.1 School built environment audit tool

Two different schools were selected for this study. It was therefore necessary to describe the school built environment of each school to improve the understanding of possible differences or correspondences in the PA levels of the study sample in their school environment.

A limited number of instruments are available to assess the built environment of schools. Surveys completed by school principals or other school staff, including foodservice or administrative personnel, are often used.[143] Alternatively, observational methods, also known as audit tools, involving in-person observation by the researcher may pose less participant burden, thereby preventing incomplete data. However, these are more time-consuming and may require training to improve inter-observer reliability.[144] The international study of childhood obesity, lifestyle and environment[44] school audit tool, ISAT,[45] was used in this study to provide qualitative information regarding the school built environment. The ISAT was developed and is suggested as a reliable objective audit of the school PA environment across various international school settings. The tool has been used to objectively assess the school built environment of 256 schools across 12 countries, including SA. Reliability audits were conducted at 53 of the schools. Substantial reliability was reported for 56% of items completed (inter-rater reliability K = 0.61–0.79) and almost perfect reliability for

42% of items completed (K = 0.80–0.96).[45] The ISAT is a seven-page audit tool, developed for completion by research staff to assess and describe the following aspects of the school built environment linked to PA: access to school, the school's surrounding areas and support for active transportation, aesthetics and usage of school grounds, play or sports facilities and perceived suitability of the school grounds for sport and play. Features on the school grounds and in the surrounding area related to PA can be reported as being either present or absent, the number of functional amenities to a maximum of 10 should be listed and a quality score between 1, poor quality, and 5, 100%, or almost 100% functional can be allocated. The tool includes a detailed manual of procedures with specific item definitions and instructions for quality control.

#### 3.3.2.2 Sociodemographic questionnaire

A sociodemographic questionnaire (SDQ) (Annexure A-1) was used to collect sociodemographic data, including participants' age, date of birth, sex, population group, nationality and other household demographic and socio-economic information. The SDQ was developed based on the Stats SA CSHQ.[105] The relevant sociodemographic information was gathered and used to describe the study sample and to identify the familial SES of the participants. The researcher aimed to include children from a relatively homogenous socio-economic background to reduce the confounding effect of SES that may be associated with the REE and PA of participants.

Stats SA is the SA national statistics agency aimed at producing accurate and timely official statistics to advance the economic growth and development of the country. The Stats SA CSHQ was developed in 2007. It has since been used routinely by Stats SA for surveys to gather information on SA household demographics and socio-economic data with questions pertaining to income categories, housing and living conditions, access to basic household services, employment status and educational level.[105] Stats SA considers the data gathered via their CSHQ regarding income categories, along with other questions related to living conditions, as a good source of data for the measurement of money-metric poverty.[145]

**Income categories**

Information regarding income categories cannot fully explain how resources are distributed between family members, or how money is spent. However, it gives an indication of those living with severe financial constraints. Money is required to access a range of services and income poverty often compromises the rights to education and other services of members of a household.[146] Consequently, information regarding income categories was gathered to identify whether the families of participants may be at risk of financial constraints.

The most recent publication of the Stats SA Living Conditions Survey of 2014–2015,[147] provides information regarding household income and related poverty levels. According to that report, SA households had an average annual income of R138 168 ($9 140) (R11 514/month; $761/month) in 2015. However, to improve the understanding of population household income distribution, households were divided into five quintiles into which the population was equally divided according to their annual per capita income category:[147]

- Upper quintile: R71 479 and above = R5957/month
- 4th: R28 092–R71 478 = R2 341–R5 956/month
- 3rd : R13 819–R28 091 = R1 152–R2 340/month
- 2nd: R6 486–R13 818 = R541–R1 152/month
- Lower quintile: Up to R6 485 = up to R540/month

With the average SA household having 3.3 members,[145] these quintiles can be extrapolated to a monthly household income of:

- Upper quintile: R19 657
- 4th: R7 725–R19 656
- 3rd: R3 800–R7 724
- 2nd: R1 784–3 799
- Lower quintile: up to R1 783

The income categories of the CSHQ include 12 categories ranging from “no income” to “R204 801/month ($13 549/month) or more”.[46] For this study, categories 1–9 (ranging from R0–R51 200/month ($3 387/month) or more) were used, thereby providing sufficient information to enable the researcher to group participants' households into the categories most related to the five quintiles (Table 3-2). Due to inflation-related fluctuations in household income, the CSHQ categories do not precisely coincide with the quintiles. However, as an estimate of the average per capita household income of the study sample, it was considered to provide sufficient information to identify participants who might be at risk of financial constraints and poverty.

**Table 3-2:** SDQ monthly household income categories with corresponding quintiles

| Monthly household income categories | | Corresponding quintile |
|---|---|---|
| 1. | No income | Lower quintile |
| 2. | R1–R1 600 | |
| 3. | R1 601–R3 200 | 2nd quintile |
| 4 | R3 201–R6 400 | 3rd quintile |
| 5. | R6 401–R12 800 | 4th quintile |
| 6. | R12 801–R25 600 | Upper quintile |
| 7. | R25 601–R51200 | |
| 8. | More than R51 200 | |

### Housing conditions and household services

Historically, SA has faced major differences with regard to household services. Many of these disparities have been emphasised since the inauguration of the new democratic government in 1994 and they continue to date. Although much progress has been made to reduce these inequalities, many households are still facing poor household services, which serve as a key indicator of historical underdevelopment that contributed to high levels of countrywide poverty. Consequently, it is generally accepted that in SA, household income is a powerful predictor of access to household services. Access to water and electricity and other household services, along with housing conditions, are therefore used by Stats SA as a predictor of households facing poor living conditions and poverty.[145, 146] Questions from the CSHQ[46] related to housing conditions and household services, including the type of housing, home ownership, number of people living in the house, water, sanitation and electricity supply, along with ownership of household electrical appliances were used in the SDQ as indicators of poor housing conditions to identify participants from families at risk of poverty.

**Employment status and level of education**

Education has the potential to eradicate poverty; the higher a person's qualification, the more likely they are to be employed and absorbed in the formal labour force and therefore less at risk of falling into poverty.[(145)] According to the 2015 Stats SA Poverty trends[(145)] (poverty measures by education level attained for individuals aged 18 and above), the percentage of households living in poverty, i.e. just enough financial resources to afford basic nutrition and household goods in relation to the level of education of the household head, were:

- No education = 76.2% poverty
- Some primary education = 65.7% poverty
- Primary education = 59.9% poverty
- Some secondary education = 45% poverty
- Matric (secondary education) = 21.8% poverty
- Higher education = 4.3% poverty

Additionally, those living in rural areas, belonging to the black African population group or households headed by females alone, have a higher risk of living in poverty.

**Table 3-3:** Levels of education on the SDQ

| **Highest level of education obtained within the household** | |
|---|---|
| 1. | Completed Grade 5 or less (Some primary education) |
| 2. | Completed Grade 6 (Primary education) |
| 3. | Grade 7–11 (Some secondary education) |
| 4. | Completed Grade 12 (Matric/secondary education) |
| 5. | Post matric education (Higher education) |
| 6. | Diploma/degree (Higher education) |
| 7. | No formal education |

The SDQ included questions used in the CSHQ(46) to obtain information about population group, single income households and highest level of education in the household, as summarised in Table 3-3.

**Access to school**

An additional question regarding access to school was included in the SDQ as an indicator of the SES and PA of participants. In LMICs, children from a lower SES often need to rely on walking to school due to the inaccessibility to motorised transport. Transportation to school via a motor vehicle is therefore generally associated with a higher SES, but at the same time a lower level of PA.(111, 135)

3.3.2.3 Digital stadiometer and medical body composition analyzer (mBCA)

Seca 274 digital mobile stadiometer (Figure 3-5) with a heel-positioner, head piece and built-in Frankfort Line for precise head positioning was used to measure standing height in centimetres rounded to the nearest 0.1cm.(148) The height measurement reading transferred wirelessly to the Seca mBCA 514 body. The Seca mBCA 514(148) (Figure 3-6), with an integrated digital scale, was used to measure weight in kilograms rounded to the nearest 100g as well as BC.

**Figure 3-5:** Seca 274 digital stadiometer

**Figure 3-6:** Seca mBCA 514

The mBCA is designed to measure BC in the standing position on a platform with an integrated scale, a supporting handrail and a display unit for operation. Four electrodes are positioned on the platform, two for each foot, to allow contact with each heel and forefoot. The handrail carries three pairs (six) of electrodes on each side, of which two pairs were chosen depending on the participant's height, i.e. which pair they were able to reach comfortably.

Both the Seca 274 and mBCA 514 were calibrated by Delta Surgical,[149] an authorised supplier of Seca in SA, prior to the start of the study (Annexure C-1 and C-2, calibration certificates). After each move of equipment to another site, the company representative reviewed the accuracy of the equipment, and no additional calibration was required. The researcher and assistant further monitored the accuracy of the stadiometer and digital scale daily before measurements were taken by using a 100 cm metal rod and calibration weights provided by the company.

#### 3.3.2.4 Indirect calorimeter

Resting energy expenditure was measured using the Cosmed Quark RMR indirect calorimeter.[49] The Quark RMR is considered a reliable and accurate measurement of RMR and REE.[49, 150-152] When compared with methanol combustion, a technique used to assess the accuracy and precision of IC measurements, Cosmed was among the most accurate and reliable instruments with measured variables within ± 2% of the theoretical values.[151]

A ventilated canopy hood with a disposable antibacterial filter was used to collect and transfer expired gas to an $O_2$ and $CO_2$ analyser that measures gas exchange. The Quark RMR uses $VO_2$ and $VCO_2$ to determine RQ and to calculate REE by using the abbreviated Weir's equation (RMR = $[3.9(VO_2) + 1.1\ (VCO_2)]\ 1.44$).[49, 56]

A full service of the Quark RMR was completed by a SA certified Cosmed engineer prior to the study, and the system was configured with the correct reference values and gas concentration values for calibration procedures (certificate attached in Annexure C-3).

#### 3.3.2.5 Pedometer

Pedometers are considered a convenient, economical and accurate tool to objectively assess PA.[118] A spring-levered Yamax Digi-Walker SW-800 pedometer (Yamasa, Japan) (Figure 3-7) was used to measure the daily step-count of participants. A review by Clemes and Biddle[118] identified a number of studies comparing accelerometery-based PA with pedometer-measured step-count and concluded that the Yamax Digi-Walker was a reliable and accurate tool to assess PA in preadolescent children. Additionally, the Yamax Digi-Walker has been used in many large-scale studies to assess PA in young children and is considered the gold standard pedometer.(118, 121, 122)


**Figure 3-7:** Yamax Digi-Walker SW-800 pedometer

### 3.3.2.6 Physical activity questionnaire for older children (PAQ-C)

Objective measures for the assessment of PA have become more affordable and feasible and are therefore often used as the preferred method to assess PA. However, subjective methods, including self-report measures and questionnaires, are still frequently used in conjunction with objective measures to describe the type and context of PA.(117) The PAQ-C (Annexure A-2) was used in this study to describe the involvement of participants in PA. In addition, the PAQ-C was used to monitor device reactivity while wearing the pedometer by completing the questionnaire before and after the 7-day period of wearing the pedometer.

Suitable subjective measures are generally selected based on their reported validity, reliability and ease of use. Based on pre-set criteria to evaluate validity and reliability outcomes of previous publications, an expert panel rated the PAQ-C as a well-used and time-efficient tool with “moderate” validity and reliability against a variety of direct measures, including DLW.(117) The PAQ-C is a 7-day recall questionnaire developed as a guided, self-administered instrument to assess habitual MVPA of 8–14-year-old children in a school environment during the school term.(128, 130) The PAQ-C has been used in many studies, including SA studies, for children from as young as six years from varied ethnic backgrounds.[29, 33, 36, 117] Using correlation as basis for performance, the PAQ-C demonstrated an acceptable test-retest reliability sensitive to differences for males (r = 0.75) and females (r = 0.82)[117, 153] and good internal consistency (r = 0.72–0.88),[154] including internal consistency among ethnic groups.[129] Convergent validity of the PAQ-C has been established, with a moderate relationship found between an activity rating scale (r = 0.57-0.63), a week summation of 24-hour MVPA recalls (r = 0.53)[128] and actigraph accelerometery (r = 0.56–0.63),[154] thereby supporting the PAQ-C as a method to assess general PA levels in children.[117, 128]

It has been identified that the accuracy of information collected by a self-administered questionnaire may be influenced by the opinion and perception of the participant or by the ability to accurately recall details. For young children who may have varied activity patterns and differences in cognitive and linguistic ability, these influences may be amplified.[115] Although the PAQ-C was developed as a self-administered questionnaire, it has been suggested that the validity of self-administered methods in children can be increased by interviewer-administered methods.[115, 130] For this reason, the researcher or the research assistant assisted participants with the completion of the PAQ-C by reading the questions and available options to them before marking their chosen option on the questionnaire.

The PAQ-C is designed to be administered once and requests children to recall their involvement in PA for the past seven days. The survey includes nine questions based on a variety of different PA taking place during physical education classes, during school breaks, after school at “lunchtime” and thereafter, and during evenings and over the weekends. Participants are requested to check a list of activities for frequency of participation on a scale varying from “no”, “1–2” times per week, “3–4”, “5–6” and “7 times or more” per week. A measure of frequency is requested for each day, ranging from “none” to “very often”. A tenth item not used in calculating the activity score asks children if they were sick/unwell or otherwise hindered from engaging in regular PA.[130]

Guided by previous studies,[29, 33, 129] the PAQ-C was translated into Afrikaans for participants from school A, an Afrikaans teaching medium school and the existing

English PAQ-C was used at school B, an English teaching medium school. A slight adaptation was made to the list of activities to include the most popular local sports activities, e.g. in-line skating was replaced with ice/roller skating, basketball with netball, badminton with tennis, street hockey with hockey etc. (translated and adapted PAQ-C: Annexure A-3). The adapted and translated questionnaires were tested during the pilot study.

### 3.3.3 Data collection

#### 3.3.3.1 Pilot study

A pilot study was conducted on 30 March 2019, prior to the start of data collection, to quantify procedures (i.e. time for completion) and to ensure the appropriateness of equipment and measurement tools. Three children with similar inclusion and exclusion criteria, but not included in the study sample, were invited to take part in the pilot study. Measurements were taken at the venue in the Old Agricultural Building, Hatfield Campus, University of Pretoria. All the procedures and measurement protocols for the completion of the consent form and SDQ, anthropometric, BIA and REE measurements and the completion of the PAQ-C were followed in the required manner stipulated in the study protocol (measurement procedures discussed later in this chapter). For the step-count measurement, a shortened protocol was followed, with the pedometer being worn for the minimum monitoring time frame of four days.

#### 3.3.3.2 School built environment

Prior to recruitment, the ISAT was completed for each school (Annexure A-4 and A-5) by following the steps stipulated in the ISAT manual of procedures.[45] The researcher completed both audits, thereby reducing inter-observer variability. An aerial map divided into grid-squares (Annexure A-6 and A-7) was obtained of each school. The researcher met with an administrative staff member at each school to help identify school boundaries, school entrances and location of other relevant amenities on the school grounds. The school grounds were then walked for the completion of the audit. Each grid-square on the map was visited and marked to ensure no area was missed. An ISAT worksheet (Annexure A-4 and A-5) was used to list and evaluate audited items at each location.

#### 3.3.3.3 General and sociodemographic information

When a parent accepted the invitation and the child was willing to participate, a parental information letter (Annexure A-1), informed consent form (Annexure B-1) and SDQ (Annexure A-1) was sent to the parent via e-mail or an SMS (Short message service)/WhatsApp document and an appointment was scheduled to attend at the allocated venue on the University of Pretoria Hatfield Campus or at the boardroom of school B.

The parental information letter provided information regarding the preparation/prerequisites for the measurements (discussed later in the chapter). Parents were informed that measurements could not be performed should their child be ill, taking medication or not meeting the requirements as stipulated in the letter. A reminder was sent via SMS to each parent the day before their appointment. Participants were requested to arrive well-rested and in time at the venue, wearing the school's physical education uniform or school uniform. Parents were asked to complete the informed consent form and SDQ prior to, or at the appointment.

Before each measurement, the researcher/assistant explained the purpose of the study and measuring procedures to each participant and assisted in the completion of the child assent form. The researcher/assistant then completed a data collection sheet (Annexure A-8) to record the participant's date of birth, age, sex, population group and nationality, thereby confirming that each participant met the inclusion criteria.

#### 3.3.3.4 Anthropometry and BIA

To help put the participants at ease, familiar measurements including height, followed by body weight and BC were taken first. Following the recommendation of the American Centres for Disease Control and Prevention's weight measurement protocol,[(155)] participants were requested to remove their shoes before height and weight measurements were performed. In addition, for height measurements (Figure 3-8, left), participants were requested to remove any hair bands or covers from the top of their head that may affect their height. They were measured barefoot standing straight, head horizontal (Frankfort plane) with arms on the side, heels together and feet flat and evenly distributed on the heel-positioner. Positioning was checked to ensure that the head, shoulder blades, buttocks and heels touched the back rod

(Figure 3-8, right). The head piece was then moved down to compress the hair while the participant was requested to take a deep breath and hold when the reading was captured.

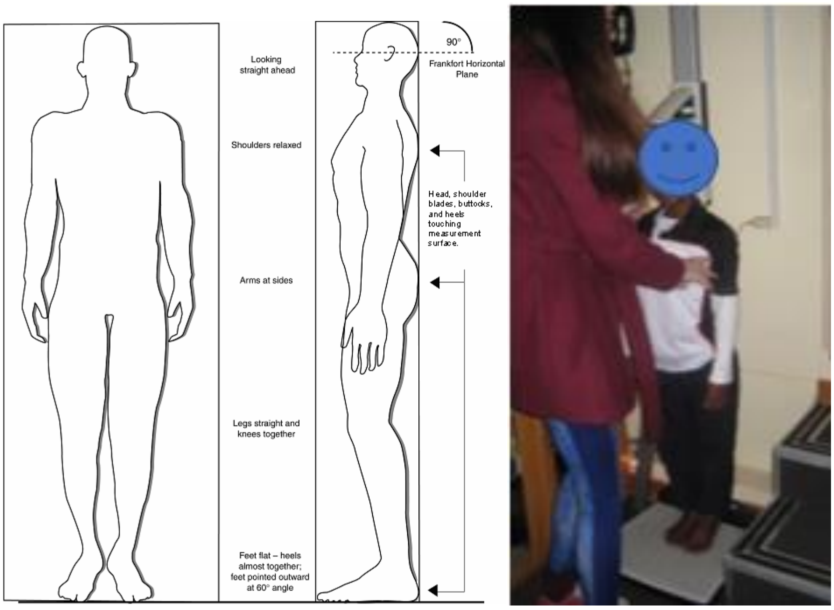


**Figure 3-8:** Height measurement protocol (left)[155] and height measurement taken by the research assistant (RD) (right)

For the BIA procedure, participants had to stand upright with outstretched arms and hands wrapping the electrodes so that the electrode separator was positioned between the middle and ring finger, and the thumb wrapping the handlebar (Figure 3.9).

**Figure 3-9:** BIA measurement

Measurement started automatically once contact with the electrodes was registered and continued for approximately 17 seconds. The eight electrodes are used to measure resistance, reactance and impedance of seven body compartments (left arm, right arm, left leg, right leg, left half of body, right half of body and torso) using a current of 100uA at 19 different frequencies.[148]

#### 3.3.3.5 REE measurements

The Quark RMR user manual,[49] supported by evidence,[55] was followed to ensure correct operating procedures:

The Quark RMR measures airflow and volume with a bidirectional turbine flowmeter. It is recommended to calibrate this turbine flowmeter periodically. Daily calibration is not required since measurements are not influenced by environmental factors such as temperature and humidity. Flow/volume calibration was therefore performed once per week with the recommended 3 litre calibration syringe and the attached antibacterial filter. Before each measurement session, the required 10-min warm-up period was allowed, followed by an "ergo calibration" test, an automatically performed analyser calibration. This procedure was repeated when the system indicated that values were outside the acceptable range. The flow rate of the pump was adjusted to ensure a continuous flow of air prior to each measurement. Between each measurement, disinfectant wipes were used to clean the canopy and surfaces in contact with the patient and a disposable antibacterial filter was connected. During measurements, the flow adjustment valve was used to increase or decrease the flow rate when $CO_2$ was respectively above or below the recommended range of 0,7 – 1.3% to protect the participant and ensure a reliable measurement.

Achieving and maintaining SS during IC is recommended to improve validity and reduce error from artefactual influences.[48, 55, 60] Steady state refers to a minimum variation in gas exchange variables from one minute to the next. According to the American Academy of Nutrition and Dietetics,[48] SS can be achieved with <10% CV for a specified time in one or more of $VO_2$, $VCO_2$, RQ, or minute ventilation. However, definitions may vary by the specified time for measurement (generally 4–25 min), CV (<5-10%) and combination of gas exchange variables. The Quark RMR SS displayed in Microsoft Excel is defined by Cosmed[49] as a time period when the average minute

$VO_2$ and $VCO_2$ changes by less than 10% and the average RQ changes by less than 5%.[48, 49]

Evidence-based measurement protocols are advised to ensure an individual reaches a complete resting state and maintains the required SS during the REE measurement. These measurement protocols can assist practitioners and researchers to identify and control the settings under which they perform IC assessments.[48] The American Academy of Nutrition and Dietetics published a review of the best practices for performing IC measurements and provided recommendations for optimal conditions to perform accurate IC measurements in adults (refer to section 2.2.1.2).[48] Research on the best procedure for measurements in young children is very limited and consensus on a standardised protocol has not yet been reached.[48, 63, 156]

Measuring REE in young children presents a challenge. Although many of the measurement recommendations for adults can be applied to children, many children cannot rest quietly for the required time. In adults, it is generally accepted that longer measurement periods may be more reflective of the REE value, but prolonged measurements may increase restlessness in children.[63] Shorter REE protocols of maximum 20 min, and possibly without a prior rest period or a shorter rest period during the measurement, appear to be more appropriate for young children due to reduction in boredom and consequent fidgeting.[48, 63] Although activities such as reading or listening to music during the measurement may increase REE,[157] previous studies used a video to help children remain quiet and still during measurements.[63, 156] Due to the lack of a measurement protocol for children, an abbreviated adult protocol along with recommendations based on previous REE measurements of children[48, 63, 156] was used for this study (summarised in Figure 3-10). Apart from a shorter measurement time, children were requested to refrain from exercise for only 12 hours. Abstinence from exercise, especially of vigorous intensity for 12–24 hours prior to a REE measurement is advised for adults. Factors such as intensity, duration, level of fitness and type of activity may influence the effect of exercise on REE typically for up to 90 min, and only in extreme cases up to 48 hours.[37, 48] Since the majority of young SA children appear to be inactive or engaged in moderate intensity school-related sports and activities,[158] abstinence from exercise at the lower end of the range was used for this study.

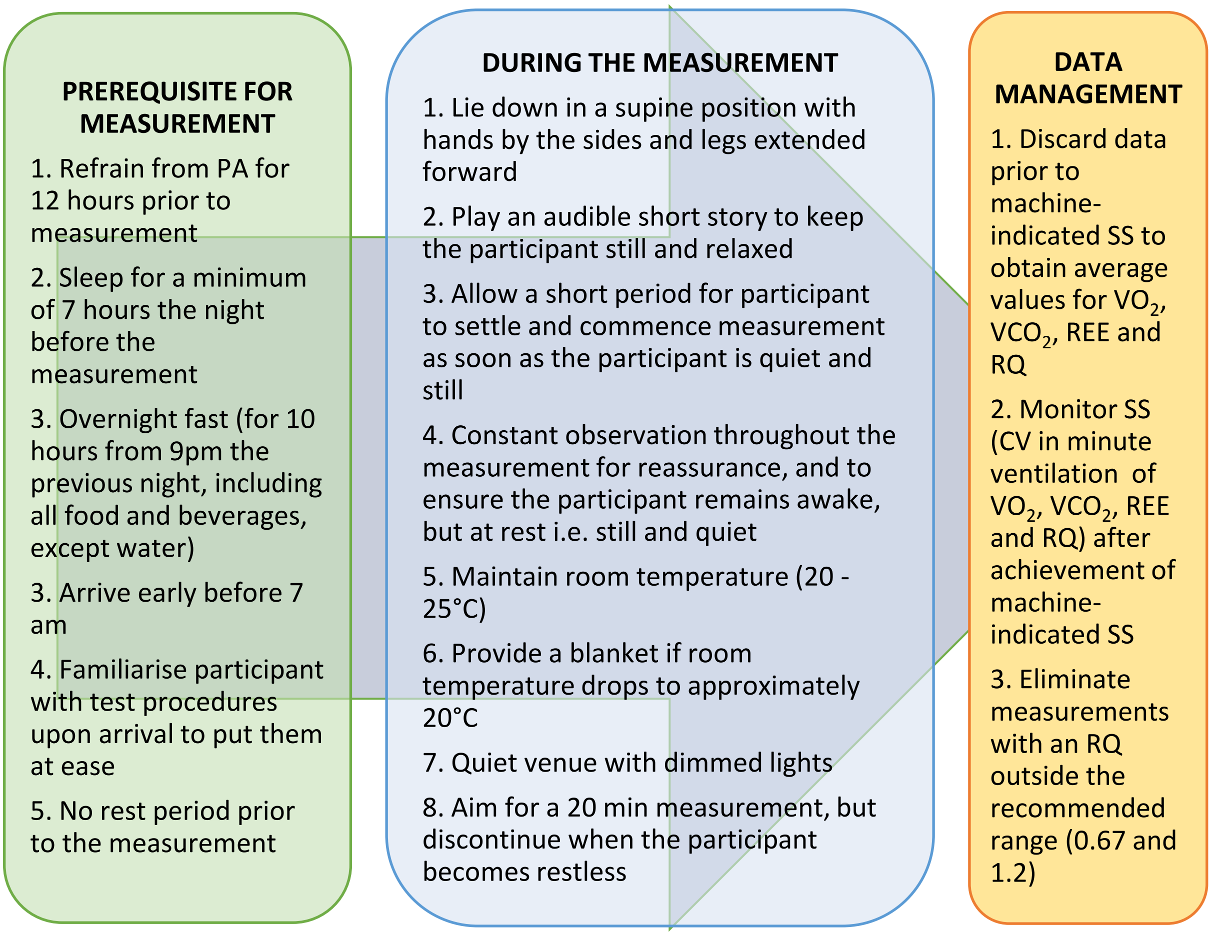


**Figure 3-10:** Procedures used for measuring the REE of participants

Information regarding the participant's fasting state, recent exercise, absence of illness, usage of medication and previous night's sleep pattern was collected by the researcher or research assistant and recorded on the data collection sheet (Annexure A-8) to confirm that they met the prerequisites for participation. Children who did not conform to the prerequisite or those who were ill or using medication were excluded from the study since medication may contain stimulants and chronic illness, or conditions related to inflammation and malignancies may affect REE.[55, 63, 64]

In addition to achieving and monitoring SS, the RQ was used as a quality indicator of measurement adequacy. RQ reflects the rate of substrate oxidation in metabolically stable individuals. Although not considered a reliable method, an RQ outside the expected range of 0.67 and 1.2 was used to provide an indication of participants who did not fast, or more likely to indicate measurement error.[55] [48]

#### 3.3.3.6 PA measurements

After completion of the IC, participants were requested to complete the PAQ-C (Annexure A-2 and A-3) with the help of the researcher/assistant. Thereafter, a spring-levered Yamax Digi-Walker SW-800 pedometer and masking tape were provided to each participant. The masking tape was initially applied to the pedometer by the researcher/assistant to demonstrate to each participant how the pedometer should be covered and attached each day. The pedometer was collected from participants after seven days. Participants were met after school at the aftercare centre or school sports grounds. At this point, the participants were requested to complete the PAQ-C again with the assistance of the researcher/assistant.

Although pedometers are generally used in research, various technical and behavioural challenges have been identified when using pedometers for the measurement of PA, especially in young children. The use of measurement protocols is therefore recommended to address these challenges and improve the validity and reliability of measurements. Despite this recommendation, there is a lack of standardised protocols for measurements in young children.(118, 159, 160) A number of collective measurement issues, including the monitoring time frame, optimum wear time, reactivity and tampering have been identified in previous research and used to provide recommendations for measurement protocols used in future research studies.(118, 160) The literature presented below guided the development of the procedures followed for pedometer measurement.

**Monitoring time frame and optimum wear time**

Previous studies(118, 160) identified that the optimum time for wearing a pedometer requires a delicate balance between maximising the monitoring time frame, i.e. the number of monitoring days along with the wear time each day, to represent habitual activity, without compromising compliance that may lead to missing data.

The optimum monitoring time frame to estimate habitual activity with pedometer measurement is currently unknown. Although a time frame of between 4–9 days is required to capture habitual PA in children,(161) it has been reported that compliance decreases with the increase in the number of monitoring days. To maximise sample size, a protocol of seven days of monitoring with a minimum of 4–5 complete days, including one weekend day, has been recommended for younger children. Data of incomplete days with non-wear time exceeding one hour, or extreme values of less than 1000 or more than 30 000 steps should be excluded.[118, 160, 162] In addition, participants should be requested to wear the pedometer for at least 8–10 hours per day,[118] or from morning until evening,[160] and to record wear time as well as participation in non-ambulatory activity such as cycling and swimming.[118]

**Reactivity and device tampering**

Reactivity refers to a change in habitual activity behaviour when participants are aware that they are being monitored.[163] Reactivity has been identified as a common behavioural problem associated with wearing a pedometer that may affect the validity of the data. Researchers have investigated the impact of sealing the pedometer to prevent participants from monitoring their activity and concluded that pedometer reactivity in children does not occur if the pedometers were sealed.[118, 159, 160, 163] Although sealed pedometers are available, closing the pedometer with a sticker or tape, is effective in counteracting reactivity. In addition, sealing also reduces the risk of accidental reset, a common problem associated with pedometers.[160]

Device tampering, especially with young children, may be another factor to influence the accuracy of pedometer measurements. Tampering may include an attempt to manipulate the step-count by manually shaking the device, putting the device on someone else, or jumping up-and-down.[159, 160] Although device tampering has been acknowledged in previous studies among children and adolescents, there is no evidence on the effect of device tampering on the validity of pedometer readings.[160] A study on adolescents indicated that wearing a sealed pedometer and withholding measurement feedback from participants, may reduce device tampering.[159]

Each participant was provided with a Yamax Digi-Walker SW-800 pedometer attached to an adjustable elastic belt that fitted securely around the waist (Figure 3-12).

**Participants were instructed (and where applicable accompanied by a demonstration) to:**

- Wear the pedometer for 7 consecutive days from when they got up in the morning until they went to sleep at night.
- Cover the pedometer each morning with masking tape provided to keep the cap closed during the day, thereby preventing reactivity and device tampering.
- Remove the pedometer during water-based activities and when taking a bath/shower.

**Parents/guardians of the participants were requested to:**

- Record the time intervals of non-ambulatory activities and activities undertaken when the device was removed (cycling, swimming, high-impact sport) and send this information via SMS to the researcher at the end of each day.
- Send an SMS with the day's step-count to the researcher at the end of each day.
- Refrain from commenting on the number of steps taken each day, since this may lead to altered habitual PA behaviour.

- A letter with instructions and an illustration (Figure 3-12) on how to use and securely attach the pedometer was provided/sent via SMS to the parents/guardians (Annexure A-1: parental information letter).
- An SMS message was sent to parents/guardians each morning as a reminder for their children to wear the pedometer and again each night as a reminder to record and send an SMS with the day's step-count and time intervals of non-ambulatory activities/removal of device.
- If a parent/guardian was unable to send an SMS with the step-count each day, the researcher/assistant met the participant daily after school to record the pedometer reading.
- The researcher/assistant monitored the individuals at school after 2-3 days of disseminating the pedometer, to ensure that it was worn correctly.

- If a participant did not wear the pedometer or was involved in non-ambulatory or water-based activities for more than 1 hour/day, the day's data for that participant were excluded.
- Extreme values of less than 1000 or more than 30 000 steps/day were excluded.

**Figure 3-11**: Procedures followed for pedometer measurement

**Wearing position**

Pedometers are commonly worn on the hip to detect vertical displacement and motion. When a pedometer is tilted away from the vertical axis, typically more than 10º, their sensitivity is diminished resulting in an undercount of steps.(120, 164) Securing the pedometer to the waist is therefore recommended to prevent tilting and improve accuracy.(118)

Many pedometers, including the Yamax Digi-Walker has a clip on the back of the pedometer that can be slipped onto clothes. However, a study by Duncan et al.(164) identified that children wearing unsuitable clothing or a loose-fitting waistband with limited elasticity often resulted in the pedometer tilting away from the vertical plane and consequently an undercounting of steps. To improve stability and reduce error, they suggested that the pedometer should be fastened to a secure elastic belt system, rather than relying on the existing clip on the back of the pedometer.

Directed by the above recommendations from the literature, a measurement protocol as summarised in Figure 3-11 was followed. An illustration with pedometer wear instructions (Figure 3-12) was given to each participant.

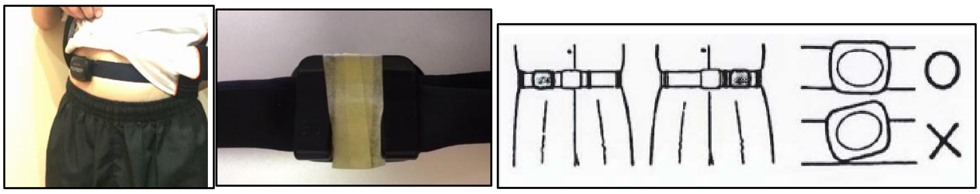


**Figure 3-12:** Pedometer with wear instructions

### 3.3.4 Data management and analysis

#### 3.3.4.1 Key variables

The following variables were obtained during data collection:

- Age (6, 7, 8, 9 years: reported and confirmed by calculating from date of birth); sex (boy or girl); population group (black African or white); nationality (Southern African)

- SES categories SDQ 1–SDQ11 categorised according to housing conditions and household services; educational level; household income
- Phenotypic variables:
  - Body weight (kg); height (m); BMI (kg/m$^2$) expressed as WFA z-score, HFA z-score, BMI-FA z-score
  - BIA total body resistance (R) (Ω) at 50 kHz to determine:
    - FFM (kg); FFMI (kg/m$^2$)
    - FM (kg); FMI (kg/m$^2$)
- REE (kcal/day), RQ ($VCO_2/VO_2$); %CV
- Time to reach SS during IC: Three time-related SS categories including
  - Early achievers (< 5min)
  - Middle achievers (≤ 5 min; <10min)
  - Late achievers (≥ 10 min)
- PAQ-C activity score; mean of the composite score of 9 items rated on a scale of 1 to 5
  - Two data sets including PAQ-C-before and PAQ-C-after (before and after the 7 days of wearing the pedometer)
  - PAQ-C average, a calculated average of PAQ-C-before and PAQ-C-after
- Objectively measured PA:
  - Average number of steps/day
  - Average number of steps/weekday
  - Average number of steps/weekend day

#### 3.3.4.2 School built environment

Information about the school built environment obtained via the ISAT was used to describe this environment in terms of access to school, the surrounding area of the school, school grounds and aesthetics and usage of sport and recreational equipment and facilities. Quantitative data regarding safety features in the school surrounding area and number of sports and recreational amenities were captured and analysed in Microsoft Excel.

#### 3.3.4.3 Sociodemographic information

The sociodemographic information collected with the SDQ was manually captured in Microsoft Excel by the researcher. When missing information was identified, the relevant parent of the participant was contacted to obtain the necessary information.

Sociodemographic information was used to describe the context of the study, including the SES of participating households, the age of participants and the sample distribution in terms of sex categories and population groups.

#### 3.3.4.4 Phenotypic variables

Anthropometric measurements and BIA were used to obtain phenotypic variables. Height and weight measurements and BIA data were transferred wirelessly from the Seca mBCA to a personal computer. Weight-for-age z-scores, HFA z-scores and BMI-FA z-scores were calculated by the built-in software from Seca based on the WHO growth reference data[50] and displayed in Microsoft Excel.

BMI-FA z-scores were used to categorise participants into weight categories based on the 2007 WHO growth reference data.[50] Participants were classified as:

- Thin when BMI-FA < -2 SD of the median
- Healthy when BMI-FA ≥ -2 and ≤ 1 SD of the median
- Overweight when their BMI-FA is > 1 SD and ≤ 2 SD of the median
- Obese when their BMI-FA is > 2 SD of the median.

The resistance (R) value of the total body bioelectrical impedance vector analysis (BIVA) was used to calculate the BC. The BIVA is based on the average bioelectrical values of the left half and right half of the body, measured at 50 Hz, standardised for the subject's body size.[148] Resistance is directly proportional to the length of the conductor and inversely proportional to its cross-section; consequently BIVA is used to remove the effect of the conductor length, i.e. height and size of the participant.[165] The equation of Horlick[39] was used to calculate FFM, since it was the only equation found in the literature validated for use in both African and white prepubertal children.

The resistance (R) values of BIVA were manually transferred to Microsoft Excel for these calculations:

FFM (kg) =

$[(0.459 \times H^2/R) + (0.064 \times W) + 3.474] / [(0.769 – (0.009 \times age) – (0.016 \times sex)]$

(H = *body height in cm*; R = *resistance in Ω*; W = *body weight in kg*).

Fat mass was calculated in Microsoft Excel by subtracting the calculated FFM from total body weight (kg). Fat-free mass index and FMI were calculated in Microsoft Excel respectively as FFM in kg divided by height in metres squared and FM in kg divided by height in metres squared.

3.3.4.5 REE-related variable

The Quark RMR is attached to a mobile cart with a personal computer where measured values are displayed. All relevant measurement data were exported to Microsoft Excel. The data in Microsoft Excel display a summary of measurement values in 5-second increments in addition to other relevant information such as participant details, ambient temperature, time and duration of the measurement and timing and duration of achieving SS (Figure 3-13).

| | A | B | C | D | E | F | G | H | I | BC | BD | BE | BF | BG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ID code: | 384 | Test number: | 409 | Barometric press. (mmHg): | 651 | time | VO2 | VCO2 | Steady Sta | EEm | EEh | EEkc | npRQ |
| 2 | Last name: | | Test date: | 2019/04/13 | Temperature (degrees C): | 20 | hh:mm:ss | ml/min | ml/min | --- | Kcal/min | Kcal/h | Kcal/day | --- |
| 3 | First name: | | Test time: | 7:09 | Humidity;% | 63 | | | | | | | | |
| 4 | Sex: | F | N. of steps: | | Temp. flowm. (degrees C): | 20 | 00:00:02 | | | | | | | |
| 5 | Age: | 7 | Duration (hh:mm:ss): | | Humidity flowm.;% | 100 | 00:00:07 | | | | | | | |
| 6 | Height (cm): | 130,3 | BSA (m^2): | | | | 00:00:12 | | | | | | | |
| 7 | Weight (Kg): | 27,23 | BMI (Kg/m^2): | | | | 00:00:17 | | | | | | | |
| 8 | Notes: | | HR max (bpm): | | | | 00:00:22 | | | | | | | |
| 9 | | | | | | | 00:00:27 | | | | | | | |
| 10 | | | | | | | 00:00:32 | | | | | | | |
| 11 | | | | | | | 00:00:37 | | | | | | | |
| 12 | | | | | | | 00:00:42 | | | | | | | |
| 13 | | | | | | | 00:00:47 | | | | | | | |
| 14 | | | | | | | 00:00:52 | | | | | | | |
| 15 | | | | | | | 00:00:57 | | | | | | | |
| 16 | | | | | | | 00:01:02 | | | | | | | |
| 17 | | | | | | | 00:01:07 | | | | | | | |
| 18 | | | | | | | 00:01:12 | 195,0716 | 169,703 | * STEADY | 0,947488 | 56,84926 | 1364,382 | 0,86 |
| 19 | | | | | | | 00:01:17 | 199,6182 | 177,474 | * STEADY | 0,974292 | 58,45752 | 1402,98 | 0,88 |
| 20 | | | | | | | 00:01:22 | 202,9172 | 182,157 | * STEADY | 0,992559 | 59,55352 | 1429,284 | 0,89 |
| 21 | | | | | | | 00:01:27 | 202,94 | 181,77 | * STEADY | 0,992166 | 59,52998 | 1428,72 | 0,89 |
| 22 | | | | | | | 00:01:32 | 194,0265 | 171,883 | * STEADY | 0,946233 | 56,77398 | 1362,576 | 0,88 |

**Figure 3-13:** Quark RMR data as displayed in Excel

Typically, all measurement values before the achievement of SS, or for the first 5 min of the procedure, are discarded.[48, 49] For this study, all values prior to the achievement of machine-indicated SS were discarded (e.g. rows 3–17; Figure 3-13), before the average $VO_2$, $VCO_2$, REE (kcal/day) and the RQ values were calculated in Microsoft

Excel and manually transferred to a data sheet to capture the values for each participant. Since the majority of the international literature reviewed for this study refers to kcal to express REE(9, 74, 76) and the Quark provides REE output in kcal/day, kcal was used as the preferred unit for REE measurements and outcomes in this study. For the final discussion, kcal was converted to kJ using a factor of 4.2 since kJ is more typically used in SA settings.

The measurements of participants who did not achieve machine-indicated SS were removed from the data set. Participants who achieved SS before 5 min of measurement lapsed were classified as "early achievers" of SS. "Middle achievers" were those who achieved machine-indicated SS at 5 min and up to 10 min and "late achievers" reached SS at 10 min or later.

To monitor the effectiveness of the REE measurement procedures, the intra-individual variability of REE-related measurements after the achievement of machine-indicated SS was determined:

The percentage CV (%CV = SD/mean*100) for $VO_2$, $VCO_2$, REE and RQ was calculated at intervals (at 10 min, 15 min, 18 min and 20 min of starting the measurement) for each participant.

The RQ values were monitored and no measurements were outside the expected RQ range of 0.67 and 1.2.

#### 3.3.4.6 PA-related variables

The daily step-count readings received from parents or monitored by the researcher/assistant were captured in Microsoft Excel. For each participant the average steps/day, steps/weekday and steps/weekend day were calculated in Microsoft Excel.

PAQ-C questions were scored on a 5-point rating scale to evaluate the frequency and intensity of activities. A higher score indicated a higher level of activity. The mean of these items formed a final composite activity score categorised from a low to high PA. A tenth item not used in calculating the activity score asked children if they were sick/unwell or otherwise hindered from engaging in regular PA.[130] Children who were unwell were excluded from the sample.

For this study the PAQ-C score was calculated for each participant and included decimal figures instead of the generally used 5-point scale to allow for a more insightful comparison of PAQ-C outcomes. The PAQ-C score was calculated before and after wearing the pedometer and an average of these scores (PAQ-C average) was captured in Microsoft Excel.

The relationship (Spearman's product-moment correlation) between average steps/day and the average (of before and after wearing the pedometer) score of each PAQ-C question was determined. However, since no significant relationship was observed for any of the PAQ-C questions, the results were omitted from the content of this report but can be viewed in Annexure D-1.

#### 3.3.4.7 Statistical analysis

Internal statistical services at the Research Office of the Faculty of Health Sciences, University of Pretoria conducted the statistical analyses. Data were initially captured in Microsoft Excel and transferred to Stata Release version 15 (Statacorp) for statistical analysis. The significance level was set at 0.05 for all analyses.

- Two-sided Fisher's exact test was used to assess and describe:
    - The age distribution of the sample
    - Differences in SES categorical variables between population groups and between schools
    - Distribution differences between sex categories and population groups
    - Distribution differences between sex categories and population groups with respect to SS categories.
- Continuous variables (age, phenotypic, REE- and PA-related) were summarised by sex categories and population groups, reporting linear estimated means (predictive margins) including a 95% confidence interval, following an analysis of variance (ANOVA) with fixed effects sex, population group and their interaction.

- Student's paired t-test was used to assess the difference in the mean PAQ-C-before and after wearing the pedometer.
- The Welch two-sample t-test with unequal variances was used to determine the difference in the mean REE between population groups per healthy and overweight/obese weight categories.
- The intra-individual percentage CV (%CV = SD/mean*100) was calculated for REE, $VCO_2$, $VO_2$ and RQ to determine variation in REE-related variables.
- Spearman's product-moment correlation, assuming a non-normal distribution of most variables, was used to determine the strength and statistical significance of the relationship between:

  - REE and each variable respectively (age, WFA z-score; HFA z-score, BMI-FA z-score, FFM, FFMI, FM, FMI, average steps/day, average steps/weekday, average steps/weekend day, PAQ-C-before and PAQ-C-after pedometer wear, PAQ-C average [average of PAQ-C before and after]).
  - Objectively measured PA and each variable respectively (age, WFA z-score; HFA z-score, BMI-FA z-score, FFM, FFMI, FM, FMI).
  - Average steps/day and PAQ-C average.

- With multivariable regression, the associations of sex and population group were assessed with respect to:

  - REE, taking interaction into account and the covariates age, WFA z-score, HFA z-score, BMI-FA z-score, FFM, FFMI, FM, FMI, average steps/day, with different models respectively.
  - PA, taking interaction into account and the covariates age, WFA z-score, HFA z-score, BMI-FA z-score, FFM, FFMI, FM, FMI, REE respectively.

- Agreement of measured and estimated REE was determined with the Bland-Altman (BA) analysis within sex categories and population groups.

## 3.4 ETHICAL AND FINANCIAL CONSIDERATIONS

Following the submission of the research protocol in November 2018, the study was approved by the University of Pretoria's Faculty of Health Sciences Research Ethics Committee, on 14 March 2019 (Ethics Reference No. 757/2018; Ethics approval certificate attached in Annexure E-1). An amendment to the initial proposal was submitted and approved (amended ethics certificate Annexure E-2) since minor changes were made to the title and content in order to

- include children up to the age of 9- years, thereby including Grade 3 learners who had already turned 9 earlier in the year
- change to a more suitable venue at the University of Pretoria where equipment could be safely stored.

- Parents/guardians were required to provide written informed consent prior to data collection or measurements (Informed consent form: Annexure B-1).
- Children were asked to complete an assent form with the assistance of the parent/researcher/assistant prior to data collection or measurements (Child assent form: Annexure B-2). Prior to the measurements, the purpose of the study and all measurement procedures were explained on a linguistic level suitable for a young child.

  - Although the procedures did not involve any health or safety risk, the parents/guardians were asked to provide an alternative contact number (informed consent form: Annexure B-1). Additionally, the operational management emergency center (at the University of Pretoria) and the relevant school's designated first aider were requested to be on site/available when measurements were being taken so as to be contacted in the event of a medical emergency.
  - Participation was entirely voluntary.
  - The researcher was next to the participant throughout the measurements. A participant was able to indicate if they felt uncomfortable and should they wish for the measurement to be discontinued at any time.

- No compensation was provided, except for a small breakfast snack after the assessment.
- The study contributed to raising awareness of a healthy lifestyle (nutrition and PA) in the participating schools and dietetic-related services were offered to the participating schools. After data collection, the researcher was invited to deliver a presentation to Grade 3 learners of school A on the principles of healthy eating, which coincided with their curriculum.
- A record with all measurements and a preliminary interpretation thereof was provided to the parent/guardian of each participant. These records can be used to seek dietetic input to accurately determine individual energy requirements for effective nutritional and PA intervention.
- The researcher was prepared to answer questions related to the study and the reasons for investigating the REE of different population groups, by explaining that every person is unique. In health and nutrition care, healthcare workers want to match the advice and treatment given to each person. One of the many possible issues that may determine how much energy your body needs could be your population group. That is why we do the study.
- Parents were informed via the parental information letter (Annexure A-1) that should their children not meet the required inclusion criteria, they might not be included in the study. There were three of these cases and measurements were still taken, a breakfast snack was provided, and the children were given the option to wear a pedometer for three days.
- All data and information were treated confidentially, and no information or identity of participants will be disclosed.
- Research articles and reports will not include any data that might identify participants.
- Annexure E-3 and E-4 contains approval letters from both schools (without disclosing the identity of the schools).

The study was funded by the South African Sugar Association. The funds were mainly used for

- servicing of equipment
- transport of equipment to the various locations
- provision of a breakfast snack for participants,
- printing of questionnaires and the research report
- conference attendance for the presentation of the study

A summary of financial expenses is available in Annexure E-5.

# CHAPTER 4: RESULTS

A summary of the study results will be provided in this chapter as shown in Figure 4-1.

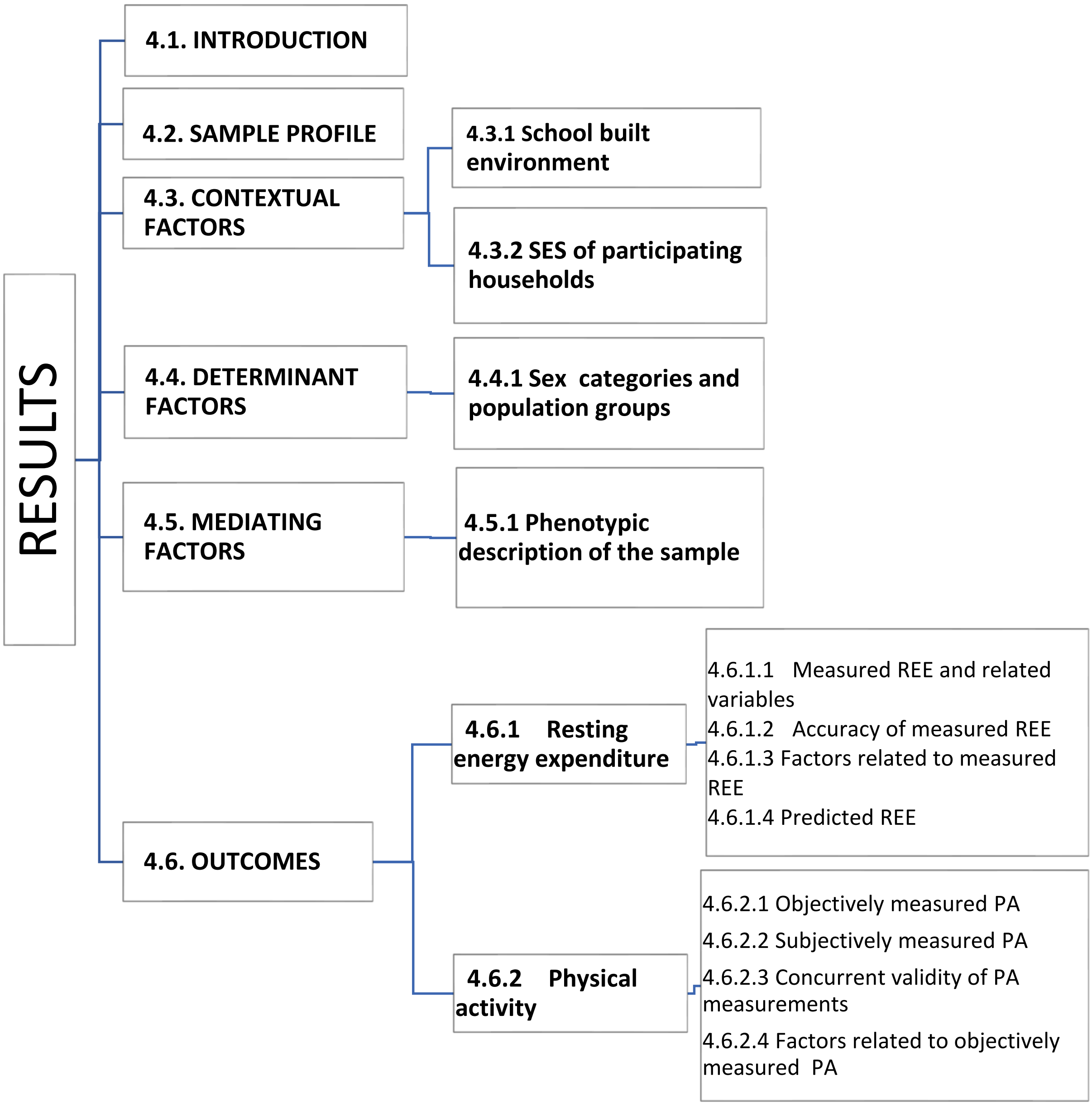


**Figure 4-1:** Outline of chapter 4

## 4.1 INTRODUCTION

Chapter 4 provides details about the results of the study. It includes a short discussion of the sample profile and the characteristics of the sample. Contextual factors, including the built environment of the two selected schools, the SES of participating households and the age distribution of participants, are described. The sample distribution among sex categories and population groups (determinant factors) is explained and graphically presented. Mediating factors, including phenotypic characteristics such anthropometric and BC data of participants, are summarised and categorised by sex categories and population groups. Outcomes of the study, including REE (measured and predicted) and PA (objectively and subjectively measured) are provided with related statistical analysis to support the accuracy of these measurements. Finally, the relationship between the relevant mediating factors and outcomes is presented.

## 4.2 SAMPLE PROFILE

The data pertaining to 26 participants were excluded from the initial 120 recruited, resulting in a final sample size of 94. For one of the 26 participants excluded from the sample, a SDQ was not available. The data on 19 children (6 black African: 3 girls; 3 boys and 13 white: 7 girls; 6 boys) were excluded since SS was not achieved during the REE measurement. Another five participants (3 black African boys; 1 white girl; 1 white boy) were excluded due to implausible REE data i.e. power failure during a measurement or extremely low outlier REE values below 420 kcal/day (2 participants). Data from two participants (black African girls) were omitted due to one or both parents being of Northern African nationality (Figure 4-2).

Fifty-eight (61.7%) of the participants (13 black African: 7 girls; 6 boys and 45 white: 29 girls; 16 boys), attended school A and 36 (38.3%) (black African: 20 girls; 16 boys) attended school B (Figure 4-2).

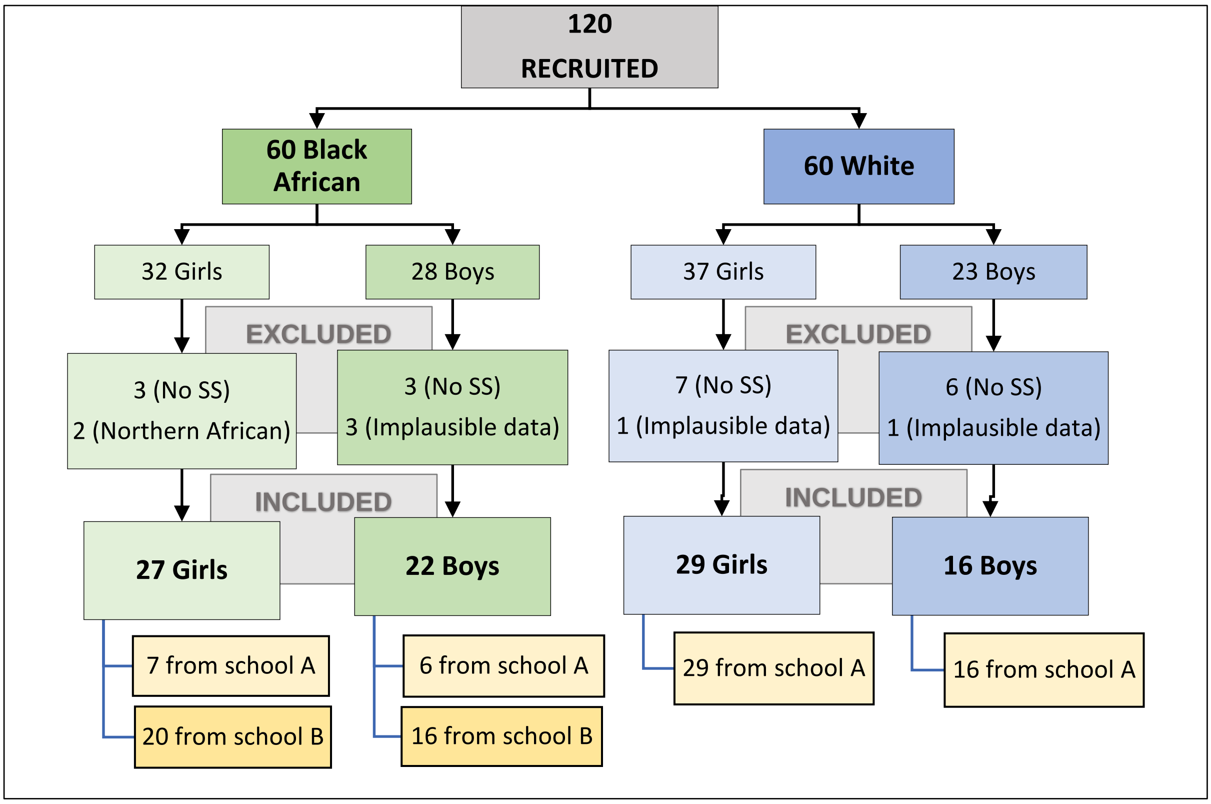


**Figure 4-2:** Sample profile

The age of participants ranged from 6.4 to 9.7 years, with a mean age of 7.9 years (SD = 0.79) for the sample. The age distribution among sex and population groups is summarised in Table 4-1 and indicates that the sample was relatively homogenous in age. There was no statistically significant difference in the mean age between sex categories (P = 0.745). Although a statistically significant difference in mean age existed between the two population groups (P = 0.027), the difference of 0.36 years is considered to have no practical significance.

**Table 4-1:** Age distribution of the sample (N = 94)[a]

| Sex | Mean age[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean age[b] | 95% CI[c] | Population difference black African-white | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|
| Girls | 7.94 | (7.74;8.15) | -0.05 | 0.745 | Black African | 8.10 | (7.88;8.32) | -0.36 | 0.027 |
| Boys | 7.89 | (7.64;8.14) | | | White | 7.73 | (7.50;7.97) | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] Two-way ANOVA

## 4.3 CONTEXTUAL FACTORS

### 4.3.1 School built environment

The ISAT was used to assess the school built environment of the two selected schools. An assessment of the school built environment was necessary to understand the opportunities for PA at the selected schools. The findings are available in Annexure A-4 and A-5. A summary of data collected for each subsection in the ISAT tool is provided below.

**Access to the school**

All school entrances from the main road to the schools were described in terms of accessibility by car, pedestrian or cyclist. The main, primary entrance to both schools was designed for use by cars, although pedestrians and cyclists, where applicable, also used these entrances. Separate pedestrian access gates adjacent to the main entrance were available at both schools, and both schools had a secondary access gate designed for use by cars. Roadside parking was available at school B, but was limited at school A, especially at the pedestrian gate. Main access gates opened onto a public road with a speed limit of 60 km/hour at both schools.

**The surrounding area**

Both schools were predominantly surrounded by a residential area, although passing traffic was more regular at school A. Both schools had parking available on and outside the school grounds and an area where parents could stop to drop off children. No bus stops or cycle lanes were available at any school. Sidewalks were present at both schools, with school A having a sidewalk on both sides of the road. A marked pedestrian crossing was available at both schools, but traffic calming and road warning signs were only observed at school A (Table 4-2).

**Table 4-2:** School surrounding area

| | School A | School B |
|---|---|---|
| Somewhere where parents can park or stop and drop children off | ✓ | ✓ |
| Bus stop | ✕ | ✕ |
| Cycle lanes | ✕ | ✕ |
| Sidewalks | ✓ | ✓ |
| Marked pedestrian crossing | ✓ | ✓ |
| Traffic calming or road warning signs | ✓ | ✕ |

### The school grounds

Both schools had a variety of good quality and functional activity and sports areas available, including paved areas for active games, markings for play surfaces, e.g. hopscotch, grass surface play areas, sports fields and running track, tennis/netball courts and swimming pool. School B also had a fitness course on the grounds. Both schools had at least ten (maximum number indicated on the ISAT tool) items of playground equipment such as swings, slides or a jungle gym. School A provided interaction with nature through a vegetable garden, whereas school B had a nature garden.

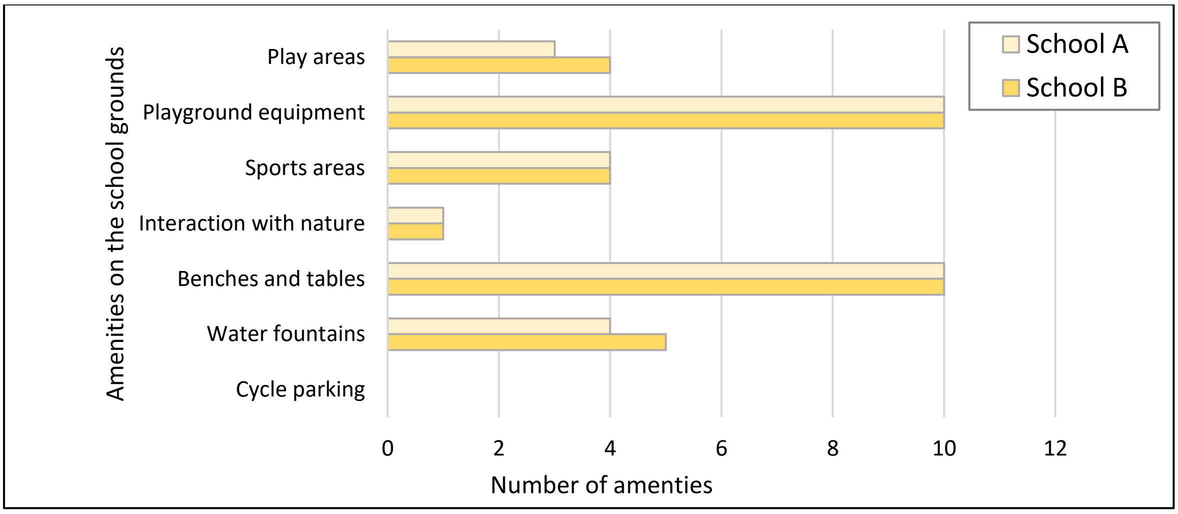


**Figure 4-3:** Number of good quality and functional amenities on the school grounds

Supporting features such as benches and picnic tables were in abundance (exceeding the maximum number of 10), however water fountains or taps were limited to four at school A and five at school B. Although functional, the quality of the water fountains was scored 4 out of 5. None of the schools had allocated cycle parking available. Both schools had predominantly flat playgrounds on one site. Figure 4-3 summarises the number of good quality and functional amenities available on the school grounds of the selected schools.

**Aesthetics**

Both schools had an abundance of trees to provide shade. Gardens were well maintained with planted beds. Artwork of learners was displayed on notice boards, along with additional photos of school activities and other murals. Localised litter on mostly litter-free grounds was observed. School A is situated near a busy road and some background noise was present, but not enough to be disturbing, while no noise was noticed at school B.

**Usage**

Both the school grounds were suitable for sports activities (organised or otherwise), informal games as well as general play.

### 4.3.2 SES of participating households

**Household income categories**

The majority of participants (96%) were from a household within the upper quintile income category, while 2% were from the 3rd and lower quintiles.

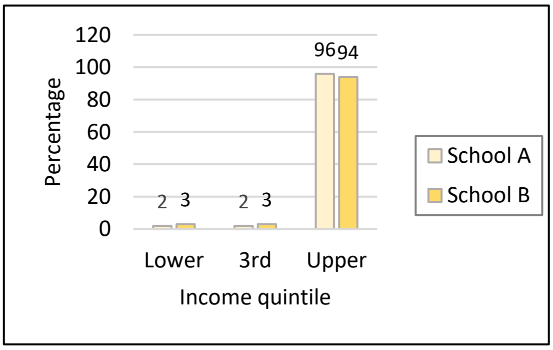


**Figure 4-4:** Percentage distribution between schools: Household income categories (School A: n = 58; School B: n = 35)

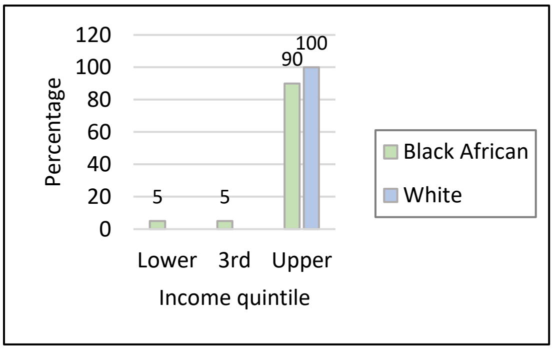


**Figure 4-5:** Percentage distribution between population groups: Household income categories (Black African: n = 48; White: n = 45)

The distribution of household income categories of participants between schools and population groups is illustrated in Figure 4-4 and 4-5 respectively. A comparison (two-sided Fisher's exact test) of household income categories indicated no significant difference between schools (P = 1.000) or between population groups (P = 0.530).

### Housing conditions

Most of the participants (84%) lived in a house, followed by those living in a flat (15%) or a rented room (1%). More participating households (75%) owned their dwelling, with 23% renting and 2% living in shared accommodation with friends or family. Most households (77%) hosted three to five people, with 13% hosting 6- to 8 people and only a few households hosting two, or more than nine people (2% and 1% respectively). Figures 4-6 to 4-11 illustrate the distribution of housing conditions between schools and population groups. A comparison (two-sided Fisher's exact tests) of housing conditions indicated a statistically significant difference in participants' type of housing between schools (P = 0.030) and between population groups (P = 0.001). Figure 4-6 shows a higher percentage of participants from school A live in a house and a lower percentage live in a flat when compared to school B. In contrast, no significant difference existed for home ownership and number of people per household with respect to schools (P = 0.310 and 1.000 respectively) and with respect to population groups (P = 6.030 and 0.610 respectively) (Figure 4-7).

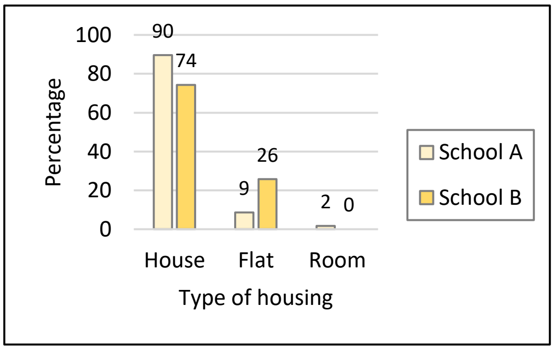


**Figure 4-6:** Percentage distribution between schools: Type of housing
(School A: n = 58; School B: n = 35)

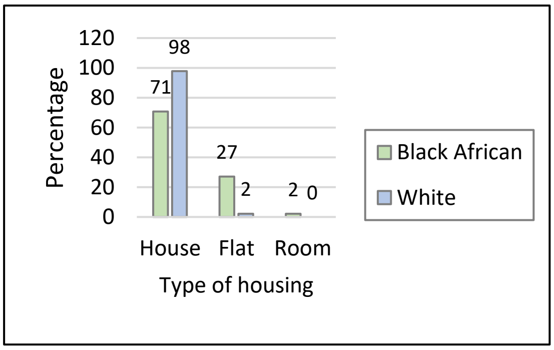


**Figure 4-7:** Percentage distribution between population groups: Type of housing
(Black African: n = 48; White: n = 45)

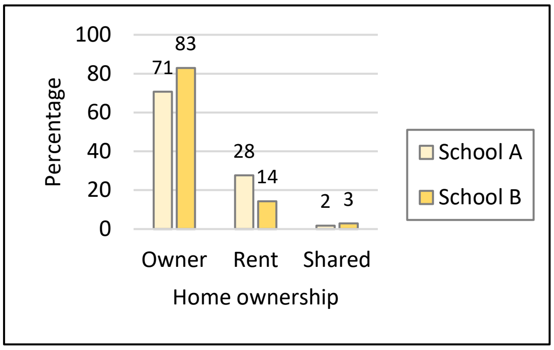


**Figure 4-8:** Percentage distribution between schools: Home ownership
(School A: n = 58; School B: n = 35)

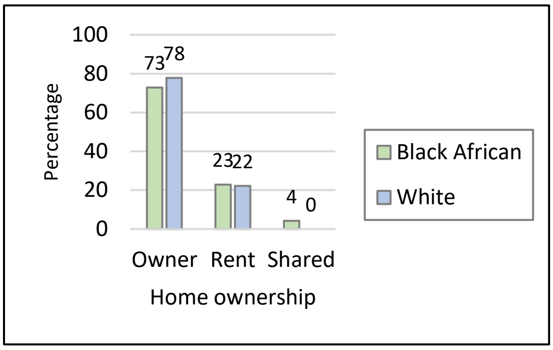


**Figure 4-9:** Percentage distribution between population groups: Home ownership
(Black African: n = 48; White: n = 45)

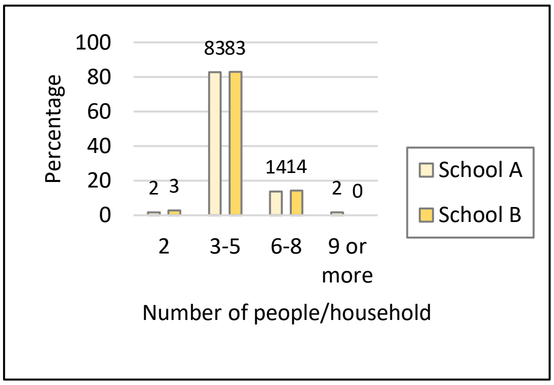


**Figure 4-10:** Percentage distribution between schools: Number of people per household
(School A: n = 58; School B: n = 35)

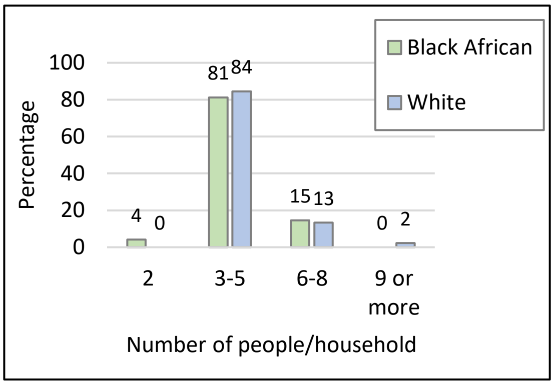


**Figure 4-11:** Percentage distribution between population groups: Number of people per household
(Black African: n = 48; White: n = 45)

### Household services

All participants had access to water, sanitation and electricity supply in their dwelling. Ownership of household electrical appliances of participants from the selected schools and population groups is illustrated in Figures 4-12 and 4-13 respectively. A comparison (two-sided Fisher's exact test) of household appliance ownership indicated a relatively equal distribution with respect to schools and population groups.

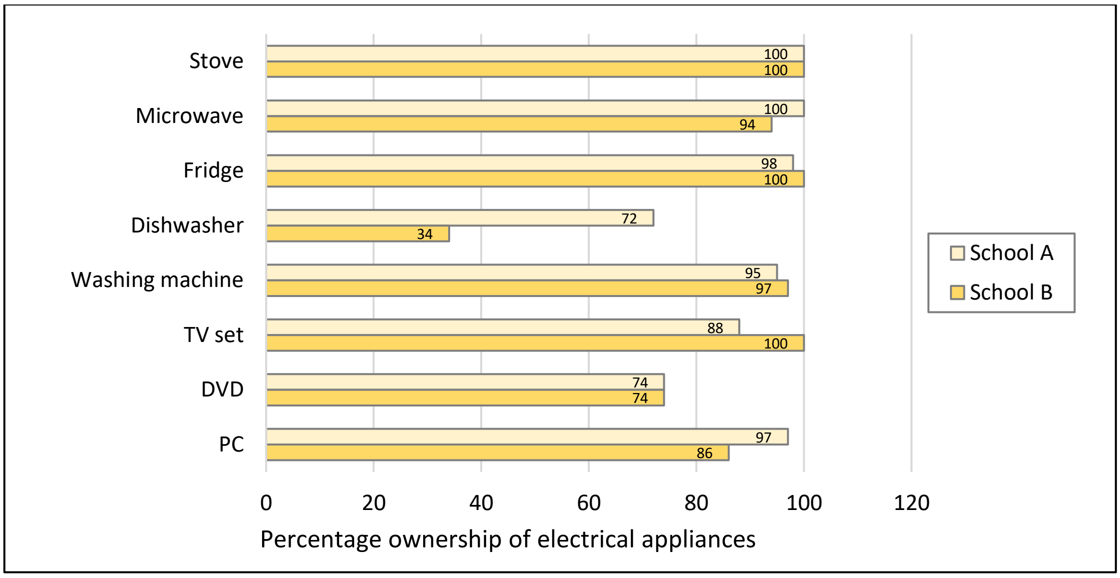


**Figure 4-12:** Percentage ownership of household electrical appliances per school (School A: n = 58; School B: n = 35)

A statistically significant difference was only indicated for two items, including ownership of a dishwasher and TV sets. Participating households from school A had a significantly higher ownership of dishwashers (P < 0.001), but a lower ownership of TV sets (P = 0.042). Between population groups, black African households indicated a significantly lower ownership of dishwashers, but higher ownership of TV sets (P < 0.001 and P = 0.005 respectively).

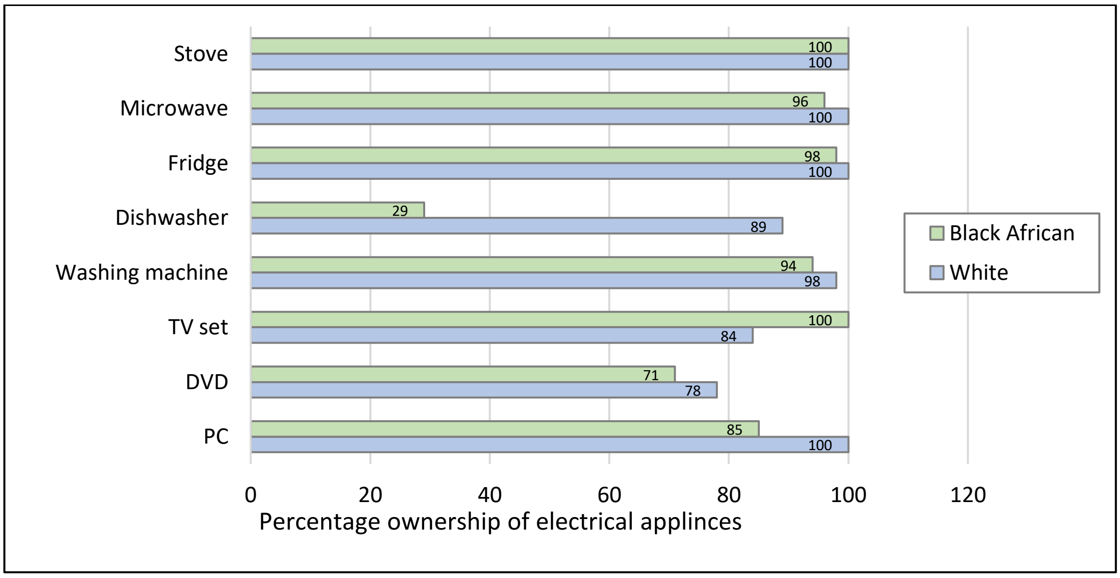


**Figure 4-13:** Percentage ownership of household appliances per population group (Black African: n = 48; White: n = 45)

**Employment status and level of education**

None of the participating households had no income. Twenty-four percent of households relied on a single person's income, with the majority (72%) having two to three people earning and only 4% having four or more people contributing to the household income.

Figures 4-14 and 4-15 illustrate the distribution of the number of people per household earning an income between schools and population groups. A comparison (two-sided Fisher's exact test) of the number of people per household earning an income indicated no statistically significant difference with respect to schools (P = 0.560). However, a statistically significant difference (P = 0.010) was indicated with respect to population groups, attributed to the higher percentage (35%) of black African households with a single income compared to the 5% of white households.

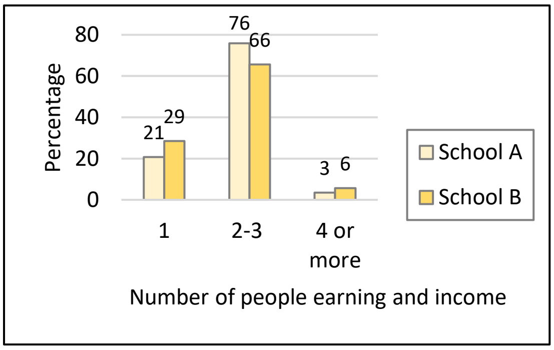


**Figure 4-14:** Percentage distribution between school: Number of people per household earning and income
(School A: n = 58; School B: n = 35)

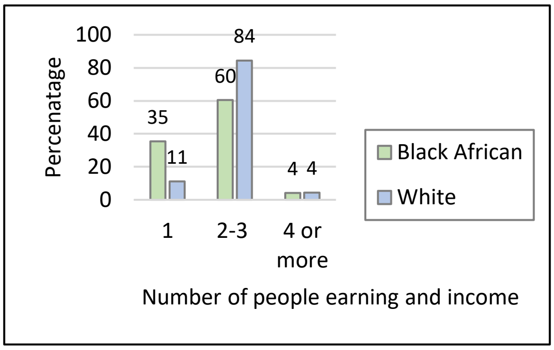


**Figure 4-15:** Percentage distribution between population groups: Number of people per household earning an income
(Black African: n = 48; White: n = 45)

All participating households had an educational level of at least matric (secondary education completed). Additionally, 97% of households had a member who had completed higher education.

Figures 4-16 and 4-17 illustrate the distribution of participating households' highest level of education between schools and population groups. A comparison (two-sided

Fisher's exact test) of highest educational level within a household indicated no difference with respect to schools (P = 1.000) or population groups (P = 0.240).

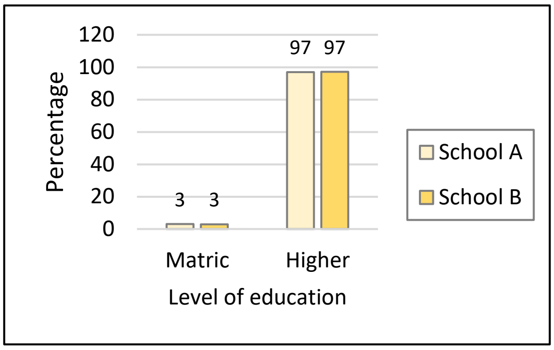


**Figure 4-16:** Percentage distribution between schools: Highest level of education in household
(School A: n = 58; School B: n = 35)

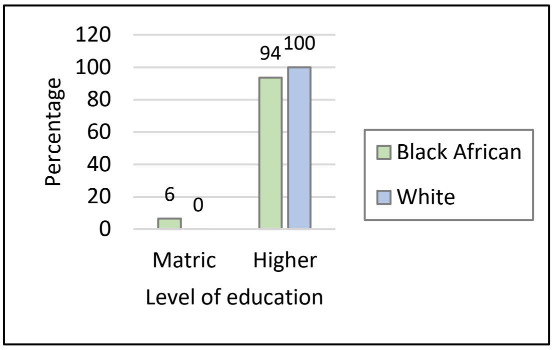


**Figure 4-17:** Percentage distribution between population groups: Highest level of education in household
(Black African: n = 48; White: n = 45)

## Access to school

Figures 4-18 and 4-19 illustrate the mode of transport used by participants distributed between schools and population groups. A comparison (two-sided Fisher's exact test) of mode of transport indicated a statistically significant difference with respect to schools (P = 0.020), but no difference in mode of transport between population groups (P = 0.070). Participants from school B relied more on an alternative means of motorised transport such as a bus or a taxi and more participants walked to school than those in school A. Between population groups, more black African children relied on bus and taxi transport. Black African children were more inclined to walk to school than white children, but it was still a very low percentage (13%).

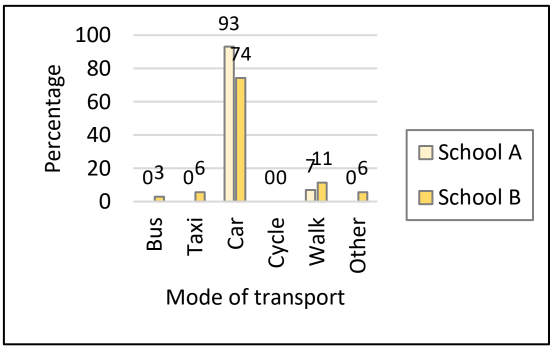


**Figure 4-18:** Percentage distribution between schools: Mode of transport
(School A: n = 58; School B: n = 35)

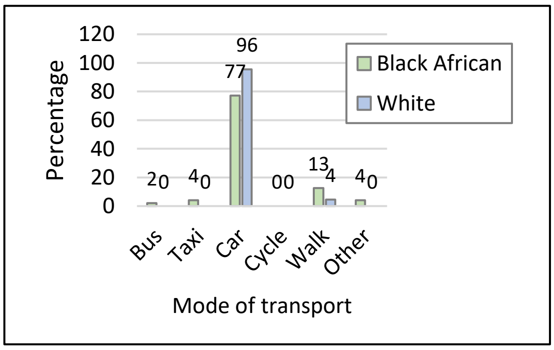


**Figure 4-19:** Percentage distribution between population groups: Mode of transport
(Black African: n = 48; White: n = 45)

## 4.4 DETERMINANT FACTORS

### 4.4.1 Sex categories and population groups

The sample distribution among sex categories and population groups is summarised in Table 4-3. Fifty-six (59.6%) participants were girls and 38 (40.4%) boys. Forty-nine participants (52.1%) were black African and 45 (47.9%) from the white population group.

A comparison (two-sided Fisher's exact test) of population groups with respect to sex categories indicated no significant difference in the sample distribution (P = 0.404).

**Table 4-3:** Distribution of the sample by sex and population group (N = 94)

| | Black African | | White | | Total sample | |
|---|---|---|---|---|---|---|
| | **Number** | **%** | **Number** | **%** | **Number** | **%** |
| Girls | 27 | | 29 | | 56 | 59.6 |
| Boys | 22 | | 16 | | 38 | 40.4 |
| Total | 49 | 52.1 | 45 | 47.9 | 94 | 100 |

## 4.5 MEDIATING FACTORS

### 4.5.1 Phenotypic description of the sample

The anthropometric and BC characteristics of the sample are summarised in Tables 4-4 and 4-5.

**Table 4-4:** Mean measured phenotypic variables of the sample (N = 94)

| | Mean | SD[a] | Minimum | Maximum |
|---|---|---|---|---|
| Weight (kg) | 27.65 | 5.38 | 19.95 | 59.50 |
| WFA z-score | 0.49 | 0.97 | -1.45 | 4.09 |
| Height (cm) | 129.52 | 6.30 | 113.90 | 142.90 |
| HFA z-score | 0.54 | 0.95 | -1.54 | 2.65 |
| BMI (kg/m$^2$) | 16.41 | 2.38 | 12.87 | 29.47 |
| BMI-FA z-score | 0.22 | 1.08 | -1.89 | 4.09 |
| FFM (kg) | 20.83 | 2.47 | 16.72 | 29.22 |
| FFMI (kg/m$^2$) | 12.40 | 0.91 | 10.78 | 14.71 |
| FM (kg) | 6.81 | 3.94 | 2.06 | 30.28 |
| FMI (kg/m$^2$) | 4.01 | 2.08 | 1.43 | 15.00 |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*
[a] SD Standard deviation of the mean

All the mean z-scores of the sample for WFA, HFA and BMI-FA were within 2 SD of the WHO reference values. The outlier values of 4.09 for WFA z-score and BMI-FA z-score were from the same participant. Between sex groups, no significant differences were observed between anthropometric measurements including WFA z-score, HFA z-score and BMI-FA z-score. However, the mean FFM and FFMI were significantly (P < 0.001 for both) lower for girls, with a difference of 1.73 kg and 0.93 kg/m$^2$ respectively. Conversely, the mean FM and FMI were significantly higher (P = 0.035 and 0.010 respectively) for girls than boys, with a difference of 1.71 kg and 1.08 kg/m$^2$ respectively.

**Table 4-5:** Phenotypic description of the sample by sex and population group (N = 94)[a]

| | Sex | Mean[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean[b] | 95% CI[c] | Population difference black African White | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| WFA z-score | Girls | 0.49 | (0.23;0.75) | 0.00 | 0.997 | Black African | 0.38 | (0.10;0.66) | -0.22 | 0.270 |
| | Boys | 0.49 | (0.17;0.81) | | | White | 0.61 | (0.32;0.90) | | |
| HFA z-score | Girls | 0.53 | (0.31;0.75) | 0.04 | 0.820 | Black African | 0.08 | (-0.16;0.32) | -0.97 | <0.001 |
| | Boys | 0.57 | (0.30;0.84) | | | White | 1.05 | (0.81;1.30) | | |
| BMI-FA z-score | Girls | 0.23 | (-0.05;0.52) | -0.06 | 0.795 | Black African | 0.43 | (0.12;0.73) | 0.46 | 0.042 |
| | Boys | 0.17 | (-0.17;0.52) | | | White | -0.03 | (-0.35;0.29) | | |
| FFM (kg) | Girls | 20.14 | (19.54;20.74) | 1.73 | <0.001 | Black African | 20.15 | (19.50;20.79) | -1.45 | 0.003 |
| | Boys | 21.87 | (21.14;22.61) | | | White | 21.60 | (20.92;22.27) | | |
| FFMI (kg/m$^2$) | Girls | 12.01 | (11.80;12.22) | 0.93 | <0.001 | Black African | 12.28 | (12.06;12.50) | -0.23 | 0.166 |
| | Boys | 12.94 | (12.69;13.20) | | | White | 12.51 | (12.27;12.74) | | |
| FM (kg) | Girls | 7.49 | (6.48;8.50) | -1.71 | 0.035 | Black African | 7.82 | (6.74;8.89) | 2.12 | 0.008 |
| | Boys | 5.78 | (4.55;7.01) | | | White | 5.70 | (4.57;6.82) | | |
| FMI (kg/m$^2$) | Girls | 4.44 | (3.92;4.96) | -1.08 | 0.010 | Black African | 4.66 | (4.11;5.22) | 1.37 | <0.001 |
| | Boys | 3.37 | (2.73;4.00) | | | White | 3.29 | (2.71; 3.87) | | |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] Two-way ANOVA

Between population groups, the mean HFA z-score and FFM were significantly lower (0.97; P <0.001 and 1.45 kg; P = 0.003 respectively) for the black African group. In contrast, the BMI-FA z-score, FM and FMI were respectively 0.46 (P = 0.042), 2.12 kg (P = 0.008) and 1.37 kg/m$^2$ (P < 0.001) higher for the black African group.

In terms of the WFA z-score, the sample was relatively homogenous, with no statistically significant differences between either sex or population groups.

The distribution of weight categories in the sample, grouped into populations with subgroups of girls and boys, as well as total girls and boys, are indicated in Table 4-6. The majority of the participating children (83.0%) had a healthy weight. A higher percentage of black African than white children were overweight (14.3% and 4.5% respectively) or obese (12.2% and 2.2% respectively). More girls (12.5%) than boys (5.3%) were overweight, while children with obesity were almost equally distributed between girls (7.1%) and boys (7.9%). All the white boys in the sample had a healthy weight.

**Table 4-6:** Distribution of the study sample: weight categories by sex and population group (N = 94**)**

| | | **Girls** | | **Boys** | | **Total** | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| Black African | Healthy[a] | 19 | 70.4 | 17 | 77.3 | 36 | 73.5 |
| | Over-weight[b] | 5 | 18.5 | 2 | 9.1 | 7 | 14.3 |
| | Obese[c] | 3 | 11.1 | 3 | 13.6 | 6 | 12.2 |
| | **Total** | **27** | **100** | **22** | **100** | **49** | **100** |
| White | Healthy[a] | 26 | 89.7 | 16 | 100 | 42 | 93.3 |
| | Over-weight[b] | 2 | 6.9 | 0 | 0 | 2 | 4.5 |
| | Obese[c] | 1 | 3.4 | 0 | 0 | 1 | 2.2 |
| | **Total** | **29** | **100** | **16** | **100** | **45** | **100** |
| Total sample | Healthy[a] | 45 | 80.4 | 33 | 86.8 | 78 | 83.0 |
| | Over-weight[b] | 7 | 12.5 | 2 | 5.3 | 9 | 9.6 |
| | Obese[c] | 4 | 7.1 | 3 | 7.9 | 7 | 7.4 |
| | **Total** | **56** | **100** | **38** | **100** | **94** | **100** |

WHO weight categories: Body mass index-for-age z-score (BMI-FA z-score):

[a] Healthy: -2≤ BMI-FA z-score ≤1 (No child with BMI-FA z-score <-2)

[b] Overweight: 1< BMI-FA z-score ≤2

[c] Obese: BMI-FA z-score >2

## 4.6 OUTCOMES

### 4.6.1 Resting energy expenditure

#### 4.6.1.1 Measured REE and related variables

A summary of measured REE and related variables is presented in Table 4-7. The mean measured REE was 1 023 kcal/day, varying between 480 kcal/day and 1 434 kcal/day.

**Table 4-7:** Mean measured REE and related variables of the sample (N = 94**)**

| | **Mean** | **SD**[a] | **Minimum** | **Maximum** |
|---|---|---|---|---|
| $VO_2$ (ml/min) | 148 | 32 | 70 | 207 |
| $VCO_2$ (ml/min) | 121 | 28 | 54 | 179 |
| REE (kcal/day) | 1023 | 225 | 480 | 1434 |
| RQ ($VCO_2/VO_2$) | 0.82 | 0.07 | 0.70 | 0.91 |

[a] SD Standard deviation of the mean

Table 4-8 indicates that the mean measured REE and all related variables ($VO_2$, $VCO_2$, RQ) were significantly lower ($P < 0.05$) for black African than white participants. No significant differences were observed between sexes for any of the REE related variables.

Table 4-9 indicates the population differences in the mean measured REE per weight category, mainly for girls. There were no boys with overweight or obesity in the white population group and the difference between boys was only determined for the healthy weight category. Girls who were obese (n = 4) and overweight (n = 7) were grouped together due to the small number of participants within these weight categories.

**Table 4-8:** REE and related variables by sex and population group (N = 94)[a]

| | Sex | Mean[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean[b] | 95% CI[c] | Population difference black African-white | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| REE (kcal/day) | Girls | 1005 | (948;1062) | 40.61 | 0.375 | Black African | 951 | (890;1013) | -145.83 | 0.002 |
| | Boys | 1045 | (976;1115) | | | White | 1097 | (1033;1161) | | |
| $VCO_2$ (ml/min) | Girls | 119 | (112;126) | 4.40 | 0.435 | Black African | 110 | (103;118) | -22.46 | <0.001 |
| | Boys | 124 | (115;132) | | | White | 133 | (125;140) | | |
| $VO_2$ (ml/min) | Girls | 146 | (137;154) | 6.02 | 0.365 | Black African | 139 | (130;148) | -19.44 | 0.004 |
| | Boys | 152 | (141;162) | | | White | 158 | (149;167) | | |
| RQ ($VCO_2$/$VO_2$) | Girls | 0.82 | (0.80;0.83) | -0.01 | 0.781 | Black African | 0.79 | (0.77;0.81) | -0.05 | <0.001 |
| | Boys | 0.81 | (0.79;0.83) | | | White | 0.84 | (0.83;0.86) | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA the with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] Two-way ANOVA

When grouped according to weight categories, the mean REE for black African girls in the healthy weight category, remained significantly lower (230 kcal/day; P < 0.001) than white girls in this weight category. However, for the overweight category, the difference was smaller and not statistically significant, with the mean REE of black African girls being 61 kcal/day (P = 0.573) less than white girls. The mean REE of all healthy weight girls was 90 kcal/day lower than overweight girls. Although not considered statistically significant (two-sample t-test; P = 0.183), this could have clinical implications. However, the number of girls in the sample who were overweight and obese (n = 11) was very low and it may not be possible to draw any reasonable conclusions from these results.

**Table 4-9:** Mean measured REE per weight category by sex and population group (N = 94)

| Weight category | Population group | Girls | | | | Boys | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Mean REE (kcal/day)** | **SD[a]** | **Population difference black African-white** | **P-value[b]** | **Mean REE (kcal/day)** | **SD[a]** | **Population difference black African-white** | **P-value[b]** |
| Healthy[c] (n = 78) | Black African | 861 | 170 | -230 | <0.001 | 945 | 240 | -155 | 0.093 |
| | White | 1091 | 179 | | | 1101 | 275 | | |
| | **Total** | 994 | 208 | | | 1021 | 265 | | |
| Overweight[d]/ Obese[e] (n = 16) | Black African | 1067 | 102 | -61 | 0.573 | | | | |
| | White | 1128 | 263 | | | | | | |
| | **Total** | 1084 | 148 | | | | | | |

[a] SD Standard deviation of the mean
[b] Welch two-sample t-test with unequal variances
WHO weight categories: Body mass index for-age z-score (BMI-FA z-score):
[c] Healthy: -2≤ BMI-FA z-score ≤1 (No child with BMI-FA z-score <-2)
[d] Overweight: 1< BMI-FA z-score ≤2
[e] Obese: BMI-FA z-score >2

### 4.6.1.2 Accuracy of measured REE

**Early, middle and late achievers of SS**

All REE measurements continued for a minimum of 15 and a maximum of 20 min, with a mean (min; max) time to reach SS of 5.65 min (0.00 min; 16.16 min). Nineteen (15.8%) of the 120 participants did not meet SS during the measurement and were among those excluded from the sample (see 4.2). This included six (12.2%) of the black African and 13 (28.9%) of the white participants. Of those excluded, ten (52.6%) were girls and nine (47.4%) were boys.

The 94 participants included in the sample were categorised according to the time that elapsed from the start of the REE measurement until machine-indicated SS was achieved. Forty-seven (50.0%) participants were categorised as early achievers of SS, 29 (30.9%) were middle achievers and 18 (19.1%) were late achievers (Table 4-10). A comparison (two-sided Fisher's exact test) of sex categories, and of population groups with respect to SS categories, indicated no significant difference in the sample distribution (P = 0.955 and P = 0.758 respectively).

**Table 4-10:** Early, middle and late achievers of SS by sex and population group (N = 94)

| SS category[a] | Sex | Black African n | White n | Total sample n |
|---|---|---|---|---|
| Early achievers[b] | Girls | 17 | 10 | 27 |
| | Boys | 10 | 10 | 20 |
| | Total | 27 | 20 | 47 (50.0%) |
| Middle achievers[c] | Girls | 6 | 11 | 17 |
| | Boys | 8 | 4 | 12 |
| | Total | 14 | 15 | 29 (30.9%) |
| Late achievers[d] | Girls | 4 | 8 | 12 |
| | Boys | 4 | 2 | 6 |
| | Total | 8 | 10 | 18 (19.1%) |

[a] Time to achieve SS:

[b] Early achievers <5 min

[c] ≤ 5 min Middle achievers < 10 min

[d] Late achievers ≥ 10 min

### Intra-individual %CV

The intra-individual %CV of the mean REE (kcal/day); $VCO_2$ (ml/min); $VO_2$ (ml/min) and RQ are indicated in Table 4-11. For six late achievers (1 black African boy and 5 white girls), intervals after achieving SS were not enough to calculate %CV and their data were consequently excluded from all %CV calculations. For the remaining 88 participants, a comparison of the mean %CV for each variable ($VO_2$, $VCO_2$, REE, RQ) indicated no statistically significant difference between sex categories (all P-values > 0.374) or between population groups (all P-values > 0.089).

**Table 4-11:** Intra-individual %CV for REE-related measurements by sex and population group (N = 88)[a]

| REE-related variable | Sex | Mean[b] %CV [c] | 95% CI[d] | Sex difference boys-girls | P-value[e] | Population group | Mean[b] %CV[c] | 95% CI[d] | Population difference black African-white | P-value[e] |
|---|---|---|---|---|---|---|---|---|---|---|
| REE (kcal/day) | Girls | 2.36 | (1.77;2.95) | -0.18 | 0.686 | Black African | 2.48 | (1.88;3.08) | -0.44 | 0.327 |
| | Boys | 2.18 | (1.50;2.85) | | | White | 2.04 | (1.38;2.70) | | |
| $VCO_2$ (ml/min) | Girls | 2.90 | (2.15;3.66) | -0.47 | 0.414 | Black African | 3.10 | (2.33;3.87) | -0.88 | 0.130 |
| | Boys | 2.43 | (1.57;3.29) | | | White | 2.22 | (1.38;3.06) | | |
| $VO_2$ (ml/min) | Girls | 2.34 | (1.75;2.92) | -0.07 | 0.872 | Black African | 2.47 | (1.88;3.07) | -0.37 | 0.412 |
| | Boys | 2.26 | (1.59;2.94) | | | White | 2.11 | (1.45;2.76) | | |
| RQ ($VCO_2$/$VO_2$) | Girls | 1.57 | (1.06;2.08) | -0.35 | 0.374 | Black African | 1.72 | (1.20;2.24) | -0.67 | 0.089 |
| | Boys | 1.22 | (0.64;1.81) | | | White | 1.06 | (0.49;1.62) | | |

[a] Girls n = 51; boys n = 37; black African n = 48; white n = 40

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] %CV = Percentage coefficient of variation: Standard deviation/mean*100

[d] 95% Confidence interval around the mean

[e] Two-way ANOVA

The mean %CV for early, middle and late achievers of SS are indicated in Table 4-12. All mean %CV remained below 2.89 across SS categories.

**Table 4-12:** Mean intra-individual %CV of REE-related measurements per SS category (N = 88)[a]

| SS category[b] | Variable | Mean %CV[c] | SD[d] |
|---|---|---|---|
| Early achievers (n = 47) | $VO_2$ (ml/min) | 2.11 | 2.23 |
| | $VCO_2$ (ml/min) | 2.86 | 3.17 |
| | REE (kcal/day) | 2.18 | 2.25 |
| | RQ ($VCO_2$/$VO_2$) | 1.59 | 2.34 |
| Middle achievers (n = 12) | VO2 (ml/min) | 2.68 | 2.06 |
| | $VCO_2$ (ml/min) | 2.89 | 2.12 |
| | REE (kcal/day) | 2.63 | 2.09 |
| | RQ ($VCO_2$/$VO_2$) | 1.28 | 0.88 |
| Late achievers (n = 29) | VO2 (ml/min) | 1.99 | 1.50 |
| | $VCO_2$ (ml/min) | 1.44 | 1.70 |
| | REE (kcal/day) | 1.68 | 1.32 |
| | RQ ($VCO_2$/$VO_2$) | 1.02 | 0.67 |

[a] Girls n = 51; boys n = 37; black African n = 48; white n = 40

[b] Time to achieve SS: Early achievers <5min; ≤5min Middle achievers <10min; Late achievers ≥10min

[c] %CV = Percentage coefficient of variation: Standard deviation/mean*100

[d] Standard deviation of the mean

### 4.6.1.3 Factors related to measured REE

Table 4-13 summarises the relationship between mean measured REE and age, phenotypic, as well as PA factors respectively.

**Table 4-13:** Relationship between measured REE and age, phenotypic and PA-related factors (N = 94)[a]

| Variable | Sex | r[b] | P-value[c] | Populationg roup | r[b] | P-value[c] | Total sample | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | r[b] | P-value[c] |
| Age | Girls | -0.27 | 0.050 | Black African | 0.34 | 0.021 | -0.08 | 0.440 |
| | Boys | 0.16 | 0.350 | White | -0.34 | 0.016 | | |
| WFA z-score | Girls | 0.32 | 0.016 | Black African | 0.56 | <0.001 | 0.37 | <0.001 |
| | Boys | 0.41 | 0.011 | White | -0.02 | 0.881 | | |
| HFA z-score | Girls | 0.37 | 0.006 | Black African | 0.32 | 0.026 | 0.36 | <0.001 |
| | Boys | 0.36 | 0.025 | White | 0.13 | 0.383 | | |
| BMI-FA z-score | Girls | 0.15 | 0.281 | Black African | 0.55 | <0.001 | 0.21 | 0.045 |
| | Boys | 0.27 | 0.100 | White | -0.10 | 0.520 | | |
| FFM (kg) | Girls | 0.35 | 0.008 | Black African | 0.39 | 0.006 | 0.45 | <0.001 |
| | Boys | 0.55 | <0.001 | White | 0.42 | 0.004 | | |
| FFMI (kg/m²) | Girls | 0.35 | 0.008 | Black African | 0.44 | <0.001 | 0.30 | 0.003 |
| | Boys | 0.28 | 0.089 | White | 0.09 | 0.581 | | |
| FM (kg) | Girls | 0.06 | 0.669 | Black African | 0.39 | 0.005 | 0.17 | 0.105 |
| | Boys | 0.28 | 0.086 | White | 0.05 | 0.752 | | |
| FMI (kg/m²) | Girls | 0.03 | 0.803 | Black African | 0.41 | 0.004 | 0.13 | 0.227 |
| | Boys | 0.24 | 0.153 | White | -0.04 | 0.772 | | |
| Average steps/day | Girls | 0.09 | 0.488 | Black African | -0.09 | 0.558 | 0.05 | 0.651 |
| | Boys | -0.01 | 0.958 | White | -0.16 | 0.286 | | |
| Average steps/ weekday | Girls | 0.04 | 0.766 | Black African | -0.20 | 0.179 | -0.02 | 0.812 |
| | Boys | -0.10 | 0.557 | White | -0.18 | 0.229 | | |
| Average steps/ weekend day | Girls | 0.16 | 0.233 | Black African | 0.07 | 0.625 | 0.14 | 0.180 |
| | Boys | 0.11 | 0.512 | White | -0.08 | 0.601 | | |
| PAQ-C-before | Girls | -0.16 | 0.240 | Black African | -0.11 | 0.471 | -0.14 | 0.189 |
| | Boys | -0.17 | 0.302 | White | 0.14 | 0.360 | | |
| PAQ-C-after | Girls | -0.20 | 0.139 | Black African | -0.10 | 0.505 | -0.02 | 0.852 |
| | Boys | 0.12 | 0.461 | White | 0.37 | 0.012 | | |
| PAQ-average | Girls | -0.21 | 0.116 | Black African | -0.12 | 0.413 | -0.10 | 0.344 |
| | Boys | -0.05 | 0.757 | White | 0.32 | 0.035 | | |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*; PAQ-C *PA questionnaire for children*

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Spearman's product-moment correlation

[c] Level of statistical significance

For the total sample, a statistically significant relationship (P <0.05) existed between REE and all phenotypic variables, except for FM and FMI, where a positive significant relationship existed for black African participants only (r = 0.39; P = 0.005 and r = 0.41; P = 0.004 respectively). In addition, for black African participants in particular, a positive, statistically significant relationship existed between REE and anthropometric measurements including WFA z-score (r = 0.56; P < 0.001), HFA z-score (r = 0.32; P = 0.26) and BMI-FA z-score (r = 0.55; P < 0.001) respectively.

For the total sample, the correlation between REE and FFM was the strongest (r = 0.45) and statistically significant for all subgroups (P <0.05), but for boys and for white participants the significance declined (P > 0.05) when the relationship between REE and FFMI was determined. Furthermore, FFM, WFA z-score (r = 0.37) and HFA z-score (r = 0.36) were significantly (P <0.001) related to REE, specifically for black African participants.

The relationship between measured REE and most PA-related variables remained low and lacked significance across sex categories and population groups. An exception was found for white participants, where a significant correlation existed between REE and PAQ-C-after (r = 0.37; P = 0.012), as well as between REE and PAQ-C-average (r = 0.32; P = 0.035).

**Adjusted REE**

Table 4-14 indicates that similar to the results observed for the mean measured REE (Table 4-8), the difference in REE between sex categories did not meet statistical significance, even after REE was adjusted for each phenotypic variable and objectively measured PA (average steps/day) respectively. However, even though the difference failed to meet statistical significance, the difference in REE adjusted for FM (70 kcal/day) and for FMI (74 kcal/day) is relatively large and may have clinical implications.

Between population groups, the REE remained statistically significantly lower (P < 0.05) for black African than white participants after REE was adjusted for each phenotypic variable as well as PA respectively, except when REE was adjusted for HFA z-score (P = 0.108).

**Table 4-14:** Mean REE (kcal/day) as measured and adjusted for covariates by sex and population group (N = 94)[a]

| REE-related variable | Sex | Mean[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean[b] | 95% CI[c] | Population difference black African-white | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| Measured REE (kcal/day) | Girls | 1005 | (948;1062) | 41 | 0.375 | Black African | 951 | (890;1013) | -146 | 0.002 |
| | Boys | 1045 | (976;1115) | | | White | 1097 | (1033;1161) | | |
| **REE adjusted[e] for:** | | | | | | | | | | |
| Age | Girls | 1005 | (947;1063) | 41 | 0.377 | Black African | 951 | (889;1014) | -146 | 0.002 |
| | Boys | 1045 | (975;1116) | | | White | 1097 | (1032;1163) | | |
| WFA z-score | Girls | 1005 | (951;1059) | 41 | 0.347 | Black African | 960 | (902;1018) | -128 | 0.003 |
| | Boys | 1046 | (980;1111) | | | White | 1088 | (1028;1149) | | |
| HFA z-score | Girls | 1006 | (950;1061) | 38 | 0.393 | Black African | 981 | (917;1046) | -82 | 0.108 |
| | Boys | 1044 | (975;1112) | | | White | 1064 | (996;1132) | | |
| BMI-FA z-score | Girls | 1004 | (949;1059) | 44 | 0.316 | Black African | 939 | (879;999) | -173 | <0.001 |
| | Boys | 1048 | (981;1115) | | | White | 1112 | (1050;1174) | | |
| FFM (kg) | Girls | 1031 | (977;1086) | -25 | 0.582 | Black African | 977 | (919;1036) | -91 | 0.039 |
| | Boys | 1006 | (939;1074) | | | White | 1069 | (1008;1129) | | |
| FFMI (kg/m$^2$) | Girls | 1034 | (975;1094) | -31 | 0.549 | Black African | 961 | (901;1020) | -128 | 0.004 |
| | Boys | 1004 | (930;1078) | | | White | 1089 | (1027;1151) | | |
| FM (kg) | Girls | 993 | (938;1049) | 70 | 0.124 | Black African | 934 | (874;994) | -182 | <0.001 |
| | Boys | 1063 | (995;1131) | | | White | 1116 | (1053;1179) | | |
| FMI (kg/m$^2$) | Girls | 991 | (935;1048) | 74 | 0.107 | Black African | 931 | (870;992) | -189 | <0.001 |
| | Boys | 1066 | (997;1135) | | | White | 1120 | (1056;1184) | | |
| Average Steps/ day | Girls | 1000 | (942;1057) | 55 | 0.244 | Black African | 936 | (870;1001) | -180 | <0.001 |
| | Boys | 1054 | (983;1125) | | | White | 1116 | (1046;1185) | | |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] Two-way ANOVA

[e] Multivariable regression analysis

### 4.6.1.4 Predicted REE

Table 4-15 indicates the agreement between mean measured REE and the REE calculated with estimation equations for sex categories and population groups. Based on the mean differences and limits of agreement in the Bland-Altman analysis, all the estimation equations overestimated the REE of black African participants, in most cases with more than 125 kcal/day. The equation by Maffeis et al.[(73)] provided the most accurate estimation of REE across sex categories for the black African group, but the overestimation of 92 and 87 kcal/day for girls and boys respectively, may still be considered unacceptable in clinical application as reflected by the 9.9 and 9.2% bias respectively. Both Harris-Benedict equations estimated the measured REE of black African boys (41 kcal/day for 1919 equation;[(66)] 35 kcal/day for 1984 equation[(68)] within acceptable accuracy with the bias value less than 5% for both, but this was not applicable to the girls.

For white participants, the difference between measured and estimated REE was in most cases smaller than for black African participants, but the accuracy of estimations varied considerably (between 6 and 285 kcal/day). Most equations were considered clinically accurate for white participants, with the exception of Schofield weight[(70)] and Maffeis[(73)] equations that underestimated the REE of white girls and the Oxford weight and height[(16)] and Harris Benedict, 1984[(68)] equations that underestimated the REE of white boys. The FAO/WHO/UNU equation[(71)] appeared to be the most accurate predictor of REE for white participants across both sexes, overestimating the REE with a marginal 18 kcal/day, 1.7% bias for girls and 13 kcal/day, 1.2% bias for boys.

**Table 4-15:** Agreement between measured and estimated REE by sex and population group (N = 94)[a]

| | | **Black African** | | | | **White** | | | | **Mean % bias[e]** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Estimation equation (kcal/day)** | **Sex** | **Mean[b] estimated REE (kcal/day)** | **95% CI[c]** | **REE difference: measured-estimated** | **BA analysis LOA[d]** | **Mean[b] estimated REE (kcal/day)** | **95% CI[c]** | **REE difference: measured-estimated** | **BA analysis LOA[d]** | **Black African** | **White** |
| Schofield (weight and height)[(70)] | Girls | 1049 | (1016;1081) | -127 | (-488;235) | 1042 | (1010;1073) | 53 | (-306;412) | -13.7 | 4.9 |
| | Boys | 1126 | (1068;1183) | -131 | (-557;296) | 1118 | (1050;1185) | -17 | (-519;485) | -13.8 | -1.5 |
| Schofield (weight)[(70)] | Girls | 1049 | (1013;1085) | -127 | (-488;234) | 1037 | (1002;1072) | 58 | (-305;422) | -13.8 | 5.3 |
| | Boys | 1136 | (1072;1200) | -141 | (575;292) | 1119 | (1045;1194) | -19 | (-522;485) | -14.9 | -1.7 |
| Oxford (weight)[(16)] | Girls | 1068 | (1032;1104) | -146 | (-507;214) | 1056 | (1021;1091) | 39 | (-324;403) | -15.9 | 3.6 |
| | Boys | 1167 | (1101;1232) | -172 | (-608;265) | 1149 | (1073;1226) | -49 | (-552;454) | -18.2 | -4.4 |

Table 4-15: Agreement between measured and estimated REE by sex and population group (N = 94)[a] (cont'd)

| | | Black African | | | | White | | | | Mean % bias[e] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Estimation equation (kcal/day) | Sex | Mean[b] estimated REE (kcal/day) | 95% CI[c] | REE difference: measured-estimated | BA analysis LOA[d] | Mean[b] estimated REE (kcal/day) | 95% CI[c] | REE difference: measured-estimated | BA analysis LOA[d] | Black African | White |
| Oxford (weight and height)[(16)] | Girls | 1063 | (1031;1094) | -141 | (-502;221) | 1057 | (1027;1088) | 38 | (-320;395) | -15.2 | 3.4 |
| | Boys | 823 | (780;867) | -171 | (-248;591) | 816 | (765;868) | 285 | (-227;796) | 18.1 | 25.9 |
| FAO/WHO/UNU[(71)] | Girls | 1127 | (1087;1168) | -205 | (-575;164) | 1113 | (1075;1152) | -18 | (-386;349) | -22.3 | -1.7 |
| | Boys | 1131 | (1067;1195) | -136 | (-570;298) | 1114 | (1039;1189) | -13 | (-517;490) | -14.4 | -1.2 |
| Maffeis[(73)] | Girls | 1014 | (993;1035) | -92 | (-442;259) | 1021 | (1001;1041) | 74 | (-279;428) | -9.9 | 6.8 |
| | Boys | 1082 | (1052;1112) | -87 | (-521;346) | 1108 | (1073;1143) | -8 | (-521;505) | -9.2 | -0.7 |
| Harris-Benedict, 1919[(66)] | Girls | 1121 | (1102;1141) | -199 | (-545;147) | 1122 | (1103;1141) | -27 | (-382;328) | -21.6 | -2.4 |
| | Boys | 1035 | (987;1084) | -41 | (-465;383) | 1052 | (995;1108) | 49 | (-449;547) | -4.3 | 4.4 |
| Harris-Benedict, 1984[(68)] | Girls | 1098 | (1077;1119) | -176 | (-529;177) | 1101 | (1081;1122) | -6 | (-360;347) | -19.1 | -0.6 |
| | Boys | 1030 | (983;1077) | -35 | (-459;389) | 1045 | (990;1100) | 55 | (-443;554) | -3.7 | 5.0 |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] BA *Bland-Altman* comparison of mean measured and estimated REE; LOA *Limits of agreement* parameter intervals

[e] ([mean measured REE-mean estimated REE]/mean measured REE)*100; mean measured REE of black African: girls = 922 kcal/day; boys = 995 kcal/day; white: girls = 1095 kcal/day ; boys = 1102 kcal/day; accurate estimation ± 5%; underprediction < -5%; overprediction >5%

### 4.6.2 Physical activity

#### 4.6.2.1 Objectively measured PA

A summary of the objectively measured PA variables for the sample is presented in Table 4-16. The average steps/weekday (10 996 ± 2 927) was significantly higher (P = 0.031) than the average for weekend days (9 823 ± 4 348).

**Table 4-16:** Objectively measured PA (N = 94)[a]

| | Mean | SD[b] | Minimum | Maximum | Sample difference: Average steps/weekday-average steps/weekend day | P-value[c] |
|---|---|---|---|---|---|---|
| Average steps/day | 10663 | 3027 | 4033 | 18271 | | |
| Average steps/weekday | 10996 | 2927 | 4687 | 18030 | 1173 | 0.031 |
| Average steps/weekend day | 9823 | 4348 | 1757 | 21381 | | |

[a] Girls n = 56; Boys n = 38; black African n = 49; White n = 45
[b] SD Standard deviation of the mean
[c] Paired t-test

Table 4.17 summarises objectively measured PA and related variables by sex and population groups. The means of all objectively measured PA variables were significantly lower (P < 0.001) for black African than white participants. Similarly, the mean values for girls were lower than for boys, although only the average steps/day and average steps/weekday (1220; P = 0.029 and 1177; P = 0.035 respectively), were considered statistically significantly lower for girls than boys.

**Table 4-17:** Objectively measured PA by sex and population group (n = 94)[a]

| | Sex | Mean[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean[b] | 95% CI[c] | Population difference black African-white | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| Average steps/ day | Girls | 10212 | (9519;10906) | 1220 | 0.029 | Black African | 9280 | (8538;10022) | -2979 | <0.001 |
| | Boys | 11433 | (10588;12277) | | | White | 12258 | (11483;13033) | | |
| Average steps/ week | Girls | 10554 | (9862; 11246) | 1177 | 0.035 | Black African | 9770 | (9030;10510) | -2631 | <0.001 |
| | Boys | 11730 | (10887; 12573) | | | White | 12401 | (11628;13174) | | |
| Average steps/ weekend day | Girls | 9345 | (8318; 10372) | 1346 | 0.105 | Black African | 7986 | (6876;9096) | -3916 | <0.001 |
| | Boys | 10691 | (9424; 11958) | | | White | 11901 | (10754;13048) | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45
[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction
[c] 95% Confidence interval around the mean
[d] Two-way ANOVA

Table 4-18 indicates the population differences in the mean objectively measured PA (average steps/day) per weight category. Similar to the results presented in Table 4-9, P-values are provided mainly for girls, since there were no boys from the white population group who were overweight or obese. Girls with obesity (BMI-FA z-score >2) (n= 4) were again grouped together with girls who were overweight (n=7), due to the small number of participants in these weight categories.

The mean average steps/day remained lower for black African than white participants across weight categories. Although no statistically significant difference was found between population groups in the overweight category (P = 0.103), the mean average steps/day was 2292 lower for black African than for white girls. This may be considered clinically significant, especially when considering the similar yet significant difference of 2057 steps/day (P = 0.010) indicated between population groups in the healthy weight category. Additionally, the mean average steps/day for girls in the healthy weight category was 1371 higher than for the girls in the overweight category, but the difference was also not statistically significant (P = 0.122). However, due to the small number of girls who were overweight and obese (n = 11), these results may not be conclusive.

**Table 4-18:** Objectively measured PA per weight category by sex and population group (N = 94)[a]

| | | **Girls** | | | | **Boys** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Weight category** | **Population group** | **Mean value: average steps/day** | **SD[b]** | **Population difference black African-white** | **P-value[c]** | **Mean value: average steps/day** | **SD[b]** | **Population difference black African-white** | **P-value[c]** |
| Healthy[d] (n = 78) | Black African | 9381 | 2375 | -2057 | 0.010 | 9059 | 2831 | -4496 | <0.001 |
| | White | 11437 | 2621 | | | 13555 | 2498 | | |
| | **Total** | 10569 | 2696 | | | 11239 | 3484 | | |
| Overweight[e]/ Obese[f] (n = 16) | Black African | 8573 | 1673 | -2292 | 0.103 | | | | |
| | White | 10865 | 2424 | | | | | | |
| | **Total** | 9198 | 2069 | | | | | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45
[b] SD Standard deviation of the mean
[c] Welch two-sample t-test with unequal variances
WHO weight categories: Body mass index for-age z-score (BMI-FA z-score):
[d] Healthy: -2≤ BMI-FA z-score ≤1 (No child with BMI-FA-z <-2)
[e] Overweight: 1< BMI-FA z-score ≤2
[f] Obese: BMI-FA z-score >2

#### 4.6.2.2 Subjectively measured PA

A summary of subjectively measured PA (PAQ-C) for the sample is presented in Table 4-19. The PAQ-C-before (prior to wearing the pedometer) was statistically significantly lower (P = 0.002) than the PAQ-C-after (after wearing the pedometer for one week).

**Table 4-19:** Subjectively measured PA (N = 94)[a]

| PAQ-C scores[b] | Mean | SD[c] | Minimum | Maximum | PAQ-C difference PAQ-C before-PAQ-C after | P-value[d] |
|---|---|---|---|---|---|---|
| PAQ-C-before | 2.67 | 0.53 | 1.62 | 3.99 | -0.17 | 0.002 |
| PAQ-C-after | 2.84 | 0.44 | 1.47 | 4.23 | | |
| PAQ-C average | 2.75 | 0.41 | 1.86 | 3.83 | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Possible scores: min 1; max 5

[c] SD Standard deviation of the mean with 95% confidence interval around the mean

[d] Paired t-test

In contrast to the objectively measured PA, all PAQ-C measurements were significantly higher (P < 0.05) for black African than white participants (Table 4-20). Additionally, and in agreement with objectively measured PA, all PAQ-C measurements were significantly lower for girls than boys (P < 0.05).

**Table 4-20:** Subjectively measured PA by sex and population group (N = 94)[a]

| PAC-C scores[b] | Sex | Mean[c] | 95% CI[d] | Sex difference boys-girls | P-value[e] | Population group | Mean[c] | 95% CI[d] | Population difference black African-white | P-value[e] |
|---|---|---|---|---|---|---|---|---|---|---|
| Before | Girls | 2.54 | (2.41;2.57) | 0.30 | 0.002 | Black African | 2.85 | (2.72;2,98) | 0.41 | <0.001 |
| | Boys | 2.84 | (2.69;2.99) | | | White | 2.44 | (2.31;2.58) | | |
| After | Girls | 2.72 | (2.61;2.83) | 0.28 | <0.001 | Black African | 2.93 | (2.82;3.05) | 0.21 | 0.013 |
| | Boys | 3.00 | (2.87;3.13) | | | White | 2.72 | (2.60;2.84) | | |
| Average | Girls | 2.63 | (2.53;2.72) | 0.29 | <0.001 | Black African | 2.89 | (2.80;2.99) | 0.31 | <0.001 |
| | Boys | 2.92 | (2.81;3.03) | | | White | 2.58 | (2.48;2.69) | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Possible scores: min 1; max 5

[c] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[d] 95% Confidence interval around the mean

[e] Two-way ANOVA

#### 4.6.2.3 Concurrent validity of PA measurements

**The relationship between objective and subjective PA measurements**

The relationship between objective and subjective PA outcomes was determined to evaluate the concurrent validity of PA measurement. There was no significant relationship between the means of the subjective PAQ-C (PAQ-C average) and objective average steps/day for the total sample (r = -0.02; P = 0.876) nor for black African participants (r = 0.15; P = 0.299) (Table 4-21). For white participants a statistically significant relationship was observed (r = 0.37; P=0.013) and for boys, a significant, negative relationship (r = -0.38; P = 0.020).

**Table 4-21:** Relationship between average steps/day and PAQ-C-average (N = 94)[a]

| Sex | r[b] | P-value[c] | Population group | r[b] | P-value[c] | Total sample | |
|---|---|---|---|---|---|---|---|
| | | | | | | r[b] | P-value[c] |
| Girls | 0.20 | 0.133 | Black African | 0.15 | 0.299 | -0.02 | 0.876 |
| Boys | -0.38 | 0.020 | White | 0.37 | 0.013 | | |

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45
[b] Spearman's product-moment correlation
[c] Level of statistical significance

#### 4.6.2.4 Factors related to objectively measured PA

Table 4-22 summarises the relationship between objectively measured PA (average steps/day) and age and phenotypic variables respectively.

For the total sample, a significant and positive relationship existed between steps/day and HFA z-score (r = 0.38; P < 0.001) and FFM (r = 0.36; P < 0.001) respectively. A similar relationship with HFA z-score (r = 0.50; P < 0.001) and FFM (r = 0.43; P = 0.007) was observed for boys. For black African participants, a significant and positive relationship was also present between steps/day and FFM. A significant and negative relationship existed between steps/day and FMI (r = -0.26; P = 0.011) and in particular among girls.

**Table 4-22:** Relationship between mean objectively measured PA (average steps/day) and age and phenotypic factors (N = 94)[a]

| Varaible | Sex | r[b] | P-value[c] | Population group | r[b] | P-value[c] | Total sample r[b] | Total sample P-value[c] |
|---|---|---|---|---|---|---|---|---|
| Age | Girls | -0.04 | 0.745 | Black African | 0.17 | 0.250 | -0.02 | 0.875 |
| | Boys | 0.02 | 0.895 | White | 0.04 | 0.770 | | |
| WFA z-score | Girls | 0.03 | 0.826 | Black African | 0.05 | 0.718 | 0.09 | 0.381 |
| | Boys | 0.15 | 0.361 | White | 0.02 | 0.877 | | |
| HFA z-score | Girls | 0.26 | 0.053 | Black African | 0.25 | 0.081 | 0.38 | <0.001 |
| | Boys | 0.50 | <0.001 | White | 0.06 | 0.688 | | |
| BMI-FA z-score | Girls | -0.12 | 0.373 | Black African | -0.06 | 0.688 | -0.14 | 0.185 |
| | Boys | -0.16 | 0.347 | White | -0.02 | 0.875 | | |
| FFM (kg) | Girls | 0.24 | 0.080 | Black African | 0.35 | 0.013 | 0.36 | <0.001 |
| | Boys | 0.43 | 0.007 | White | 0.20 | 0.188 | | |
| FFMI ($kg/m^2$) | Girls | 0.13 | 0.341 | Black African | 0.14 | 0.350 | 0.19 | 0.069 |
| | Boys | 0.14 | 0.400 | White | 0.23 | 0.129 | | |
| FM (kg) | Girls | -0.22 | 0.108 | Black African | -0.04 | 0.792 | -0.20 | 0.056 |
| | Boys | -0.143 | 0.393 | White | -0.24 | 0.117 | | |
| FMI ($kg/m^2$) | Girls | -0.27 | 0.043 | Black African | -0.10 | 0.490 | -0.26 | 0.011 |
| | Boys | -0.21 | 0.207 | White | -0.24 | 0.109 | | |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*; PAQ-C *PA questionnaire for children*

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Spearman’s product-moment correlation

[c] Level of statistical significance

## Adjusted PA

Table 4-23 shows that similar to the results observed for the mean average steps/day (Table 4-17), the difference in objective PA between population groups remained statistically significant (P < 0.001) after being adjusted for age, phenotypic variables and REE. However, between sex categories, the objective PA remained significantly lower (P < 0.05) for girls than boys after PA was adjusted for age, REE, FM and anthropometric-related variables, including WFA z-score, HFA z-score, BMI-FA z-score and REE. When adjusted for FFM, FFMI and FMI the sex differences decreased (P > 0.05).

**Table 4-23:** Objectively measured PA (average steps/day) adjusted for covariates by sex and population group (N = 94)[a]

| REE-related variable | Sex | Mean[b] | 95% CI[c] | Sex difference boys-girls | P-value[d] | Population group | Mean[b] | 95% CI[c] | Population difference black African-white | P-value[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean Average steps/day | Girls | 10212 | (9519;10906) | 1220 | 0.029 | Black African | 9280 | (8538;10022) | -2979 | <0.001 |
| | Boys | 11433 | (10588;12277) | | | White | 12258 | (11483;13033) | | |
| **Average steps/day adjusted[e] for:** | | | | | | | | | | |
| Age | Girls | 10202 | (9509;10 896) | 1239 | 0.027 | Black African | 9217 | (8464;9970) | -3105 | <0.001 |
| | Boys | 11441 | (10596;12286) | | | White | 12322 | (11536;13108) | | |
| WFA z-score | Girls | 10213 | (9516;10909) | 1220 | 0.030 | Black African | 9293 | (8545;10041) | -2951 | <0.001 |
| | Boys | 11433 | (10584;12228) | | | White | 12244 | (11463;13026) | | |
| HFA z-score | Girls | 10217 | (9530;10905) | 1200 | 0.031 | Black African | 9519 | (8724;10314) | -2472 | <0.001 |
| | Boys | 11417 | (10579;12255) | | | White | 11991 | (11152;12830) | | |
| BMI-FA z-score | Girls | 10213 | (9516;10910) | 1217 | 0.030 | Black African | 9293 | (8539;10047) | -2950 | <0.001 |
| | Boys | 11430 | (10580;12279) | | | White | 12243 | (11453;13032) | | |
| FFM (kg) | Girls | 10391 | (9692;11090) | 775 | 0.183 | Black African | 9457 | (8711;10202) | -2606 | <0.001 |
| | Boys | 11166 | (10302;12030) | | | White | 12062 | (11281;12843) | | |
| FFMI ($kg/m^2$) | Girls | 10339 | (9595;11083) | 915 | 0.156 | Black African | 9319 | (8572;10066) | -2904 | <0.001 |
| | Boys | 11254 | (10328;12180) | | | White | 12223 | (11443;13002) | | |
| FM (kg) | Girls | 10233 | (9529;10937) | 1169 | 0.042 | Black African | 9310 | (8551;10070) | -2915 | <0.001 |
| | Boys | 11402 | (10540;12263) | | | White | 12225 | (11429;13020) | | |
| FMI ($kg/m^2$) | Girls | 10259 | (9554;10965) | 1102 | 0.057 | Black African | 9351 | (8585;10117) | -2828 | <0.001 |
| | Boys | 11362 | (10495;12228) | | | White | 12179 | (11377;12982) | | |
| REE (kcal/day) | Girls | 10182 | (9490;10874) | 1288 | 0.021 | Black African | 9161 | (8400;9921) | -3222 | <0.001 |
| | Boys | 11470 | (10627;12314) | | | White | 12383 | (11588;13177) | | |

WFA *Weight-for-age*; HFA *Height-for-age*; BMI-FA *Body mass index-for-age*; FFM *Fat-free mass*; FFMI *Fat-free mass index*; FM *Fat mass*; FMI *Fat mass index*

[a] Girls n = 56; boys n = 38; black African n = 49; white n = 45

[b] Adjusted mean: Predictive margins of the general linear model for ANOVA with the factors sex and population group and their interaction

[c] 95% Confidence interval around the mean

[d] Two-way ANOVA

[e] Multivariate regression analysis

The results of the study illustrated that the sample was homogenous in terms of age. Participating families had a similar SES, and the PA environments of the two schools were comparable. REE of girls and boys did not differ significantly, but REE in black

African participants was lower than for their white participants, even after being adjusted for phenotypic variables and PA.

None of the prediction equations to estimate REE performed well across sex categories and population groups.

The PA of girls was lower than in boys, and in black African participants lower than in white participants. PA values remained relatively unchanged when adjusted for phenotypic variables. No significant relationship was observed between REE and PA.

A detailed discussion of the findings will be provided in the following chapter.

# CHAPTER 5: DISCUSSION

This chapter will present a detailed discussion of study outcomes in relation to existing evidence. Figure 5-1 displays the schematic outline of this chapter.

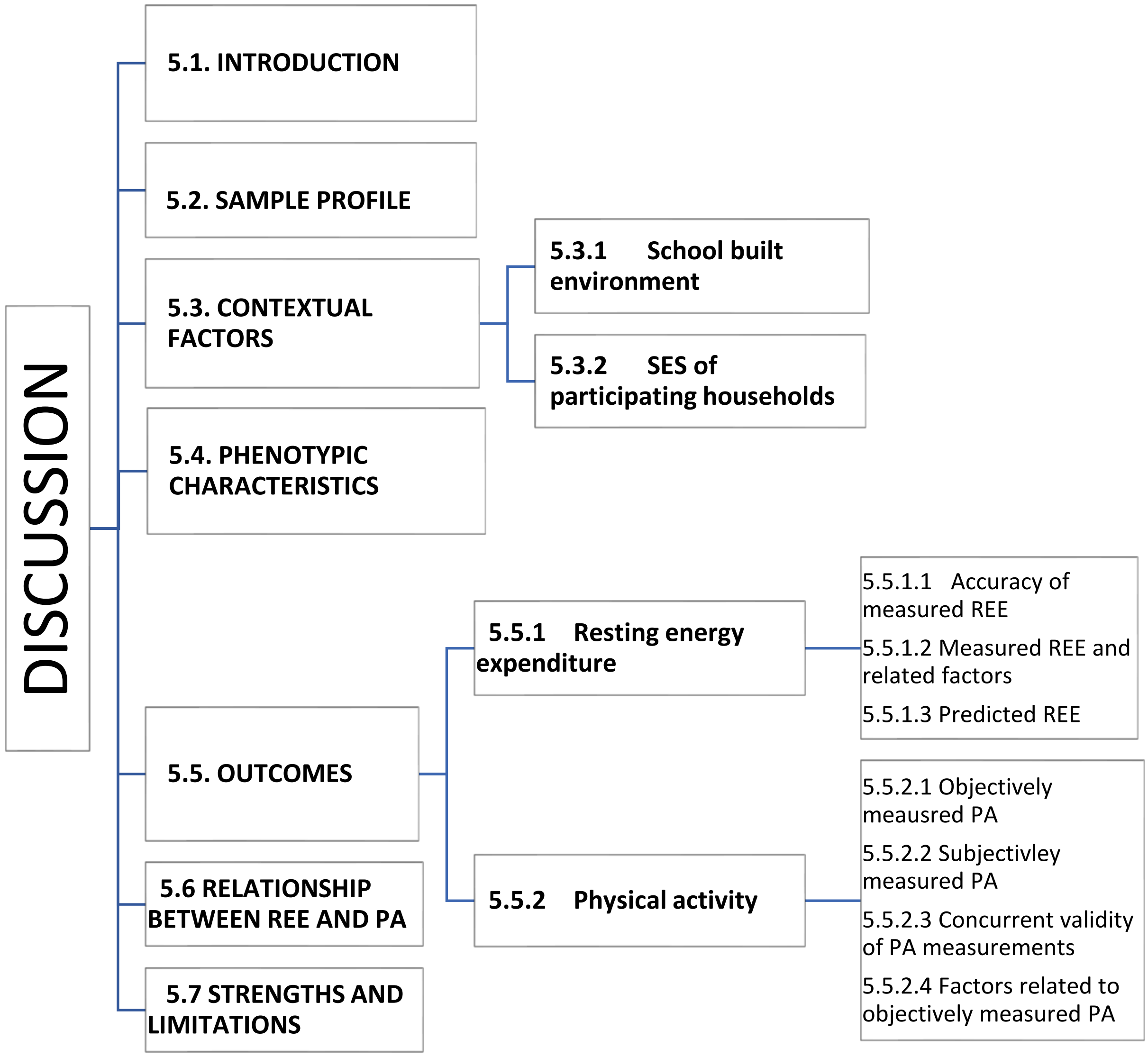


**Figure 5-1:** Outline of chapter 5

## 5.1 INTRODUCTION

This study aimed to describe the REE and PA of young children and to gain an understanding of the factors related to these outcomes. In order to draw a substantiated conclusion about the REE and PA outcomes, it was therefore necessary to identify contextual and determinant factors, while taking mediating factors into account that may influence these outcomes. Sex, age and BC have been identified in numerous studies[74-76] as the primary factors related to the REE of children. Population groups and level of PA are considered additional factors that may influence REE, but the evidence is still inconclusive.[6, 7, 74, 75] PA, in turn, is a complex behaviour and may be influenced by a variety of interrelated multifactorial environmental, biological, social and psychological factors and it may often be very difficult to discern specific influences.[111] [131] Nevertheless, sex has been identified as one of the primary factors, with age becoming increasingly important during the adolescent years. Additionally, the environment in which people live, as well as their population group and SES, are considered complex and interactive contributing factors affecting the PA of children[3, 24, 27, 28, 141, 142] and should to be considered in the interpretation of the results of the study.

This chapter discusses the REE and PA of black African and white girls and boys in the context of the study. The accuracy of REE and PA measurements will be discussed, and mediating factors related to the REE and PA will be explained.

## 5.2 SAMPLE PROFILE

Appropriate sampling in cross-sectional research is critical to ensure that objectives can be met.[137] For this study, the goal was to recruit a sample with an equal distribution of girls and boys from black African and white population groups to determine factors related to REE and PA. The sample size and composition were determined by statistical considerations that, in turn, were guided by the study objectives. One hundred and twenty participants, 60 black African and 60 white were recruited, with a similar distribution of boys and girls within each of the two population groups included in the study (black African: 53% girls; white: 61% girls). It was expected that a sample of 30 per subgroup was required to obtain statistical power

(60 participants in each population group; statistical power = 90%; significance level = 0.05). Sampling challenges and non-compliance were anticipated. However, previous studies determining the REE of SA children were not available for accurate sample size calculation (refer to section 3.3.1.3), and the power of the sample was therefore recalculated at the completion of data collection. Since statistical testing was one-sided (white children had a higher measured REE), the sample size and power still applied for the 94 participants when the family wise error of 0.05 was preserved by doing the one-sided subgroup testing at the 0.025 level of significance. The data of 26 (21.6%) participants needed to be excluded from the sample, mainly due to implausible REE measurements. The final sample of 94 included 49 (52.1%) black African (55.1% girls) and 45 (47.9%) white (64.4% girls) participants, with 61.7% of the sample having been recruited from school A and the remainder from school B. The distribution of sex categories within each population group was not significantly different (P = 0.404) and consequently allowed for comparison of PA and REE between population groups with respect to sex categories.

The sample included children between 6.4 and 9.8 years of age. Within this age range, children are relatively stable in terms of growth and development: At the end of infancy and before the onset of puberty, children do not experience a rapid growth spurt and energy needs for growth are considered marginal.(15, 167) With the onset of puberty, growth and gonadal hormones increase which affects growth patterns and may consequently increase REE.(168) In addition, age-related changes in the PA of Southern African children have been observed during the adolescent years from around the age of 12 years.(27, 111) The average age of puberty onset for SA children ranges between 11 and 12 years. Below the age of 10 years, the large majority of SA girls and boys from black African and white population groups have not yet reached the initial stage of pubertal development.(169) Confining the age range therefore limited the confounding effect of age-related growth and development that may have influenced the outcomes of the study.

## 5.3 CONTEXTUAL FACTORS

### 5.3.1 School built environment

The environment in which people live and spend most of their time has repeatedly been identified as a major factor that may influence their PA patterns. Increasing urbanisation has resulted in a PA and nutrition transition, especially in LMICs. This initiated a particular research focus on the influence of the environment on PA.[111, 135] In SA, urban environments have been found to adversely influence the PA of children. Those who live in cities are generally less active and depend more on motorised transport than children in rural areas.[111, 135] Additionally, the geographical and built environment in which children live, go to school and play may further influence their PA, depending on their physical characteristics and the accessibility of facilities to support involvement in PA.[141, 142, 170, 171]

People are mobile and are expected to move between environments that may influence their health behaviour, including PA, in various ways. Since it is generally not feasible to assess the effect of all the relevant environments on PA behaviour, it is often advised to create a homogenous geographical zone in which people may spend most of their time for studying health behaviours.[170, 172] Children spend a great amount of time at school and the school built environment and surrounding areas are often used as the primary environmental determinant to describe access and opportunities that may influence their PA.[43]

Exploring the environmental influence on PA was beyond the scope of this study, but it was important to acknowledge the possible environmental influences on the PA of the sample. To enable an accurate description and comparison of participants' PA, it was therefore necessary to recruit from schools with a similar school built environment, thereby reducing the environmental influences on PA. The study was consequently designed to purposively include two schools located in a suburban area in the same geographical region of Tshwane. The school built environments were very similar, with both schools accommodating motorised transport to schools, suboptimal access for pedestrians and no allocated access for bicycles. Likewise, for both schools, the surrounding areas had some pedestrian road safety features, but not sufficient to encourage walking or cycling to school. This was confirmed by the low percentage of children who walked to school (9%) (none cycled to school) compared to those relying on motorised transport (89%) (the remaining 2% did not indicate their mode of transport).

In SA, neighbourhood environments often present barriers to PA due to crime-related safety.[135, 173] It was therefore not surprising that the areas surrounding both schools did not support PA. Due to safety issues, children are frequently confined to enclosed spaces such as the school grounds. Many schools in SA therefore generally offer a school built environment that supports PA.[173] Both selected schools had multiple access to good quality sports and recreational amenities to encourage informal play as well as organised sports activities. A number of playgrounds, sports areas and opportunities to interact with nature were also available, with an abundance of trees and gardens. School grounds appeared neat and clean and provided a pleasant aesthetic environment.

### 5.3.2 SES of participating households

Socio-economic status is a multifaceted construct used to indicate an individual's position in society.[174] In health-related research, SES is generally used to describe the knowledge and the economic ability of individuals or households to access resources that may improve health-related behaviour.[175] However, SES is considered a complex and relative concept, often entangled with influences at various environmental levels. Consequently, measures of wealth may not be the same across populations, cultural groups and regions. Furthermore, using household income as a measure of SES may not fully reflect differences in cost of living or expense patterns applied to improve health behaviour.[135, 174, 175] In SA, historic disparities have compromised many SES-related aspects such as education and income capacity of primarily black African populations, which may further mask the true effect of SES on health behaviours.[135, 147]

Differentiating the contributory role of SES on health behaviour such as PA remains a challenge.[135, 175] Regardless of these challenges, SES assessment is essential when comparing the health-related behaviour of individuals and populations. To facilitate

SES-related research, the construct of homogenous geographical zones, previously explained, can be applied. People of the same socio-economic and cultural background tend to cluster together. Geographical zones are often homogenous along socio-economic dimensions and may assist in reducing the confounding effect of SES on health behaviour.(170)

In this study the school, with its surrounding neighbourhood, was purposively selected within a homogenous geographical and socio-economic zone. The study included two schools located in an affluent neighbourhood of Tshwane.(176) Both schools offered well-maintained school grounds and facilities with a similar school fee structure more suited to accommodate learners from a higher SES. The type of school has previously been used in research as a proxy for individual SES of children attending that school.(177)

In LMICs, including SA, a higher SES is generally associated with lower levels of PA.(111) Typical indicators of SES associated with the PA of children in LMICs include neighbourhood environment and crime-related safety, parental education, household income and living conditions.(111, 135) Guided by this previous research, socio-economic data were collected for this study by means of the SDQ. In agreement with the school and community level SES, the results supported a higher SES at household level. Good housing conditions, with the majority (75%) being homeowners, a relatively low number of people living in each household (3-5/household) and households being well equipped with appliances indicated relative prosperity. Although almost a quarter (24%) of households relied on a single person's income, the majority (96%) had an income within the upper quintile. For almost all the SES indicators, no significant differences were observed between schools and population groups, confirming a relatively homogenous sample in terms of SES.

## 5.4 PHENOTYPIC CHARACTERISTICS

Anthropometric and BC measures are phenotypic characteristics that have been identified in previous research as confounders of REE and PA.(52, 76, 80) A comprehensive analysis and description of the phenotypic characteristics of the sample were therefore required. Anthropometric measures, including weight, height and BMI, are widely applied in clinical and research settings to determine growth and protein-energy status of children. Since growth affects weight, height and consequently the BMI of children at different stages during development, age-related z-scores were used, which allowed for inter-group comparison of anthropometric variables independent of age and growth.[82]

Although BMI calculation is useful to describe anthropometric status, it cannot be used to differentiate between BC compartments.[83] Body composition is considered one of the main determining factors of REE in both adults and children[11, 74, 76] and therefore necessitated further exploration to interpret the measured REE.

All the mean z-scores of the sample for WFA, HFA and BMI-FA were within 2 SD of the WHO reference values, indicating that the sample represented a healthy population in terms of physical growth.[1] The mean WFA z-scores were relatively consistent across sex categories and population groups. Black African participants had a significantly lower HFA z-score ($P < 0.001$) than the white group. No evidence of stunting was observed, since the minimum HFA z-score of -1.54 SD was within the healthy range (greater than -2 SD). When considering BMI-FA z-scores, the mean for black African participants was significantly higher than for white participants ($P = 0.042$). Although slightly above the median of the health reference values (0.43 SD), it was still within the healthy BMI range (-2 SD ≤ BMI-FA ≤ 1 SD). There were no significant differences in anthropometric indices between the girls and boys of this sample.

Although many of the anthropometric characteristics of the present study compare relatively well with previous SA studies, some discrepancies were identified. Previous SA surveys only reported on absolute measurements and not in terms of z-scores. To allow for comparison of the present study in relation to other SA studies, the mean weight (27.6 ± 5.4 kg), height (129.5 ± 6.3 cm) and BMI (16.4 ± 2.4 kg/$m^2$) values were used. The First South African National Health and Nutrition Examination Survey (SANHANES-1)[4] was conducted in 2012 to assess health behaviour and health status of a nationally representative sample of over 25 000 individuals, stratified into age categories. For the age category 6–9 years, the mean weight and height reported in the survey were slightly lower (girls: 25.4 kg and 123.9 cm; boys: 24.4 kg and 123.2

cm) than the mean values of the present study. The SANHANES-1 survey concluded that children, in particular boys, living in formal urban areas, were heavier and taller than those in informal rural areas. This may explain the reason for the higher mean values observed in the present study when compared to the SANHANES-1 results.

For BMI, survey values were relatively consistent with the present sample. The SANHANES-1[(4)] reported a mean of 16.1 kg/m$^2$ for 6–9-year-old children, whereas the South African National Food Consumption Survey Fortification Baseline undertaken in 2005 (NFCS-FB-1),[(178)] reported a mean BMI of 16.0 kg/m$^2$ for children aged 6–9 years. When categorised according to BMI-related weight categories, the proportion of children who were classified as being underweight or normal weight was very similar for both the SANHANES-1 (89.0%) and the NFCS-FB-1 (89.8%), but slightly more than in the present study (83.0%). However, it should be noted that although the NFCS-FB-1 used the same WHO classification for weight categories as used in the present study, the SANHANES-1 used Cole's[(179)] classification.[1] The proportions of children with overweight and obesity identified by SANHANES-1 were 7.0% and 3.3% respectively, and by the NFCS-FB-1 7.8% and 2.5% respectively. All of these being lower than the respective 9.6% and 7.4 % measured in the present study. Urban SA children, especially in Gauteng, generally have a higher BMI than those in rural areas, which could explain the higher percentages of children with overweight and obesity observed in the present study.[(4)]

When considering differences between sex categories and population groups, the SANHANES-1 identified that the prevalence of overweight and obesity was significantly higher in girls than boys aged 0–14 years. Although the SANHANES-1 indicated that insufficient data were available to report on the difference between population groups, children from the black African group had a BMI higher than the mean. These results conform with the findings of this sample, with 19.6% of girls compared to 13.2% of boys being overweight or obese, along with the significantly

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[1] Cole's classification for childhood overweight and obesity: Based on adult cut off values, centile curves for children were developed that at the age 18 years passes through the adults cut off points of 25 and 30 kg/m$^2$ for overweight and obesity respectively.l

higher BMI-FA z-score for black African participants. These findings are also in line with adult data suggesting that the black African populations in SA, especially women, are disproportionately affected by overweight and obesity.[4]

Along with overweight and obesity, underweight and stunting have been identified as the most common nutritional disorders in young children, especially in black African populations living in less affluent rural settings.[4, 178] However, in this study, no underweight or stunted children were identified (all relevant z-scores above -2 SD). This could be explained by the high SES and the urban setting of this study together with the dramatic decrease in the prevalence of stunting reported during the past decades, especially for children above the age of 5 years living in urban areas.[4]

It should be noted that although not classified as stunted, the black African children in this study had a significantly lower HFA z-score, along with a significantly higher BMI-FA z-score than the white children. These findings are in line with previous SA studies indicating that children with a shorter stature may be more at risk of being overweight.[180, 181]

For BC, all variables were significantly different between sex categories. Girls had a lower FFM and FFMI, along with a higher FM and FMI than boys. These results are similar to findings of previous SA and international studies.[84, 98, 182]

Between population groups, significant differences were also observed for all variables, except FFMI. Black African participants had a lower FFM, but a higher FM and FMI than white participants. The difference observed for FFM was possibly related to more fat-free tissue associated with a taller stature. When FFM was adjusted for height, i.e. FFMI, the population differences declined, indicating that the taller stature of white participants may explain the higher FFM.

South African studies reporting on BC of different populations are very limited, especially for children. Available data presented in Table 5-1 vary considerably, and since only absolute FM and FFM values were available in most cases, comparison of BC in relation to height was limited. The only meaningful comparison could be made with the study of Griffith et al.[84] However, all their reported FFMI and FMI values were well below the values in this study, possibly due to the different method (DEXA) used for BC measurements.

When considering differences in BC between population groups, the study by Micklesfield et al.[(183)] concluded that, in line with the observations in the present study, FFM of black African children was lower than white. In contrast, the FM of white children was higher than black Africans. A higher FM in children can often be associated with a lower SES.[(84)] However, since information regarding the SES was not available in their publication, no reasonable explanation could be provided for the discrepancies observed when compared to the higher FM of the black African group observed in the present study.

**Table 5-1:** BC of SA children

| Study and method | Age and setting | Population group (N) | Sex | Mean FFM (kg) ± SD[a] (CI)[b] | Mean FFMI (kg/m²) ± SD[a] | Mean FM (kg) ± SD[a] (CI)[b] | Mean FMI (kg/m²) ± SD[aN] |
|---|---|---|---|---|---|---|---|
| Present study BIA[c] | 8.1 ± 0.8 Urban | Black African (49) | No differentiation | 20.2 (19.5;20.8) | 12.3 (12.1;12.5) | 7.8 (6.7;8.9) | 4.7 (4.1;5.2) |
| | | White (45) | | 21.6 (20.9;22.3) | 12.5 (12.3;12.7) | 5.7 (4.6;6.8) | 3.3 (2.7;3.9) |
| | | - | Girls | 20.1 (19.5;20.7) | 12.0 (11.8;12.2) | 7.5 (6.4;8.5) | 4.4 (3.9;5.0) |
| | | - | Boys | 21.9 (2.1;22.6) | 12.9 (12.7;13.2) | 5.8 (4.6;7.0) | 3.4 (2.7;4.0) |
| Van Zyl[(182)] DEXA[d] | 8.5± 1.4 Urban | Black African (84) | No differentiation | 21.5 ± 4.9 | - | 11.8 ± 7.1 | - |
| Micklesfield[(183)] DEXA[d] | 9.5± 0.3 Urban | Black African (263) | Girls | 17.1 (15.6;19.4) | - | 7.1 (5.4;10.0) | - |
| | | | Boys | 18.4 (17.0;20.2) | - | 5.7 (4.2;7.5) | - |
| | | White (73) | Girls | 17.1 (16.1;19.4) | - | 8.1 (5.8;9.4) | - |
| | | | Boys | 20.2 (18.4;22.5) | - | 6.4 (5.4; 7.2) | - |
| Griffiths[(84)] DEXA[d] | 9-10 years Urban | Black African and White (429) | Girls | 18.4 ± 3.37 | 10.1 ± 1.4 | 9.0 ± 4.7 | 2.7 ± 1.5 |
| | | | Boys | 19.5 ± 3.0 | 10.7 ± 1.1 | 6.7 ±4.0 | 2.0 ± 1.0 |

[a] SD = Standard deviation of the mean
[b] 95% Confidence interval around the mean
[c] BIA *Bioelectrical impedance analysis*
[d] DEXA *Dual-energy X-ray absorptiometry*
[e] BMI-FA *Body mass index-for-age*

When considering European reference data for children aged 6–9 years,[98] the means for FFMI in the present study (12.0 kg/m$^2$ and 12.9 kg/m$^2$ girls and boys respectively) were slightly lower than the reference ranges (medians: 12.4–13.2 kg/m$^2$ for girls; 13.3–13.4 kg/m$^2$ for boys). For FMI, the means (4.4 kg/m$^2$ and 3.4 kg/m$^2$ for girls and boys respectively) were higher than the reference ranges (medians: 3.5–4.2 kg/m$^2$ for girls; 2.7–3.0 kg/m$^2$ for boys). When compared to reference ranges for 8–10-year old American children,[97] the means for FFMI in the present study were close to the reference range (medians: 11.3–12.1 kg/m$^2$ for girls; 12.3–12.7 kg/m$^2$ for boys), but the means for FMI were lower (medians: 5.1–5.8 kg/m$^2$ for girls; 4.6–4.8 kg/m$^2$ for boys).

In contrast with the findings of the present study, research indicated[94, 97] that prepubertal African American children have a higher FFM and FFMI than their white counterparts, but no differences in FM and FMI between these population groups were reported. Subsequently, Shypailo and Wong[94] suggested population-specific reference standards. When considering their suggested reference range for 6–9-year-old African American children, the FFMI of black African participants in the present study (12.3 kg/m$^2$) was lower than the reference values (13.3–14.2 kg/m$^2$ for girls; 13.6–14.7 kg/m$^2$ for boys). Fat mass index values were not provided, and comparison was therefore not possible. These findings are in line with previous research,[183] indicating that black African children in SA have a lower FFM along with a higher FM than African American children.

It should be noted that between-study comparison of BC in children is often difficult. Several techniques and methods are used to convert raw measurements to BC. Due to these different theoretical assumptions, along with population variability in body size and protein-energy status, data sets are often heterogeneous, thus hindering inter-population comparison.[98] However, regardless of inter-study heterogeneity in BC results, only one equation[39] was used in the present study to calculate BC, thereby allowing for inter-participant comparison. The equation by Horlick et al.[39] was considered the most suitable to determine the FFM of both black African and white children, since it is the only known equation validated for use in different population groups.

Nevertheless, the results of this study conform with international indications that the FFM and FFMI of girls are consistently lower than for boys, whereas the FM and FMI of girls are consistently higher. Between populations groups, the FFM and FFMI of black African children appear to be lower than white groups and African Americans. The FM for black Africans seems to be higher than for their white and African Americans peers, supporting indications that black African children may be at higher risk of obesity than white children.(4, 178)

## 5.5 OUTCOMES

### 5.5.1 Resting energy expenditure

5.5.1.1 Accuracy of measured REE

**Steady state**

The concept of SS was introduced to improve the accuracy of REE measurements via IC.(48, 52, 55, 60, 62) A standardised protocol is recommended to ensure individuals achieve and maintain a SS.(52, 55, 62) Since no standardised evidence-based protocol to achieve SS is available for children, procedures based on previous studies performed on children,(48, 62, 63) were applied in the present study (refer to sections 2.2.1.2 and 3.3.3.5). To assess the efficiency of the procedures followed, the intra-individual %CV was determined for REE and related variables, which is a method used in previous research to determine variation.(52, 60, 62, 63)

For adults, it is generally advised that the data from the first 5 min of IC measurements be discarded.(52, 60, 62) Although IC research in children is limited, it has been suggested up to 10 min of measurements should be discarded when a prior rest period is not allowed.(48, 63) However, in this study it was noticed that since measurements were taken early in the morning, children were still calm and, gauged by machine-indicated SS, participants achieved resting state at average 5.6 min of measurements. These findings support a protocol of discarding the first 5 min of IC measurements in young children, even without a prior rest period if measurements are taken early in the morning.

The majority of children (84.2%) achieved SS during the REE measurement, of which half (50.0%) were early achievers (< 5 min). No significant difference was observed between sex categories (P = 0.955) and between population groups (P = 0.758) regarding the time to achieve SS. Furthermore, the time that lapsed before SS was achieved was not related to the mean %CV. For all participants who achieved SS, the mean %CV for all REE-related variables remained at 3% or lower throughout the measurement, well below the recommendation of less than 5–10% for adults. Although the mean %CV of all variables was consistently higher for girls than boys, and likewise for black African than white participants, the differences were not significant.

The findings of the present study are in agreement with previous research performed on children aged 7–12 years.[(63)] Mellecker and McManus[(63)] observed that children were restless during the first 5 min of the measurement. Thereafter, no significant differences were found in REE when measured at 10, 15, 20 and 25 min without a prior rest period. Although %CV was acceptable throughout, the least variation (CV = 6%) existed after 20 min of measurement, but thereafter compliance decreased when children started to become restless. The %CV generally reported was higher than the 3% observed in this study. This may be explained by the use of different gas-collection devices. The study by Mellecker and McManus[(63)] used a face mask and a nose clip, whereas the present study used a ventilated canopy hood. Evidence exists[(17, 48, 52, 60, 62, 63, 184)] that gas-collection devices may have a significant influence on REE measurements. The discomfort of using a nose clip or face mask rather than a ventilated canopy hood may result in a significantly higher REE and related variables.

In addition to SS, RQ is often used to determine the accuracy of REE measurements or the violation of the fasting protocol. Respiratory quotient values outside the range of 0.67 and 1.2 are beyond human physiological limits and may indicate measurement error.[(48, 52, 55, 60, 185)] Based on the RQ values in this study ranging between 0.70 and 0.91, measurement errors were unlikely. The maximum RQ value above 0.90 may be indicative of a participant who violated the fasting protocol. However, RQ is not considered an accurate way of assessing individual fasting[(185, 186)] and the data for this participant were therefore not excluded from the sample.

In conclusion, the results of this study support the suggestions of previous studies[48, 63] whereby an abbreviated IC measurement protocol of 15–20 min, without a prior rest period can be used for children when measurements are taken early in the morning. Consistent with a suggested protocol for adults,[55] there is no need to prolong the test beyond 15 min if SS is achieved. There are no known studies that have investigated the achievement of SS in children across different population groups. The present study indicates that a consistent protocol can be considered when measuring REE of black African and white girls and boys.

#### 5.5.1.2 Measured REE and related factors

The mean measured REE for the sample was 1 023 ± 225 kcal/day (4 297 ± 945 kJ/day), with a minimum of 480 kcal/day (2 016 kJ/day) and a maximum of 1 434 kcal/day (6 023 kJ/day). These values are slightly lower when compared to previous research on prepubertal children. Two pioneer studies reported a mean measured REE of 1 054 kcal/day (±138 kcal/day) (N = 113 children; aged 4–8 years)[74] and 1 078 kcal/day (±118 kcal/day) (N = 130; aged 6–10 years).[73] However, absolute measured REE should not be used for inter-group comparison, since many factors may influence REE outcomes. Numerous previous researchers[6, 7, 73-75] have identified age, sex and BC, specifically FFM, as the most significant factors, with population group and PA as possible contributing factors that need to be considered when comparing the REE of children. It is therefore important to adjust for REE related factors to allow for sensible inter-group comparison.

**Age**

Apart from age-related hormonal changes, various studies[73, 75, 76, 169, 187, 188] identified age in itself to be a noticeable factor related to REE. However, most of these studies included children with a wide age range and did not differentiate between age categories. When considering studies investigating only prepubertal children, the pioneer study of Goran et al.[74] did not find age to be a significant predictor of REE. In addition, popular prediction equations for BMR were developed for age categories, with one equation considered suitable for children aged 3–10 years.[15, 16, 70] Various models were evaluated for the development of these equations, including age and body weight as predictors of TEE with DLW. It was identified that age and weight for this age category were highly correlated. However, the effect of weight was more significant than age and consequently weight was selected as the single predictor of TEE and the exclusion of age from the equations did not increase the error in estimates.[15]

The present study found that age was not significantly related to the mean REE of the total sample (r = -0.08, P = 0.440). Although not strong, a significant and negative correlation was present for girls (r = -0.27; P = 0.050) and the white population group (r = -0.34; P = 0.016), whereas for the black African population group a positive correlation was observed (r = 0.34; P = 0.021). There is no reasonable explanation for the observed negative correlation, since an increase in REE would be expected with an increase in age as children grow and gain weight. When REE was adjusted for age, the mean REE for all categories remained unchanged, indicating that the observed correlation between REE and age may be explained by other influencing factors. The sample included a narrow age range with the aim of minimising age as a confounder when investigating REE and PA. The results of this study, in line with existing evidence,[15, 74] supported the theory that between 6 and 9 years, age was not significantly related to REE across sex categories and population groups and confirmed that age was not a confounding factor in this study.

**Sex**

Several studies[73-76, 109] recognised sex as a significant predictor of REE in children of all ages, with boys having a higher measured REE than girls. These differences, often to a lesser extent, persisted after being adjusted for influencing factors, including body size and BC.

Maffeis et al.[73] (N = 130; ages 6–10 years) reported a mean measured REE of 40 kcal/day (168 kJ/day) lower for girls than boys. No adjusted REE values were provided, but they reported that FFM explained 64% of the variability in REE for the total sample. Another study[9] investigating the REE of prepubertal children aged 5–12 years identified that after adjusted for FFM and population group, the effect of sex on REE was negligible. Likewise, Kaneko et al.[187] observed no significant difference (P > 0.050) in mean measured REE between prepubertal Japanese boys (n = 37) and girls (n = 33) aged 6–11 years. When adjusted for body weight or FFM, significant sex differences in REE (P < 0.050) were only observed from the age of 12 years.

Similar to the above research on prepubertal children, the results of this study indicated that the mean measured REE for girls was 41 kcal/day (172 kJ/day) lower than for boys (P = 0.375). When adjusted for WFA z-score, HFA z-score and BMI-FA z-score, REE values remained almost unchanged for both boys and girls, and the difference between sexes did not meet statistical significance. When adjusted for FFM and FFMI respectively, the difference in REE not only decreased, but changed direction with girls having a higher adjusted REE than boys (25 and 31 kcal/day [105 and 130 kJ/day] [P = 0.582 and 0.549] respectively for FFM and FFMI). These results are consistent with the findings of Lazzer et al.,[75] who reported that a higher BMR in boys can be explained mainly by their higher FFM when compared to girls. They further suggested that the confounding effects of sex may be eliminated when REE is adjusted for FFM. The sex differences (although not significant) in measured REE observed in the present study may therefore be partially explained by the higher FFM in boys.

When adjusted for FM and FMI respectively, the REE difference between sexes increased (70 and 74 kcal/day [294 and 311 kJ/day] [P = 0.124 and 0.107] respectively for FM and FMI). This conforms with previous research,[9, 187] indicating that FM contributes to REE. It appears that in the present study, the higher FM and FMI of girls compared to boys contributed to their REE, thereby decreasing the sex difference in the measured REE.

Nevertheless, measured and adjusted sex differences in REE in this sample did not meet statistical significance. The small differences in REE observed between boys and girls can be explained by differences in BC.

**Phenotype**

In line with previous research,[9, 74, 76] the strongest, yet moderate, correlation in the total sample was observed between REE and FFM (r = 0.45; P < 0.001). Although the significance of this correlation persisted across sex categories and population groups, a stronger correlation was observed for boys (r = 0.55; P < 0.001) and for the white population group (r = 0.42; P = 0.004). However, the strength of the correlation decreased considerably for boys (r = 0.28; P = 0.089) and for white participants (r = 0.09; P = 0.581) when FFM was expressed per height unit as FFMI, whereas the correlation remained unchanged for girls (r = 0.35; P = 0.008) and grew slightly stronger for black African participants (r = 0.44; P < 0.001). This reveals the possibility that the higher REE of the white population group, and in particular boys, may be related to a higher FFM associated with their taller stature.

When considering the correlation between REE and FM, a significant and positive relationship existed only for black African participants (r = 0.39; P = 0.005) and the relationship remained almost unchanged when FM was expressed per unit of height, i.e. FMI (r = 0.41; P = 0.004). This may indicate that in black African participants, FM contributed to REE. Since no changes were observed in the relationship with FMI, it may be an indication that the influence of FM on REE, especially in black African participants, may not be related to height.

For black African participants only, the strength of the relationship observed between REE and FM and FMI respectively, was very similar to the relationship between REE and FFM and FFMI respectively. Both FM and FFM, independent of height, may therefore be equally and positively related to the REE of black African children. Similar to the black African participants, girls had a significantly higher FM and FMI than boys (P = 0.035 and P = 0.010 respectively). However, contrary to expectations, the correlation between REE and FM as well as FMI, lacked significance for girls (r = 0.06; P = 0.669 and r = 0.03; P = 0.803 respectively). In addition, for black African participants, the relationship between REE and WFA z-score (r = 0.56; P < 0.001) and BMI-FA z-score (r = 0.55; P < 0.001) respectively was even stronger than that observed for FM and FFM (r = 0.39; P = 0.006), but this was not mirrored in the white participants. It therefore appears that body weight and the absolute weight of FM and FFM may contribute more to REE for black African participants than in the case of white participants. This is not completely surprising, since individual variances in metabolic activity of FM and FFM in adults have been reported in literature.[189] Metabolic activity of FFM is not consistent across all organs and skeletal muscle,[11, 87, 88] and in children the effect of growth on the size of FFM and its composition may further contribute to variations in REE.[11, 18, 190]

**Population group**

The differences observed in the measured REE between population groups (146 kcal/day = 613 kJ/day) decreased by a mere 19 kcal/day (80 kJ/day) after adjustments were made for WFA z-score and FFMI respectively, suggesting that weight and FFMI did not contribute considerably to the differences in REE between population groups. When adjusted for FFM and HFA z-score respectively, the population differences decreased considerably (to 91 kcal/day ≈ 382 kJ/day; P = 0.039 and 82 kcal/day ≈ 344 kJ/day; P = 0.108 respectively) and confirms that variances in FFM and height can partially explain differences in REE between population groups. Although the difference of 82 kcal/day did not reach statistical significance, it may have clinical implications. It has been proposed that as little as 50-100 kcal/day (210-420 kJ/day) could affect long-term body weight and related health consequences in adults.(110) If the same principle applies to children, an excess of around 80 kcal/day (336 kJ/day; 7.8% of mean measured REE) may lead to long-term health consequences.

Adjustments for BMI-FA z-score, FM and FMI increased the population difference by up to 43 kcal/day (307 kJ/day) (P < 0.001). This indicates that variation in weight, including the weight of FM and in relation to height, may have partially contributed to the observed population differences. These differences remained significant after being adjusted, indicating that the mean REE of black African participants was lower, despite their higher BMI and FM or FMI.

The mean REE of participants who were overweight/obese (1 084 kcal/day = 4 553 kJ/day) (girls only) was higher than healthy weight participants (994 kcal/day = 4 175 kJ/day) (girls only); while the mean REE of white girls remained consistently higher than their black African counterparts across weight categories. The REE difference between population groups among girls who were overweight/obese was much smaller, yet clinically significant at 61 kcal/day (256 kJ/day), compared to the population difference observed among girls with a healthy weight (230 kcal/day = 966 kJ/day). Although the number of participants in the overweight/obese category was insufficient to draw any reasonable conclusions, it must be acknowledged that these results coincide with a previous study performed by Kaplan et al.,(9) one of the few studies investigating population differences in REE in prepubertal children (aged 5–12 years). The results of that study indicated that in both African American and white American children, participants with obesity had a higher REE than those who were not obese. Additionally, the REE of black American children remained significantly lower than the white American children across weight categories. Within the black American group with obesity, the REE (1 361± 58 kcal/day) was lower than for the white American children who were obese (1 590 ± 59 kcal/day) and non-obese (1 457 ± 66 kcal/day). They further concluded that despite differences in body size and BC, the REE of African American children remained significantly lower than white American children.

The results of the study and the preceding discussion indicate that the REE of black African participants was lower (statistically and clinically) than for white participants, even after being adjusted for all phenotypic variables. These results are in line with previous studies(6, 9, 21, 22) performed on mainly American children. However, it is often argued that the lower REE of African American population groups may be explained by differences in the type and distribution of FFM rather than an absolute difference in REE.(18, 21, 86) Since FFM is considered the most metabolically active tissue, variations in metabolic activity between types of muscle mass may lead to considerable differences in REE.(87) Trunk lean mass is more metabolically active, thereby contributing more to REE variations. Many studies(18, 21, 86, 87, 107, 109) have indicated that African American populations have a lower trunk lean mass, consistent with lower organ mass, which may explain a lower REE than white populations. In addition, a greater appendicular lean mass, which contributes little energy at rest, along with a higher metabolically inactive bone mass in African American groups, may further reduce REE.(22, 191) Although a limited number of studies have been carried out on children, similar findings were observed. A lower trunk lean mass, along with a higher appendicular lean mass, explained most of the differences in REE between African American and white children. Broadney at al.(21) indicated that the REE of African American children aged 5–18 years was 77 ± 16 kcal/day lower than their white counterparts after being adjusted for lean mass (skeletal muscle and organ mass). When adjusted for trunk and appendicular lean mass, the difference declined to 28 ± 19 kcal/day. Similar findings were observed by Tershakovec et al.,(109) reporting that the difference in REE between African American and white children declined from 111 kcal/day to 77 kcal/day when adjusted for FFM and trunk FFM respectively. These arguments were contradicted by the research of Adzika et al.[12] who reported that for adults, the REE of Sub-Saharan black African populations was 240–275 kcal/day lower than the REE of white groups, even after adjustments were made for trunk and appendicular lean mass and for bone mass. No known studies have been undertaken to explore the effect of BC compartments on REE in Southern African children.

Although multi-compartment BC techniques may better explain these differences, costly BC analysis along with IC is not feasible in resource-limited LMICs such as SA. As the only alternative, clinicians and dietitians need to rely on prediction equations to determine energy requirements in a community or clinical setting. Regardless of contributing factors to REE, inaccurate estimation of REE may have clinical implications for the prevention and treatment of childhood obesity. The accurate estimation by means of reliable prediction equations of REE is therefore a requirement to effectively prevent and treat diet-related diseases.

#### 5.5.1.3 Predicted REE

The accurate estimation of an individual's energy requirement is essential for appropriate dietary prescription to maintain health, combat overweight or obesity and prevent diet-related disease.[15] Although IC is recommended to determine energy expenditure in a clinical setting,[15, 52] it is costly and not feasible in resource-limited LMICs such as SA. Clinicians and dietitians therefore often have no alternative other than to rely on prediction equations when planning dietary interventions for the prevention and treatment of diet-related diseases. Many studies[64, 72, 192] have been aimed at developing and improving prediction equations, but accuracy, especially across population groups, remains inconsistent. This may partially be explained by the development of forerunner equations that were based solely on white European and white North American populations.[16, 70, 71] These equations generally overestimated the energy requirements of most other populations, including African Americans. The development of subsequent equations included a wider population, e.g. Asians and Chinese subjects,[16] but, to date, no known studies have been performed to determine the accuracy of these equations for SA children.

The performance of the Harris-Benedict,[66, 68] Schofield,[70] FAO/WHO/UNU[71] and Oxford[16] equations was investigated in this study due to their popularity in SA clinical settings. Additionally, the Maffeis[73] equation was added, since the age group selected by Maffeis et al. was similar to this study. Although the inclusion of BC variables is often suggested to improve the accuracy of prediction equations,[64, 72] BC-based equations were not included. Research in children[73] reported that the addition of BC did not improve the accuracy of estimation equations. In addition, since BC measurements are relatively costly, these are not generally used in SA settings.

When considering the agreement between measured and estimated REE, the results of this study indicate that none of the prediction equations performed well in estimating the REE across both sex categories and population groups. All the prediction equations included in the analysis overestimated the REE of black African participants. These findings are in agreement with previous research[16] indicating that prediction equations generally overestimate energy requirements of most other populations including African Americans. For white participants in the present study, although results were variable, the FAO/WHO/UNU[71] equation performed best by estimating REE within 13 kcal/day (55 kJ/day) (LOA: -386;349 kcal/day) and 18 kcal/day (76 kJ/day) (LOA: -517;490 kcal/day) for girls and boys respectively. These results are in line with a literature review by Carpenter et al.[64] determining the accuracy of predicting REE in children with commonly used predictive equations, including Schofield (weight and height; weight)[70], Oxford (weight; weight and height)[16], FAO/WHO/UNU[71] and Harris-Benedict (1984).[68] They concluded that although the FAO/WHO/UNU equations performed best, none of the equations was consistent in accurately estimating the REE across a variety of children. Similar findings were reported in the systematic review by Chima et al.[192] and a study by Acar-Tec et al.,[72] investigating the accuracy of prediction equations for children who are overweight and obese. They concluded that although the Schofield[70] equation may be the most suitable for children with overweight and obesity, no single equation can be used to accurately estimate the REE of different children.

Studies performed on specifically prepubertal white populations are limited but delivered similar results. Finan et al.[193] reported that the FAO/WHO/UNU[71] performed better than the Maffeis[73] and Harris-Benedict[68] equations. The

FAO/WHO/UNU was the only equation that consistently predicted measured REE, with over half of predictions within 50 kcal/day of the measured values.

McDuffie et al.[10] was one of the first studies that included African American and white population groups to determine the accuracy of prediction equations of 502 healthy- and overweight American children aged 6–11 years. They identified the FAO/WHO/UNU[71] equation as the most consistent in accurately predicting measured REE across the whole sample. However, similar to the findings of the present study, when data were split by sex and population group, no equation accurately predicted REE for all four sub-groups. They further identified that the FAO/WHO/UNU equation provided an accurate estimate of the mean REE for white males, but greatly underestimated the REE of African American and white females and overestimated the REE of African American males. Additionally, the Harris-Benedict equation accurately estimated the mean REE of African American females but underestimated that of white females and of African American and white males. Nevertheless, they suggested the inclusion of population groups as a variable to improve the accuracy prediction of REE.

In agreement with the above findings and discussion, and in line with suggestions of the FAO/WHO/UNU Expert committee,[15] it is evident that a single equation cannot be used to accurately predict REE across sex categories and population groups. This emphasises the importance of population-specific nutrition assessments and the need for the development of methods to accurately determine the REE of children in SA.

### 5.5.2 Physical activity

#### 5.5.2.1 Objectively measured PA

Although no gold standard device has been identified to objectively measure PA, accelerometers are often the preferred option to deliver more accurate results. However, these devices may still include measurement errors and are relatively costly.[30, 116] Due to resource limitations, the use of pedometers, an inexpensive alternative for the objective measurement of PA, was therefore considered the most feasible option for this study. Along with a detailed measurement protocol (described in section 3.3.2.5), pedometer measurements are considered reliable and accurate when compared to accelerometers.[118]

The mean step-count of the sample was 10 663/day (± 3 026), with the count of black African participants significantly lower than white (9 280 and 12 258 respectively; P < 0.001). For girls, the average step-count was significantly lower than boys (10 212 and 11 433 respectively; P = 0.029). This corresponds with previous SA and international research[31, 33] indicating a lower step-count among girls.

Many studies[30-32, 123, 125] explored the use of steps/day indices associated with health outcomes in children and indicated the need for population and country-specific guidelines. Although no single set of guidelines is available, international studies recommended a daily step-count range between approximately 10 000–15 000 and 12 000–18 000 for girls and boys respectively.[32, 125] More specifically, the Canadian CANPLAY study, based on an extended database, suggests 11 000–12 000 and 13 000–15 000 steps/day for girls and boys respectively aged 6–11 years, to meet the equivalent of the WHO recommendations of approximately 60 min per day of MVPA.[31, 123]

In light of these recommendations, the mean step-count of the sample barely met the minimum suggested range associated with improved health outcomes and WHO PA recommendations.[31, 123] Insufficient PA levels were specifically observed for black African participants. These results are similar to the few studies[26, 27, 33] which have previously described PA patterns in SA children. Although limited data exist regarding the PA of young SA children, especially for objective PA measurements, there is sufficient indication that SA children are not meeting PA requirements.[26, 27]

Malan and Nolte[33] measured step-count in white prepubertal children in a similar research setting and reported an insufficient step-count for girls and boys (7988 and 10 504 respectively) attending school in an urban Tshwane neighbourhood. Two larger-scale studies also indicated that at least 50% of prepubertal SA children, especially girls and those living in a disadvantaged neighbourhood, did not meet the recommended MVPA of 60 min/day.[44, 53, 194] In addition, a study in older SA children

(5–18 years)[27] reported insufficient PA, especially among girls and black African populations, similar to the findings of the present study.

The results of this study further indicated that PA during weekends was significantly lower (1173 steps/day; P = 0.031) than during the week. This was observed across sex categories and population groups. The difference in step-count between sex categories and population groups increased during weekends, indicating that participants who were generally less involved in PA (girls and black African), were even less active during weekends, than those with a generally higher PA (boys and white). These results are similar to the findings of Malan and Nolte,[33] indicating a lower step-count during weekends than weekdays (6795 ± 3289 and 10 219 ± 2761 respectively) across girls and boys. Additional evidence exists that more active prepubertal children, especially boys, were more likely to maintain their PA during weekends, whereas for less active peers, PA during weekends declined.[195, 196]

Fu et al.[124] reported that children who met the recommended step-count (based on Tudor-Locke et al.[32]) during weekdays were less likely (36%; P = 0.02) to be overweight or obese than those not meeting the recommendations. For those meeting the recommendations during both weekdays and weekends, the odds were even lower (67%; P = 0.01) compared to those not meeting the recommendation. Meeting weekend step-count guidelines only was not associated with weight status. They concluded that a positive relationship exists between recommended step-count accumulation and the healthy weight status of children, which may be used to guide public health recommendations.

Although the number of participants who were overweight and obese in this study was insufficient to draw reasonable conclusions, results suggested that these children were less active than those within the healthy weight category. Additionally, although statistical significance was not met, a negative correlation was observed between the average steps/day and BMI-FA, FM and FMI respectively. It is therefore evident from the PA outcomes that the worldwide PA transition associated with increasing levels of overweight and obesity have not escaped SA children. Since children with obesity are more likely to become obese during adulthood,[197] appropriate intervention is essential. The results of this study emphasise the need for PA interventions to prevent overweight and obesity in SA children, especially for black African children and specifically among girls, who were less active during weekdays and weekend days.

#### 5.5.2.2 Subjectively measured PA

No single method is able to accurately quantify PA and the use of a combination of objective and subjective methods is therefore recommended.[30, 130] One of the disadvantages of using pedometers to measure PA includes the reactive changes in habitual activity behaviour.[163] To monitor the possibility of reactive changes in PA of participants in this study, the PAQ-C[130] was introduced as an alternative, subjective measure to assess PA before and after wearing the pedometer. In addition, the subjective measurement was intended to add further insight into the PA of participants.

The use of PAQs presents various limitations.[30, 36] Despite precautionary efforts to overcome these limitations, including the use of a population-appropriate and validated tool, interviewee assistance and training of the research assistant to provide interviewee support, the PAQ-C outcomes could not be applied to identify possible reactive changes in PA or provide further insight into the PA of the sample. In line with previous research,[30] this study identified that PA questionnaires lacked the precision to detect daily changes in PA.

Although the PAQ-C has been identified as a reliable subjective tool for the assessment of PA in international and SA populations,[29, 33, 128] the findings of the present study delivered contradictory results. A correlation analysis was performed to determine the relationship between the PAQ-C average (average between PAQ-C measured before and after wearing the pedometer) (subjective PA measurement) and average steps/day (objective PA measurement). However, the correlation coefficient failed to meet statistical significance in the total sample ($r = -0.02$; $P = 0.876$). Furthermore, a negative relationship ($r = -0.38$; $P = 0.020$) was observed in boys, confirming that subjective measurements did not correlate with objective measurements of PA and could not be used to identify reactive changes in PA while wearing the pedometer. In contrast, for white participants, a moderate correlation ($r = 0.37$; $P = 0.013$) was observed. This corresponds with previous research performed on white SA children of a similar age (7–9 years) attending school in Tshwane, reporting a moderate relationship ($r = 0.49$; $P < 0.001$) between steps/day (averaged over 7 days) and PAQ-C.[33]

The original English PAQ-C[130] and a previously developed translated Afrikaans version[33] were used for data collection. For most of the white participants, Afrikaans was their teaching medium as well as their first home language. Many of the black African participants attended an English medium school and therefore the English PAQ-C version was considered appropriate. Although the English communication skills of black African participants were considered sufficient, Sepedi or Setswana are the home languages spoken by the majority of black African families in Gauteng.[42] It is therefore possible that misinterpretation of PAQ-C questions due to a language barrier may explain the lower correlation ($r = 0.15$; $P = 2.99$) between the PAQ-C average and average steps/day observed in the black African population of this sample. Language barrier is considered a typical limitation of PA questionnaires[30] that may have influenced the outcomes of this study.

A more in-depth exploration of the individual PAQ-C questions was performed to identify whether a relationship existed between average steps/day and each PAQ-C question. However, no significant relationship was observed and no reasonable conclusion could be drawn from this analysis.

#### 5.5.2.3 Concurrent validity of PA measurements

Despite taking precautionary measures to overcome the limitations generally associated with PAQs (section 2.3.1.2), the PAQ-C lacked the sensitivity to monitor reactive changes in PA that related to pedometer measurements. The objectively measured average steps/day (step-count) was therefore used to further describe and discuss factors related to the PA of the sample.

#### 5.5.2.4 Factors related to objectively measured PA

**The influence of sex and age on PA**

The results of this study and the above discussion showed that across various studies, the PA of prepubertal girls is consistently lower than for boys. These results are also supported by two systematic reviews,[111, 132] including international as well as Sub-Saharan research, reporting that sex differences persist in children of all ages. In addition to sex, age has been identified as a possible predictor of PA in children. Although results are conflicting, both systematic reviews concluded that the effect of age only became significant during the adolescent years, with older children more likely to be less engaged in PA. This supports the results of the present study, since no significant correlation existed between step-count and age ($r = -0.02$; $P = 0.875$) and step-count remained relatively unchanged across sex categories and population groups after being adjusted for age.

**PA of population groups**

An international review[24] concluded that although the population group may be related to PA, conflicting results were reported. This may be explained by evidence that similar populations and ethnic groups tend to cluster in the same sociodemographic areas, and it may often not be possible to distinguish between the contributory role of SES versus population group.[24, 27] Previous SA studies[27, 28] indicated that white children were more engaged in PA than black African children and that a lower SES was associated with lower activity. However, these observations may have been influenced by cultural differences, since in SA black African populations often associate a higher body weight, especially among females, with health and wealth, and therefore tend to be less engaged in PA.[183] It should therefore be acknowledged that the lower PA of black African than white participants in this sample may have been influenced by cultural differences.

**The relationship between phenotype and PA**

When considering the influence of phenotypic characteristics on the PA of the total sample, no significant correlation was observed between PA and WFA z-score ($r = 0.09$; $P = 0.381$) and BMI-FA z-score ($r = -0.14$; $P = 0.185$) respectively. When the average step-count was adjusted for these variables, the values barely changed and the differences between sex categories and population groups remained significant. These results explain that differences in PA between sex categories and between populations groups exist, regardless of differences in body weight and BMI.

However, the lack of a significant correlation between PA and BMI-FA z-score observed in this study is not absolute. Although BMI is widely applied in research to determine associations between overweight or obesity and PA, it has the limitation of not differentiating between FM and FFM. Evidence suggests[198, 199] that regular PA may decrease FM, but at the same time, it may not necessarily increase FFM. Since FFM per kg contributes more to body weight than FM, the effect of PA on body weight is not constant. A perceived relationship between body weight and PA may therefore be affected by BC. In addition, BC between populations may vary, and it is therefore suggested to consider BC rather than BMI when investigating PA of different populations.[198]

A positive significant correlation was observed between step-count and HFA z-score ($r = 0.50$; $P < 0.001$) and FFM ($r = 0.43$; $P = 0.007$) respectively in boys, indicating that taller boys with more FFM have higher PA. Although a significant correlation existed between step-count and HFA z-score, the step-count for boys remained almost unchanged when adjusted for HFA z-score, showing that PA was not influenced by stature. In addition, the correlation observed between step-count and FFM, especially in black African boys, decreased when FFM was expressed per unit of height, i.e. FFMI. The observed correlation between PA and FFM could therefore be explained by an increased FFM related to a taller stature.

When adjusted for FFMI the difference in step-count between sexes decreased considerably. These findings support the above explanation that the higher FFM associated with a taller stature may partially explain the observed sex differences in PA. However, this only affects sex categories. Between population groups, the difference in step-count remained significant after being adjusted for FFMI.

Between step-count and FMI, a small, yet significant and negative, correlation ($r = 0.27$; $P = 0.043$) was observed for girls, indicating that their higher FMI was related to a lower average step-count (1371) for overweight/obese than for healthy weight participants. These results are not surprising since previous studies reported that a higher body weight of children was inversely related to PA levels.[27, 124, 198] A systematic review by Kelley et al.[199] concluded that regular PA significantly reduced the BMI-FA z-score of children (3 % reduction; $P = 0.02$) and a positive association between BMI and PA can be explained by insufficient PA. Furthermore, evidence suggests[198, 199] that regular PA may specifically be associated with lower FM, but it may not necessarily increase FFM. This was mirrored in the results of this study. This sample did not include enough partcipants who were overweight and obese to identify whether a higher BMI-FA z-score was related to PA. However, the higher FMI associated with the lower PA may indicate that children with a lower level of PA may be at risk of increased FM.

Nevertheless, when PA was adjusted for all available variables, the population differences remained. Differences in PA between population groups are therefore not related to differences in phenotypic characteristics.

## 5.6 THE RELATIONSHIP BETWEEN REE AND PA

Physical activity can affect REE in various ways. It is well known that an increase in PA affects metabolic processes, thereby increasing BMR and REE for up to 48 hours after an exercise session (EPOC).[37, 48] It is for this reason that REE measurement protocols require abstinence from PA beforehand.[48] Additionally, regular PA may result in muscle growth. Since FFM is related to REE, regular PA may indirectly increase REE. Apart from these influences of PA on REE, previous[114] yet limited research indicated the possibility of a long-lasting effect of PA on REE beyond the effect of EPOC. Furthermore, it has been proposed that these long-lasting effects of PA on REE may partially explain population differences in REE. Shook et al.[38] reported that a lower PA among African American than white American women resulted in lower fitness which partially explained a lower REE among African American women. Although higher PA is generally associated with higher levels of fitness[8] there is limited evidence to support an association between PA and REE.[8, 12, 38]

When considering the results of this study, the difference in step-count between population groups remained significant even after adjusted for FFM and FFMI. This indicates that the higher FFM of white participants was not associated with their higher PA. In addition, the REE remained almost the same across the sample and the population difference in REE remained significant, even when it was adjusted for daily step-count. It can therefore be concluded that the population difference in REE of this sample was not related to differences in PA.

## 5.7 STRENGTHS AND LIMITATIONS

Limitations to this study included the following:

- As a result of time restrictions, the data of children who did not achieve SS during IC measurement were excluded and a subsequent measurement was not provided.
- Participants from school A were measured at the University of Pretoria and not on their school premises. The unfamiliar setting may have caused participants to feel unsettled and may have influenced their achievement of SS, leading to the unnecessary exclusion of data.
- Parental self-report measures, instead of clinical assessments, were used to determine health and, thus, underlying conditions such as a common cold, attention deficit disorder or other illnesses of participants that may have affected REE.
- Cost-limitations necessitated the use of BIA instead of a gold standard measure such as DEXA for BC analysis and pedometers were used instead of accelerometry for the measurement of PA.
- An estimation equation was used to calculate FFM using BIA resistance values. Although numerous international equations are available to calculate FFM of children by using measured BIA reactance and resistance values, only one equation was suitable for both black African and white children. There were no validated equations available to estimate FFM of specifically SA children of various population groups.
- The use of different frequencies during BIA may improve the accuracy of BC assessments. However, available prediction equations to determine FFM of children from different populations were derived using a single-frequency resistance value measured at 50 Hz. Although octa-polar multifrequency BIA equipment was available and is considered superior to single-frequency BIA, a single frequency at 50 Hz had to be used to determine FFM with the available equation.
- The study recruited participants from a relatively homogenous SES; however, no statistical analysis was performed to determine possible

confounding effects of SES on PA. Although not statistically significant, the SES indicators were consistently lower in black African participants and may have influenced their PA.

- All the white participants were recruited from school A, whereas only black participants were recruited from school B. Even though precautionary measures were taken to prevent heterogeneity in the school built environment and SES of the sample, possible unobserved differences may have influenced differences in PA between population groups.
- The PAQ-C could not be used to monitor reactive changes in PA while wearing the pedometer.
- The PAQ-C was not translated in the home language of participants.

Nevertheless, the study included many strengths that may contribute to clinical practice and dietetics internationally and in SA:

- The study was the first known to investigate the REE of children in SA.
- The study represents two population groups in SA, white (for whom most prediction equations are developed) as well as black African populations.
- The measurement of REE is suggested in clinical practice to determine energy requirements, however this is not feasible in many SA settings and necessitates the use of prediction equations. The measurement of REE in SA children allowed for the performance of prediction equations generally used in SA to be evaluated, but no suitable equation was identified to determine the REE of specifically black African participants. This study indicated the need for the development of a population-specific prediction equation to accurately determine the energy requirements of SA children.
- Evidence-based measurement protocols to achieve SS during REE measurements of children are limited. The study contributes to existing recommendations for the achievement of SS during REE measurement of children.

- This is the first known study to investigate the relationship between REE and PA of children.
- The study provides a comprehensive description of a multitude of factors, within the study framework, related to REE and PA.
- SA children do not meet PA recommendations to maintain health. This study identified the need for population-specific PA intervention and recommendations for SA children.
- The study identified the need for a validated and reliable PAQ to be used across various population groups.

# CHAPTER 6: CONCLUDING SUMMARY

The following chapter provides a summary of the study by concluding the main findings with practical and clinical implications.

Increasing urbanisation has resulted in a worldwide PA and nutrition transition.(1) Children living in LMICs, including SA, have not escaped its effects.(111) An inappropriate diet along with insufficient PA, may increase the risk of developing overweight and obesity and the associated long-term health consequences of NCDs. Children with obesity are at risk of becoming adults with obesity. Additionally, many adults with obesity were not obese during childhood, yet still developed obesity later during life.(197) Children are our future generation and to break the cycle and improve future health, action is required to improve the PA and diets of all children.

The results of this study conform with previous national surveys,(4, 178) indicating that at least 8% and 3% of SA children are overweight or obese respectively, and girls and black African populations are disproportionately affected. It has been suggested that a lower REE among the African American population group may contribute to their increased risk of overweight and obesity.(6, 7, 11) However, some research has indicated that a lower REE in the black African population may be related to differences in BC compartments with less metabolically active muscle tissue.(18, 21, 86)

Nevertheless, multi-compartment BC analysis is not always feasible in many settings and, in SA, clinicians and researchers often rely on alternative methods to determine REE. Further investigation regarding possible variations in REE between SA population groups, regardless of the underlying reason, is therefore required to develop population-specific assessment methods for the accurate determination of energy requirements.

Studies on REE in Sub-Saharan black African populations are limited(12, 19, 20, 108) and to date, no known studies have investigated the REE of children in SA. The present study therefore introduced REE-related research among young children in SA, thereby contributing to the development of population-specific interventions to combat overweight and obesity.

Along with REE, PA-related energy expenditure contributes to an individual's energy requirements. Increasing PA during childhood provides an important means of maintaining a healthy weight into adulthood.[198, 199] Additionally, previous research has suggested[8, 38] a possible positive relationship between PA and REE that may explain individual differences in REE; however evidence is limited. Understanding the PA levels of children and exploring a possible relationship between PA and REE may therefore add some further insight into the prevalence of obesity that disproportionately affects various population groups. The study therefore determined the PA of participants and to explore its relationship with REE.

The results of the study indicate that the measured REE of black African children aged 6–9 years was lower than for their white counterparts. However, for further interpretation, factors related to REE were measured to determine REE adjusted for each measured confounding factor. Body composition, considered to have the greatest influence on REE in children,[9, 74, 76] was measured to determine FFM, FFMI, FM and FMI. In addition, other phenotypic confounding factors including BMI-FA z-score, WFA z-score and HFA z-score were considered. Both age and sex are known to influence REE in children[75, 76, 187] and the study was therefore designed to recruit only prepubertal children categorised according to sex categories, thereby eliminating the confounding effect of sex and age-related hormonal changes.

In line with previous research,[9, 74, 76] the strongest correlation in the total sample was observed between REE and FFM ($r = 0.45$; $P < 0.001$). For boys and for the white population group this correlation could be explained by a higher FFM associated with their taller stature. When REE was adjusted for FFM and HFA z-score respectively, population differences decreased, confirming that variations in FFM (along with a taller stature) may partially explain the observed population difference in REE. When REE was adjusted for FFM and FFMI respectively, differences in REE between sex categories changed slightly, but did not meet statistical significance ($P = 0.582$ and 0.549 respectively). Additionally, when adjusted for FM and FMI the difference in REE between sexes increased. This confirms that REE differences, although not significant, between boys and girls could be explained by differences in BC.

For black African participants only, FFM and FM, irrespective of height, were equally and positively related to REE ($r = 0.39$; $P = 0.006$ and $r = 0.39$; $P = 0.005$ respectively). In addition, the relationship between REE and the WFA z-score ($r = 0.56$; $P < 0.001$) and BMI-FA z-score ($r = 0.55$; $P < 0.001$) respectively was even stronger than that observed for FM and FFM. This was not mirrored in the white participants. It therefore appears that body weight and the absolute weight of FM and FFM may have contributed more to the REE of black African participants than in white participants.

Absolute weight and FFMI did not considerably contribute to the observed population differences in REE. Although variation in BMI and FMI may have somewhat contributed to the observed population differences, REE adjusted for BMI, FM and FMI remained significantly lower (all P-values < 0.001) for black African participants. Body weight, including the weight of FM, regardless of height differences, did not therefore completely explain the population differences in REE.

Since FFM and a taller stature were related to the higher REE of white participants, it was not surprising that the population differences declined when REE was adjusted for HFA z-score and FFM. Nevertheless, the REE of black African participants remained between 82 and 91 kcal/day (344 and 382 kJ/day) lower than for white counterparts and could be considered clinically significant.(110)

The number of participants in the overweight/obese category was insufficient to draw any reasonable conclusions, but the results of the present study concur with a previous study on prepubertal children.(9) The mean REE of participants who were overweight/obese (girls only) was higher than participants with a healthy weight (girls only), and the mean REE of black African girls remained consistently lower than their white counterparts across weight categories.

REE prediction equations are often used as an alternative method for calculating energy requirements. The performance of prediction equations typically used in SA was explored, however none of the equations performed well in estimating the REE across both sex categories and population groups and overestimated the REE of black African participants. For white participants only, the FAO/WHO/UNU(71) equation performed the best by estimating REE within 13 kcal/day (55 kJ/day) (LOA: -386; 349

kcal/day) and 18 kcal/day (76 kJ/day) (LOA: -517; 490 kcal/day) for girls and boys respectively. The results therefore support the suggestions of the FAO/WHO/UNU Expert committee[15] that a single equation cannot be used to accurately predict REE across sex categories and population groups. This emphasises the importance of population-specific nutrition assessments and the need for the development of methods to accurately determine the REE of children in Southern Africa.

Objective and subjective measurements of PA were taken to obtain an average daily step-count and activity score. The activity score was intended to add further insight into PA and identify possible reactive changes in PA associated with wearing a pedometer. However, due to the limitations generally associated with PAQ outcomes, the PAQ-C could not be used for its intended purpose. Consequently, step-count measurements were used to describe the PA of the sample.

The average step-count of black African participants was lower than for white participants, and for girls, it was lower than for boys. These differences persisted even after PA was adjusted for possible phenotypic confounding factors. None of the sub-groups met the minimum suggested daily step-count to meet the equivalent of the WHO recommendation[43] of 60 min of MVPA per day.

When considering the influence of phenotypic characteristics on PA, results were similar to the observations related to REE. A higher PA was related to FFM and a taller stature. However, when PA was adjusted for FFMI, sex differences decreased but population differences remained significant ($P < 0.001$).

The PA of the sample was inversely related to FM. Evidence suggests that regular PA can reduce BMI[199] and FM[198, 199] in children. The sample of the present study did not include enough overweight and obese participants to identify whether overweight/obesity was related to PA. However, the negative relationship between PA and FMI may indicate that children with a lower level of PA may be at risk of increased FM.

Finally, no significant correlation (P = 0.812) was observed between REE and PA in the sample and it can therefore be concluded that the population difference in REE in this sample was not related to differences in PA.

In conclusion, the results of the study indicate that the REE of 6–9-year-old black African children in SA is clinically and significantly lower than for their white counterparts, regardless of differences in phenotypic characteristics and PA. Population-specific prediction equations are therefore required to accurately estimate the energy requirements of black African children in SA. Furthermore, the PA of girls was lower than in boys, and in black African participants lower than in white participants. The PA of participating children did not meet the WHO minimum PA requirement to maintain a healthy body weight for the prevention of overweight and obesity, and these children may be at risk of developing NCDs later in life. Therefore, the results of this study emphasise the need for PA interventions to address the PA transition, which may be specifically applicable to black African children in an urban setting.

# REFERENCES

1. World Health Organization. *Obesity and overweight 2020* [homepage on the internet]. 2020 [updated 2020 April; cited 2020 June]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

2. World Health Organization. *Assessing and managing children at primary health-care facilities to prevent overweight and obesity in the context of the double burden of malnutrition*. Geneva: WHO; 2017. Available from: http://who.int/entity/nutrition/publications/guidelines/children-primaryhealthcare-obesity-dbm/en/.

3. Caprio S, Daniels SR, Drewnowski A, Kaufman FR, Palinkas LA, Rosenbloom AL, Schwimmer JB. Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment: a consensus statement of Shaping America's Health and the Obesity Society. *Diabetes Care*. 2008;31(11): 2211–2221.

4. Shisana O, Labadarios D, Rehle T, Simbayi I, Zuma K, Dhansay A, et al. *South African National Health and Nutrition Examination Survey, 2012* (SANHANES-1). Cape Town; 2014.

5. Human Sciences Research Council. *Strategic plan for the prevention and control of non-communicable diseases 2013–2017.* Pretoria, South Africa: HSRC; 2013. Document No.: RP06/2013.

6. De Lany JP, Bray GA, Harsha DW, Volaufova J. Energy expenditure in preadolescent African American and white boys and girls: the Baton Rouge Children's Study. *Am J Clin Nutr.* 2002;75(4): 705–713.

7. Jakicic JM, Wing RR. Differences in resting energy expenditure in African-American vs Caucasian overweight females. *Int J Obes*. 1998;22(3): 236–242.

8. Johnson MS, Figueroa-Colon R, Herd SL, Fields DA, Sun M, Hunter GR, Goran MI. Aerobic fitness, not energy expenditure, influences subsequent increase in adiposity in black and white children. *Pediatrics*. 2000;106(4): e50.

9. Kaplan AS, Zemel ZB, Stallings VA. Differences in resting energy expenditure in prepubertal black children and white children. *J Pediatr.* 1996;129(5): 643–647.

10. McDuffie JR, Adler-Wailes DC, Elberg J, Steinberg EN, Fallon EM, Tershakovec AM, et al. Prediction equations for resting energy expenditure in overweight and normal-weight black and white children. *Am J Clin Nutr*. 2004;80(2): 365–373.

11. Muller MJ, Geisler C. From the past to future: from energy expenditure to energy intake to energy expenditure. *Eur J Clin Nutr*. 2017;71(3): 358–364.

12. Adzika Nsatimba PA, Pathak K, Soares MJ. Ethnic differences in resting metabolic rate, respiratory quotient and body temperature: a comparison of Africans and European Australians. *Eur J Nutr.* 2016;55(5): 1831–1838.

13. Manini TM, Patel KV, Bauer DC, Ziv E, Schoeller DA, Mackey DC, et al. European ancestry and resting metabolic rate in older African Americans. *Eur J Clin Nutr.* 2011;65(6): 663–667.

14. McGuire M, Beerman KA. *Nutritional sciences: from fundamentals to food*. California: Wadsworth, Cengage Learning; 2012.

15. Food and Agriculture Organization. *Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation.* Rome: FAO; 2001. Available from: http://www.fao.org/3/y5686e/y5686e00.htm.

16. Henry CJK. Basal metabolic rate studies in humans: measurement and development of new equations. *Public Health Nutr*. 2005;8(7A): 1133–1152.

17. Ravussin E, Lillioja S, Anderson TE, Christin L, Bogardus C. Determinants of 24-hour energy expenditure in man. Methods and results using a respiratory chamber. *J Clin Invest*. 1986;78(6): 1568–1578.

18. Reneau J, Obi B, Moosreiner A, Kidambi S. Do we need race-specific resting metabolic rate prediction equations? *Nutr Diabetes*. 2019;9(1): 21–28.

19. Olivier N, Wenhold FA, Becker P. Resting energy expenditure of black overweight women in South Africa is lower than of white women. *Ann Nutr Metab*. 2016;69(1): 24–30.

20. Wenhold FAM, Pretorius A, Piderit M, Becker PJ. Race/ethnicity differences in resting energy expenditure of South African men and women. Poster presentation at: 27th Biennial Congress of the Nutrition Society of South Africa; 2018 Sept 5–7; Johannesburg, South Africa.

21. Broadney MM, Shareef F, Marwitz SE, Brady SM, Yanovski SZ, DeLany JP, et al. Evaluating the contribution of differences in lean mass compartments for resting energy expenditure in African American and Caucasian American children. *Pediatric Obesity.* 2018;13(7): 413–420.

22. Morrison JA, Shumei SG, Specker B, Chumlea WMC, Yanovski SZ, Yanovski JA. Assessing the body composition of 6-17-year-old black and white girls in field studies. *Am J Hum Biol.* 2001;13(2): 249–254.

23. Sun M, Gower BA, Nagy TR, Trowbridge CA, Dezenberg C, Goran MI. Total, resting, and activity-related energy expenditures are similar in Caucasian and African-American children. *Am J Physiol.* 1998;274(2): E232–237.

24. Eyre EL, Duncan MJ. The impact of ethnicity on objectively measured physical activity in children. *ISRN Obes*. 2013 Jan 22;2013: 757431.

25. World Health Organization. *Ambition and Action in nutrition 2016-2025*. Geneva: WHO; 2017. Available from: https://www.who.int/publications/i/item/9789241512435.

26. Draper CE, Tomaz SA, Bassett SH, Burnett C, Christie CJ, Cozett C, et al. Results from South Africa's 2018 Report Card on Physical Activity for Children and Youth. *J Phys Act Health.* 2018;15(S2): S406–4S8.

27. McVeigh J, Meiring R. Physical activity and sedentary behavior in an ethnically diverse group of South african school children. *J Sports Sci Med.* 2014;13(2): 371–378.

28. McVeigh JA, Norris SA, de Wet T. The relationship between socio-economic status and physical activity patterns in South African children. *Acta Paediatr*. 2004;93(7): 982–988.

29. Van Biljon A, McKune AJ, DuBose KD, Kolanisi U, Semple SJ. Physical activity levels in urban-based South African learners: A cross-sectional study of 7 348 participants. *S Afr Med J.* 2018;108(2): 126–131.

30. Hills AP, Mokhtar N, Byrne NM. Assessment of physical activity and energy expenditure: an overview of objective measures. *Front Nutr*. 2014;1(5): 1–16.

31. Cameron C, Craig CL, Bauman A, Tudor-Locke C. CANPLAY study: Secular trends in steps/day amongst 5–19 year-old Canadians between 2005 and 2014. *Prev Med.* 2016 May;86: 28–33.

32. Tudor-Locke C, Hatano Y, Pangrazi RP, Kang M. Revisiting "how many steps are enough?". *Med Sci Sports Exerc.* 2008;40(7 Suppl): S537–543.

33. Malan GF, Nolte, K. Measuring physical activity in South African Grade 2 and 3 learners: A self-report questionnaire versus pedometer testing. *South African Journal for Research in Sport, Physical Education and Recreation.* 2017;39(3): 79–91.

34. McVeigh JA, Norris SA. Criterion validity and test-retest reliability of a physical activity questionnaire in South African primary school-aged children. *S Afr J SM.* 2012;24(2): 43–48.

35. Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of physical activity in youth. *Journal of Applied Physiology.* 2008;105(3): 977–987.

36. Ellery CV, Weiler HA, Hazell TJ. Physical activity assessment tools for use in overweight and obese children. *Int J Obes* (Lond). 2014;38(1): 1–10.

37. Speakman JR, Selman C. Physical activity and resting metabolic rate. *Proc Nutr Soc.* 2003;62(3): 621–634.

38. Shook RP, Hand GA, Wang X, Paluch AE, Moran R, Hebert JR, et al. Low fitness partially explains resting metabolic rate differences between African American and white women. *Am J Med.* 2014;127(5): 436–442.

39. Horlick M, Arpadi SM, Bethel J, Wang J, Moye J, Jr., Cuff P, et al. Bioelectrical impedance analysis models for prediction of total body water and fat-free mass in healthy and HIV-infected children and adolescents. *Am J Clin Nutr.* 2002;76(5): 991–999.

40. Institute of Medicine. *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids*. Washington, D.C.: The National Academies Press; 2005.

41. Lee C. "Race" and "ethnicity" in biomedical research: how do scientists construct and explain differences in health? *Soc Sci Med.* 2009;68(6): 1183–1190.

42. Statistics South Africa. Census 2011. Pretoria: Statistics South Africa; 2012. Document No.: 03-01-41. Available from: http://www.statssa.gov.za/.

43. World Health Organization. *A guide for population-based approaches to increasing levels of physical activity: Implementation of the WHO global strategy on diet, physical activity and health*. Geneva: WHO; 2007. Available from: https://apps.who.int/iris/handle/10665/43612https://www.who.int/dietphysicalactivity/physical-activity-promotion-2007.pdf.

44. Roman-Vinas B, Chaput JP, Katzmarzyk PT, Fogelholm M, Lambert EV, Maher C, et al. Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. *Int J Behav Nutr Phys Act*. 2016;13(1): 123.

45. Broyles ST, Drazba KT, Church TS, Chaput JP, Fogelholm M, Hu G, et al. Development and reliability of an audit tool to assess the school physical activity environment across 12 countries. *Int J Obes.* 2015;5(Suppl 2): S36–42.

46. Statistics South Africa. Community Survey Household Questionnaire. South Africa: Statistics South Africa; 2007. Document No.: P03101/P031012018. Available from: http://www.statssa.gov.za/.

47. Encyclopaedia Britannica [homepage on the intrenet]. 2020 [updated 2020; cited 2020 August]. Available from: https://www.britannica.com/topic/Encyclopaedia-Britannica-English-language-reference-work/

48. Fullmer S, Benson-Davies S, Earthman CP, Frankenfield DC, Gradwell E, Lee PS, et al. Evidence analysis library review of best practices for performing indirect calorimetry in healthy and non-critically ill individuals. *J Acad Nutr Diet.* 2015;115(9): 1417–1446 e2.

49. Cosmed. Cosmed Quark RMR [homepage on the internet]. 2020. [Updated 2020; cited 2020 April]. Available from: https://www.cosmed.com/en/products/indirect-calorimetry/quark-rmr.

50. World Health Organization. Growth reference data for 5-19 years: World Health Organization [homepage on the internet]. 2007 [updated 2020; cited 2020 May 8]. Available from: https://www.who.int/growthref/en/.

51. Subar AF, Freedman LS, Tooze JA, Kirkpatrick SI, Boushey C, Neuhouser ML, et al. Addressing current criticism regarding the value of self-report dietary data. *J Nutr.* 2015;145(12): 2639–2645.

52. Lam YY, Ravussin E. Indirect calorimetry: an indispensable tool to understand and predict obesity. *European Journal of Clinical Nutrition*. 2017;71(3): 318–322.

53. Salvini M, Gall S, Müller I, Walter C, du Randt R, Steinmann P, et al. Physical activity and health-related quality of life among schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa. *Quality of Life Research*. 2017;27(1): 205–216.

54. Kenny GP, Notley SR, Gagnon D. Direct calorimetry: a brief historical review of its use in the study of human metabolism and thermoregulation. *Eur J Appl Physiol.* 2017;117(9): 1765–1785.

55. Achamrah N, Delsoglio M, De Waele E, Berger MM, Pichard C. Indirect calorimetry: The 6 main issues [published online ahead of print, 2020 Jul 2]. *Clin Nutr.* 2020;S0261-5614(20)30335-6.

56. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol.* 1949;109(1-2): 1–9.

57. Volp ACO, de Oliveira FCE, Alves RDM, Esteves EA, Bressan J. Energy expenditure: components and evaluation methods. *Nutr Hosp.* 2011;26(3): 430–40.

58. Levine JA. Measurement of energy expenditure. *Public Health Nutr*. 2005;8(7A): 1123–1132.

59. Oshima T, Delsoglio M, Dupertuis YM, Singer P, De Waele E, Veraar C, et al. The clinical evaluation of the new indirect calorimeter developed by the ICALIC project. *Clin Nutr*. 2020;39(10): 3105–3111.

60. Irving CJ, Eggett DL, Fullmer S. Comparing Steady state to time interval and non-steady state measurements of resting metabolic rate. *Nutr Clin Pract*. 2017;32(1): 77–83.

61. Popp CJ, Butler M, Curran M, Illiano P, Sevick MA, St-Jules DE. Evaluating steady-state resting energy expenditure using indirect calorimetry in adults with overweight and obesity. *Clinical Nutrition*. 2020;39(7): 2220–2226.

62. McClave SA, Spain DA, Skolnick, JL, Lowen CC, Kleber MJ, Wickerham PS, Vogt JR, Looney SW. Achievement of steady state optimizes results when performing indirect calorimetry. *J Parenter Enteral Nutr.* 2003;27(1): 16–20.

63. Mellecker RR, McManus AM. Measurement of resting energy expenditure in healthy children. *J Parenter Enteral Nutr.* 2009;33(6): 640–645.

64. Carpenter A, Pencharz P, Mouzaki M. Accurate estimation of energy requirements of young patients. J *Pediatr Gastroenterol Nutr.* 2015;60(1) :4–10.

65. Jésus P, Achamrah N, Grigioni S, Charles J, Rimbert A, Folope V, et al. Validity of predictive equations for resting energy expenditure according to the body

mass index in a population of 1726 patients followed in a Nutrition Unit. *Clinical Nutrition*. 2015;34(3): 529–535.

66. Harris JA, Benedict FG. *A biometric study of basal metabolism in man*. Washington, D.C.: Carnegie Institution of Washington; 1919.

67. Compher C, Frankenfield D, Keim N, Roth-Yousey L. Evidence analysis working G. Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *J Am Diet Assoc.* 2006;106(6): 881–903.

68. Roza AM, Shizgal HM. The Harris Benedict equation reevaluated: resting energy requirements and the body cell mass. *Am J Clin Nutr.* 1984;40(1): 168–182.

69. Penagini F, Borsani B, Bosetti A, Mameli C, Dilillo D, Ramponi G, et al. Resting energy expenditure in children with cerebral palsy: Accuracy of available prediction formulae and development of a population-specific formula. *Clin Nutr ESPEN*. 2018 Jun;25: 44–49.

70. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. *Human Nutrition: Clinical Nutrition.* 1985;39C(Suppl. 1): 5–41.

71. FAO/WHO/UNU. *Energy and protein requirements*. Geneva: World Health Organisation; 1985. Available form: http://www.fao.org/3/aa040e/aa040e00.htm.

72. Acar-Tek N, Ağagündüz D, Çelik B, Bozbulut R. Estimation of resting energy expenditure: validation of previous and new predictive equations in obese children and adolescents. *J Am Coll Nutr.* 2017;36(6): 470–480.

73. Maffeis C, Schutz Y, Micciolo R, Zoccante L, Pinelli L. Resting metabolic rate in six- to ten-year-old obese and nonobese children. *J Pediatr.* 1993;122(4): 556–562.

74. Goran MI, Kaskoun M, Johnson R. Determinants of resting energy expenditure in young children. *J Pediatr.* 1994;125(3): 362–267.

75. Lazzer S, Bedogni G, Lafortuna CL, Marazzi N, Busti C, Galli R, et al. Relationship between basal metabolic rate, gender, age, and body composition in 8,780 white obese subjects. *Obesity* (Silver Spring). 2010;18(1): 71–78.

76. Herrmann SD, McMurray RG, Kim Y, Willis EA, Kang M, McCurdy T. The influence of physical characteristics on the resting energy expenditure of youth: A meta-analysis. *Am J Hum Biol.* 2017;29(3): 1–12.

77. Schulze TG, McMahon FJ. Defining the phenotype in human genetic studies: forward genetics and reverse phenotyping. *Hum Hered.* 2004;58(3-4): 131–138.

78. Ghosh S, Bouchard C. Convergence between biological, behavioural and genetic determinants of obesity. *Nature Reviews Genetics*. 2017;18(12): 731–748.

79. Payab M, Qorbani M, Shahbal N, Motlagh ME, Hasani-Ranjbar S, Zahedi H, et al. Association of anthropometric indices with metabolic phenotypes of obesity in children and adolescents: the CASPIAN-V Study. *Front Endocrinol*. 2019 Dec;10: 786–791.

80. Heymsfield SB, Thomas D, Bosy-Westphal A, Shen W, Peterson CM, Muller MJ. Evolving concepts on adjusting human resting energy expenditure measurements for body size. *Obes Rev.* 2012;13(11): 1001–1014.

81. Lee R, Nieman D. *Nutritional assessment:* 6th ed: McGraw-Hill Higher Education; 2012.

82. De Onis M. Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization.* 2007;85(09): 660–667.

83. Maynard LM, Wisemandle W, Roche AF, Chumlea C, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. *Pediatrics*. 2001;107(2): 344–350.

84. Griffiths PL, Rousham EK, Norris SA, Pettifor JM, Cameron N. Socio-economic status and body composition outcomes in urban South African children. *Arch Dis Child.* 2008;93(10): 862–867.

85. Trowbridge CA, Gower BA, Nagy TR, Hunter GR, Treuth MS, Goran MI. Maximal aerobic capacity in African-American and Caucasian prepubertal children. *Am J Physiol.* 1997;273(4): E809–814.

86. Gallagher D, Albu J, He Q, Heshka S, Boxt L, Krasnow N, et al. Small organs with a high metabolic rate explain lower resting energy expenditure in African American than in white adults. *Am J Clin Nutr.* 2006;83(5): 1062–1067.

87. Muller MJ, Bosy-Westphal A, Kutzner D, Heller M. Metabolically active components of fat-free mass and resting energy expenditure in humans: recent lessons from imaging technologies. *Obes Rev.* 2002;3(2): 113–122.

88. Müller MJ, Wang Z, Heymsfield SB, Schautz B, Bosy-Westphal A. Advances in the understanding of specific metabolic rates of major organs and tissues in humans. *Curr Opin Clin Nutr Metab Care.* 2013;16(5): 501–508.

89. Kyle UG, Earthman CP, Pichard C, Coss-Bu JA. Body composition during growth in children: limitations and perspectives of bioelectrical impedance analysis. *Eur J Clin Nutr.* 2015;69(12): 1298–1305.

90. Brantlov S, Ward LC, Jodal L, Rittig S, Lange A. Critical factors and their impact on bioelectrical impedance analysis in children: a review. *J Med Eng Technol*. 2017;41(1): 22–35.

91. Wang L, Hui SS, Wong SH. Validity of bioelectrical impedance measurement in predicting fat-free mass of Chinese children and adolescents. *Med Sci Monit.* 2014 Nov; 20: 2298–2310.

92. Kriemler S, Puder J, Zähner L, Roth R, Braun-Fahrländer C, Bedogni G. Cross-validation of bioelectrical impedance analyis for the assessment of body composition in a representative sample of 6- to 13-year-old chilrden. *Eur J Clin Nutr*. 2009;63(5): 619–626.

93. Chula de Castro JA, Lima TR, Silva DAS. Body composition estimation in children and adolescents by bioelectrical impedance analysis: A systematic review. *J Bodyw Mov The*r. 2018;22(1): 134–146.

94. Shypailo RJ, Wong WW. Fat and fat-free mass index references in children and young adults: assessments along racial and ethnic lines. *Am J Clin Nutr.* 2020;112(3): 566–575.

95. Wells JC. A critique of the expression of paediatric body composition data. *Arch Dis Child.* 2001;85(1): 67–72.

96. Wells JC, Cole TJ, steam As. Adjustment of fat-free mass and fat mass for height in children aged 8 y. *Int J Obes Relat Metab Disord*. 2002;26(7): 947–952.

97. Weber DR, Moore RH, Leonard MB, Zemel BS. Fat and lean BMI reference curves in children and adolescents and their utility in identifying excess adiposity compared with BMI and percentage body fat. *Am J Clin Nutr.* 2013;98(1): 49–56.

98. Wells JC, Williams JE, Chomtho S, Darch T, Grijalva-Eternod C, Kennedy K, et al. Body-composition reference data for simple and reference techniques and a 4-component model: a new UK reference child. *Am J Clin Nutr*. 2012;96(6): 1316–1326.

99. Kindig D, Stoddart G. What is population health? *Am J Public Health.* 2003;93(3): 380–383.

100. Ribeiro TVC, Ferreira LB. Description of color/race in Brazilian biomedical research. *Sao Paulo Med J*. 2012;130(2): 115–118.

101. Wells JCK, Davies PSW, Fewtrell MS, Cole TJ. Body composition reference charts for UK infants and children aged 6 weeks to 5 years based on measurement of total body water by isotope dilution. *Eur J Clin Nutr.* 2020;74(1): 141–148.

102. Kon ZR, Lackan N. Ethnic Disparities in access to care in post-apartheid South Africa. *American Journal of Public Health*. 2008;98(12): 2272–2277.

103. McLaren ZM, Ardington C, Leibbrandt M. Distance decay and persistent health care disparities in South Africa. *BMC Health Serv Res*. 2014 Nov;14: 541.

104. Oosthuizen M. R*acial inequality and demographic change in South Africa: impact on economic development. Southern Africa – Towards inclusive economic development; 2019.* Document No.: 5/19.

105. Statitsic South Africa SS. Census questionnaire [homepage on the internet]. c2018 [updated 2011; cited 2018 Oct 3]. Available from: http://www.statssa.gov.za.

106. Gannon B, DiPietro L, Poehlman ET. Do African Americans have lower energy expenditure than Caucasians? I*nt J Obes Relat Metab Disord*. 2000;24(1): 4–13.

107. Luke A, Dugas L, Kramer H. Ethnicity, energy expenditure and obesity: are the observed black/white differences meaningful? *Curr Opin Endocrinol Diabetes Obes.* 2007;14(5): 370–373.

108. Dugas LR, Cohen R, Carstens MT, Schoffelen PF, Luke A, Durazo-Arvizu RA, et al. Total daily energy expenditure in black and white, lean and obese South African women. *Eur J Clin Nutr.* 2009;63(5): 667–673.

109. Tershakovec AM, Kuppler KM, Zemel B, Stallings VA. Age, sex, ethnicity, body composition, and resting energy expenditure of obese African American and white children and adolescents. Am J Clin Nutr. 2002;75(5): 867–871.

110. Hill JO, Wyatt HR, Reed GW, Peters JC. Obesity and the environment: where do we go from here? *Science*. 2003;299(5608): 853–855.

111. Muthuri S, Wachira L-J, Leblanc A, Francis C, Sampson M, Onywera V, et al. Temporal trends and correlates of physical activity, sedentary behaviour, and physical fitness among school-aged children in Sub-Saharan Africa: A systematic review. *Int J Environ Res.* 2014;11(3): 3327–3359.

112. LaForgia J, Withers RT, Gore CJ. Effects of exercise intensity and duration on the excess post-exercise oxygen consumption. *J Sports Sci.* 2006;24(12): 1247–1264.

113. Frankenfield DC, Coleman A. Recovery to resting metabolic state after walking. *J Am Diet Assoc.* 2009;109(11): 1914–1916.

114. Gilliat-Wimberly M, Manore MM, Woolf K, Swan PD, Carroll SS. Effects of habitual physical activity on the resting metabolic rates and body compositions of women aged 35 to 50 years. *J Am Diet Assoc.* 2001;101(10): 1181–1188.

115. Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of physical activity in youth. *J Appl Physiol.* 2008;105(3): 977–987.

116. Sardinha LB, Judice PB. Usefulness of motion sensors to estimate energy expenditure in children and adults: a narrative review of studies using DLW. *Eur J Clin Nutr.* 2017;71(3): 331–339.

117. Biddle SJ, Gorely T, Pearson N, Bull FC. An assessment of self-reported physical activity instruments in young people for population surveillance: Project ALPHA. *Int J Behav Nutr Phys Act.* 2011;8: 1.

118. Clemes SA, Biddle SJ. The use of pedometers for monitoring physical activity in children and adolescents: measurement considerations. *J Phys Act Health*. 2013;10(2): 249–262.

119. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. *Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009.* Canadian Health Measures Survey. Canada: Statistics Canada; 2011 January 2011. Document No.:82-003-X.

120. Bassett DR, Jr., Toth LP, LaMunion SR, Crouter SE. Step counting: a review of measurement considerations and health-related applications. *Sports Med.* 2017;47(7): 1303–1315.

121. Craig CL, Cameron C, Griffiths JM, Tudor-Locke C. Descriptive epidemiology of youth pedometer-determined physical activity: CANPLAY. *Med Sci Sports Exerc.* 2010;42(9): 1639–1643.

122. Le Masurier GC, Tudor-Locke C. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc.* 2003;35(5): 867–871.

123. Colley RC, Carson V, Garriguet D, Janssen I, Roberts KC, Tremblay MS. Physical activity of Canadian children and youth, 2007 to 2015. *Health Rep*. 2017;28(10): 8–16.

124. Fu Y, Burns RD, Brusseau TA, Zhang P, Constantino N. Influence of meeting weekday and weekend step count recommendations on weight status in children [published online ahead of print, 2020 Nov 10]. *J Sports Sci.* 2020; 1–7.

125. Vincent SD, Pangrazi RP, Raustorp A, Tomson LM, Cuddihy TF. Activity levels and body mass index of children in the United States, Sweden, and Australia. *Med Sci Sports Exerc.* 2003;35(8): 1367–1373.

126. Troiano RP, Pettee Gabriel KK, Welk GJ, Owen N, Sternfeld B. Reported physical activity and sedentary behavior: why do you ask? *J Phys Act Health.* 2012;9 Suppl 1: S68–75.

127. Benitez-Porres J, Lopez-Fernandez I, Raya JF, Alvarez Carnero S, Alvero-Cruz JR, Alvarez Carnero E. Reliability and validity of the PAQ-C questionnaire to assess physical activity in children. J *Sch Health.* 2016;86(9): 677–685.

128. Kowalski KC, Crocker PR, Faulkner RA. Validation of the physical activity questionnaire for older children. *Pediatr Exerc Sci.* 1997;9(2): 174–186.

129. Moore JB, Hanes JC, Jr., Barbeau P, Gutin B, Trevino RP, Yin Z. Validation of the physical activity questionnaire for older children in children of different races. *Pediatr Exerc Sci.* 2007;19(1): 6–19.

130. Kowalski KC CP, Donen RM. The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual. Saskatoon, Canada: University of Saskatchewan, Kinesiology Co; August 2004: 1–38.

131. Hesketh KR, Lakshman R, van Sluijs EMF. Barriers and facilitators to young children's physical activity and sedentary behaviour: a systematic review and synthesis of qualitative literature. *Obesity Reviews*. 2017;18(9): 987–1017.

132. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Sci Sports Exerc.* 2000;32(5): 963–75.

133. Gray WN, Janicke DM, Ingerski LM, Silverstein JH. The impact of peer victimization, parent distress and child depression on barrier formation and physical activity in overweight youth. *J Dev Behav Pediatr.* 2008;29(1): 26–33.

134. Pulido R, Banks C, Ragan K, Pang D, Blake JJ, McKyer EL. The impact of school bullying on physical activity in overweight youth: Exploring race and ethnic differences. *J Sch Health.* 2019;89(4): 319–327.

135. Micklesfield LK, Lambert EV, Hume DJ, Chantler S, Pienaar PR, Dickie K, et al. Socio-cultural, environmental and behavioural determinants of obesity in black South African women. *Cardiovasc J Afr.* 2013;24(9-10): 369–375.

136. Joubert G, Ehrlich R. *Epidemiology: A research manual for South Africa.* 3rd ed. Southern Africa: Oxford University Press; 2008.

137. Margetts BM, Nelson M. *Design concepts in nutritional epidemiology.* 2nd ed. Oxford, Great Britain: Oxford University Press; 2006.

138. Department of Basic Education. Department of Basic Education quintile system 2019 [homepage on the internet] c2020 [updated 2019; cited 2020] Available from: https://www.education.gov.za.

139. Pretorius DM. Private schools in South African legal history. *Fundamina*. 2019;25(2): 94–134.

140. Map of City of Tshwane. Map data 2020 [updated 2020; cited 2020] Available from: http//www.google.com/maps.

141. Chawla NT, T. Effectiveness of school built environment on physical activity in children: a systematic review. *J Health Sci.* 2014;23(4): 739–752.

142. Zaltauske V, Petrauskiene A. Associations between built environment and physical activity of 7–8-year-old children. Cross-sectional results from the Lithuanian COSI study. *Medicina* (Kaunas). 2016;52(6): 366–371.

143. Turner K, Foster C, Allender S, Plugge E. A systematic review of how researchers characterize the school environment in determining its effect on student obesity. *BMC Obesity*. 2015;2(1): 13.

144. Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF. Measuring the built environment for physical activity. *Am J Prev Med*. 2009;36(4): S99–S123.

145. Statistics South Africa. *Poverty trends in South Africa: An examination of absolute poverty between 2006 and 2015.* Pretoria: Statistics South Africa; 2017 2017. Report No.: 03-10-06.

146. Rhodes B, McKenzie T. To what extent does socio-economic status still afffect household access to water and sanitation services in South Africa. South Africa: Economic Research Southern Africa; 2018 March 2018. Document No.: 738.

147. Africa SS. *Living conditions of households in South Africa: An analysis of households expenditure and income data using the LCS 2014/2015.* Statistics South Africa; 2017 27 January 2017. Document No.: P0310 (2015). Available from: http://www.statssa.gov.za.

148. Seca Science Center S. Seca Science Center Deutschland [homepage on the internet]. 2020 [updated 2020; cited 2020 June 6]. Available from: https://science.seca.com/.

149. Delta Surgical [homepage on the internet]. 2019 [updated 2019; cited 2020 June 6] Available from: http://deltasurgical.co.za.

150. Ashcraft CM, Frankenfield DC. Validity test of a new open-circuit indirect calorimeter. *JPEN J Parenter Enteral Nutr*. 2015;39(6): 738–742.

151. Kaviani S, Schoeller DA, Ravussin E, Melanson EL, Henes ST, Dugas LR, et al. Determining the accuracy and reliability of indirect calorimeters utilizing the methanol combustion technique. *Nutr Clin Pract.* 2018;33(2): 206–216.

152. Graf S, Karsegard VL, Viatte V, Heidegger CP, Fleury Y, Pichard C, et al. Evaluation of three indirect calorimetry devices in mechanically ventilated patients: which device compares best with the Deltatrac? A prospective observational study. *Clin Nutr.* 2015;34(1): 60–65.

153. Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity

Questionnaire for Older Children. *Med Sci Sports Exerc.* 1997;29(10): 1344–1349.

154. Janz KF, Lutuchy EM, Wenthe P, Levy SM. Measuring activity in children and adolescents using self-report: PAQ-C and PAQ-A. *Med Sci Sports Exerc*. 2008;40(4): 767–772.

155. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey (NHANES): Anthropometry procedures manual. United States of America: Centers for Disease Control and Prevention; 2017 January 2017.

156. Jackson DM, Pace L, Speakman JR. The measurement of resting metabolic rate in preschool children. *Obesity* (Silver Spring). 2007;15(8): 1930–1932.

157. Snell B, Fullmer S, Eggett DL. Reading and listening to music increase resting energy expenditure during an indirect calorimetry test. *J Acad Nutr Diet.* 2014;114(12): 1939–1942.

158. Draper C, Basset S, de Villiers A, Lambert EV, Group HW. Results from South Africa's 2014 report card on physical activity for children and youth. *J Phys Act Health*. 2014;11 Suppl 1: S98–104.

159. Scott JJ, Morgan PJ, Plotnikoff RC, Trost SG, Lubans DR. Adolescent pedometer protocols: examining reactivity, tampering and participants' perceptions. *J Sports Sci.* 2014;32(2): 183–190.

160. Lubans DR, Plotnikoff RC, Miller A, Scott JJ, Thompson D, Tudor-Locke C. Using pedometers for measuring and increasing physical activity in children and adolescents. *Am J Lifestyle Med*. 2014;9(6): 418–427.

161. Lubans DR, Morgan PJ, Tudor-Locke C. A systematic review of studies using pedometers to promote physical activity among youth. *Prev Med.* 2009;48(4): 307–315.

162. Rowe DA, Mahar, MT, Raedeke, TD, Lore J. Measuring physical activity in children wih pedometers: Reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci.* 2004;16(4): 343–354.

163. Vincent SD, Pangrazi RP. Does reactivity exist in children when measuring activity levels with pedometers? *Pediatr Exerc Sci*. 2002;14(1): 56–63.

164. Duncan JS, Schofield G, Duncan EK, Hinckson EA. Effects of age, walking speed, and body composition on pedometer accuracy in children. *Res Q Exerc Sport.* 2007;78(5): 420–428.

165. Piccoli A, Rossi B, Pillon L, Bucciante G. A new method for monitoring body fluid variation by bioimpedance analysis: the RXc graph. *Kidney Int.* 1994;46(2): 534–539.

166. Roza AM,Shizgal HM. The Harris Benedict equation reevaluated: resting energy requirements and the body cells. *Am J Clin Nutr*. 1984;40(1): 168–182.

167. Butte NF, Wong WW, Hopkinson JM, Heinz CJ, Mehta NR, Smith EO. Energy requirements derived from total energy expenditure and energy deposition during the first 2 y of life. Am J Clin Nutr. 2000;72(6): 1558–1569.

168. Cheng HL, Amatoury M, Steinbeck K. Energy expenditure and intake during puberty in healthy nonobese adolescents: a systematic review. *Am J Clin Nutr*. 2016;104(4): 1061–1074.

169. Lundeen EA, Norris SA, Martorell R, Suchdev PS, Mehta NK, Richter LM, et al. Early life growth predicts pubertal development in South African adolescents. *J Nutr.* 2016;146(3): 622–629.

170. Riva M, Gauvin L, Apparicio P, Brodeur JM. Disentangling the relative influence of built and socioeconomic environments on walking: the contribution of areas homogeneous along exposures of interest. *Soc Sci Med*. 2009;69(9): 1296–1305.

171. Sterdt E, Liersch S, Walter U. Correlates of physical activity of children and adolescents: A systematic review of reviews. *Health Educ J.* 2013;73(1): 72–89.

172. Kwan MP. The limits of the neighborhood effect: Contextual uncertainties in geographic, environmental health, and social science research. *Ann Am Assoc Geogr.* 2018;108(6): 1482–1490.

173. Uys M, Bassett S, Draper CE, Micklesfield L, Monyeki A, de Villiers A, Lambert EV. Results from South Africa's 2016 report card on physical activity for children and youth. *J Phys Act Health.* 2016;13(11 Suppl 2): S265–S273.

174. American Psychological Association. Report of the APA task force on socioeconomic status. Washington, DC.: American Psychological Association; 2007. [Available form http://www.apa.org/pi].

175. Schuz B. Socio-economic status and theories of health behaviour: Time to upgrade a control variable. *Br J Health Psychol*. 2017;22(1): 1–7.

176. City of Tshwane. City of Tshwane Socio-economic profile [homepage on the internet]. 2015 [updated 2015; cited 2020 Aug]. [Available from: https://www.tshwane.gov.za].

177. Piovesan C, Padua MC, Ardenghi TM, Mendes FM, Bonini GC. Can type of school be used as an alternative indicator of socioeconomic status in dental caries studies? A cross-sectional study. *BMC Med Res Methodol.* 2011(1);11: 37.

178. Labadarios D, Swart R, Maunder E, Kruger HS, Gericke G, Kuzwayo PMN, et al. Executive summary of the National Food Consumption Survey Fortification Baseline (NFCS-FB-1) South Africa, 2005. *S Afr J Clin Nutr.* 2008;21(3(Suppl 2)): 247–300.

179. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244): 1240–1243.

180. Steyn NP, Labadarios D, Maunder E, Nel J, Lombard C, Directors of the National Food Consumption S. Secondary anthropometric data analysis of the National Food Consumption Survey in South Africa: the double burden. *Nutrition*. 2005;21(1): 4–13.

181. Symington EA, Gericke GJ, Nel JH, Labadarios D. The relationship between stunting and overweight among children from South Africa: Secondary analysis of the National Food Consumption Survey-Fortification Baseline I. *S Afr Med J.* 2015;106(1): 65–69.

182. van Zyl A, White Z, Ferreira J, Wenhold FAM. Developing an impedance based equation for fat-free mass of black preadolescent South African children. *Nutrients*. 2019;11(9).

183. Micklesfield LK, Norris SA, Nelson DA, Lambert EV, van der Merwe L, Pettifor JM. Comparisons of body size, composition, and whole body bone mass between North American and South African children. *J Bone Miner Res.* 2007;22(12): 1869–1877.

184. Forse RA. Comparison of gas exchange measurements with a mouthpiece, face mask, and ventilated canopy. *J Parenter Enteral Nutr.* 1993;17(4): 388–391.

185. McClave SA, Lowen CC, Kleber MJ, McConnell JW, Jung LY, Goldsmith LJ. Clinical use of the respiratory quotient obtained from indirect Ccalorimetry. *J Parenter Enteral Nutr.* 2003;27(1): 21–26.

186. Matarese LE. Indirect calorimetry. *J Am Diet Assoc.* 1997;97(10): S154–S160.

187. Kaneko K, Ito C, Koizumi K, Watanabe S, Umeda Y, Ishikawa-Takata K. Resting energy expenditure (REE) in six- to seventeen-year-old Japanese children and adolescents. *J Nutr Sci Vitaminol.* 2013;59(4): 299–309.

188. Molnár D, Schutz Y. The effect of obesity, age, puberty and gender on resting metabolic rate in children and adolescents. *Eur J Pediatr*. 1997;156(5): 376–381.

189. Muller MJ, Bosy-Westphal A, Later W, Haas V, Heller M. Functional body composition: insights into the regulation of energy metabolism and some clinical applications. Eur J Clin Nutr. 2009;63(9): 1045–1056.

190. Midorikawa T, Hikihara Y, Ohta M, Ando T, Torii S, Sakamoto S, et al. The relationship between organ-tissue body composition and resting energy expenditure in prepubertal children. *Eur J Clin Nutr*. 2019;73(8): 1149–1154.

191. Hanks LJ, Gutiérrez OM, Ashraf AP, Casazza K. Bone mineral content as a driver of energy expenditure in prepubertal and early pubertal boys. *J Pediat.* 2015;166(6): 1397–1403.

192. Chima L, Mulrooney HM, Warren J, Madden AM. A systematic review and quantitative analysis of resting energy expenditure prediction equations in healthy overweight and obese children and adolescents. *J Hum Nutr Diet.* 2020;33(3): 373–385.

193. Finan K, Larson DE, Goran MI. Cross-validation of prediction equations for resting energy expenditure in young, healthy children. *J Am Diet Assoc.* 1997;97(2): 140–145.

194. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, Hu G, Johnson WD, Kuriyan R, Kurpad A, Lambert EV. The international study of childhood obesity, lifestyle and the environment (ISCOLE): design and methods. *BMC Public Health.* 2013;13(1): 900.

195. Fairclough SJ, Boddy LM, Mackintosh KA, Valencia-Peris A, Ramirez-Rico E. Weekday and weekend sedentary time and physical activity in differentially active children. *J Sci MedSport.* 2015;18(4): 444–9.

196. Rowlands AV, Pilgrim EL, Eston RG. Patterns of habitual activity across weekdays and weekend days in 9–11-year-old children. *Prev Med.* 2008;46(4): 317–324.

197. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. *Obes Rev.* 2016;17(2): 95–107.

198. Bosch L, Wells JCK, Lum S, Reid AM. Associations of extracurricular physical activity patterns and body composition components in a multi-ethnic population of UK children (the size and lung function in children study): a multilevel modelling analysis. *BMC Public Health*. 2019;19(1): 573.

199. Kelley GA, Kelley KS, Pate RR. Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis. *BMC Pediatr.* 2014;14(1): 225.

# ANNEXURES

## ANNEXURE A

# Data collection instruments

## A-1: PARENTAL INFORMATION LETTER, QUESTIONNAIRE AND SDQ

Dear Parent

Thank you for permitting your child to participate in the research study to determine resting energy expenditure and physical activity of 6-9-year old children in two primary schools in the City of Tshwane..

Your child will be assessed on ____________ at _____________.

Please arrive on time to allow us to complete all measurements before the school starts.

Please complete this letter and questionnaire and send this with your child to the assessment.

In preparation for the measurements, your child:

- Should wear their school uniform or physical education uniform, according to the school's policy for the assessment.
- Should abstain from physical activity from 7pm the night before the assessment.
- Should sleep at least 7 hours the night before the assessment.
- Should not eat or drink anything except water from 9pm the previous night. A small breakfast including a 30g packet of gluten-free rice cakes, a Ceres grape juice and an apple will be provided after the measurements.

Please indicate by signing below if you agree for your child to take this breakfast after the measurements:

I _____________________ (name) hereby give permission for my child ______________________ (name) to receive a 30g packet of gluten-free rice cakes, a Ceres grape juice and an apple after the measurement.
Please specify any food allergies that your child may have: _________________________
Signature: _________________________ Date: _____________________

Your child will receive a pedometer (step-counter) secured to a waist belt (please note that these pedometers are the property of the University of Pretoria and will need to be returned to the researcher after 7 days).

- Please ensure that your child wears the pedometer securely attached to the provided waist belt for the 7 days following the assessment.
- The pedometer must be worn from when your child gets up in the morning, until they go to bed at night. Please remove the pedometer during water-based activities and when taking a bath/shower.
- At the end of each day, please record the step-counts and send us an SMS with the number of steps taken during that day.
- We will send you an SMS every morning as a reminder to wear the pedometer and every night as a reminder to record and send an SMS with the step-count.
- Use the provided masking tape to close and secure the pedometer each morning, since we do not want your child to monitor their steps during the day or to fiddle with the device, since this may alter their step-count.
- Do not encourage or praise your child for taking more or less steps than a previous day, since these may change their habitual activity behaviour.

Please answer the questions below regarding your child by filling in or circling the applicable answer (these questions may help us to describe the population we are investigating and possible differences in resting energy expenditure and activity levels of the participants.

Please note that should your child not meet all the criteria that we require, they may not be able to participate in the study. However, they will still receive a record of all the measurements taken, they will be provided with the breakfast snack and would have the option of wearing the pedometer for 3 days.

| **Section A: Participant (child's) Information** | | | | | |
|---|---|---|---|---|---|
| Age (years) of your child | | | | | |
| Date of birth of your child | | | | | |
| Sex | M | | F | | |
| Population group | Black | White | Coloured | Indian/Asian | Other |
| Country of birth of both parents | Mother: | | Father: | | |
| Nationality of your child | | | | | |
| **Section B: Health Information** | | | | | |
| Does your child have any injuries | No | Yes, please specify: | | | |
| Does your child suffer from any illness (any illness, including a cold or flu)? | No | Yes, please specify: | | | |

| | | |
|---|---|---|
| Does your child take any medication? | No | Yes, please specify: |
| **Section C: Sociodemographic Information** | | |
| 1. Where does your child live during the school terms? Please provide the name of the town and neighbourhood. | | |
| 2. How does your child get to school? | Bus<br>Taxi<br>Car<br>Cycle<br>Walk<br>Other; please specify | |
| 3. What type of house do you live in? | Brick house/flat<br>Room in a backyard<br>Traditional hut<br>Squatter hut<br>Don't want to answer | |
| 4. Please tick one of the following boxes: | Do you live with family/friends?<br>Do you own your home?<br>Do you rent a home?<br>Homeless<br>None of the above; Please specify: | |
| 5. How many people live in your house? | 2<br>3-5<br>6-8<br>9 or more | |
| 6. Do you have electricity in your house? | Yes<br>No, but we have gas<br>No electricity | |
| 7. Where do you get your water from? | Tap inside the house<br>Tap outside the house, on our own plot<br>Communal tap not on our own plot<br>No access to tap water | |
| 8. What is your highest qualification? | Completed Grade 5 or less<br>Completed Grade 6<br>Grade 7-11<br>Completed Grade 12<br>Post matric education<br>Diploma / degree | |

| | |
|---|---|
| | No formal education, |
| 9. How many people in your household earn an income (Including pensioners, excluding children)? | 0-1<br>2-3<br>4 or more |
| 10. What is the income category that best describes the total monthly income (after tax deduction) of your household? | Less than R1000/month<br>R1000 – R 2500/month<br>R2501- R4300/month<br>R4301 – R5700/month<br>R5701 – R9000/month<br>R9001/month – R25000/month<br>More than R 25 000/month |
| 11. Please tick relevant items in your household: | Electric stove<br>Gas stove<br>Microwave oven<br>Refrigerator/fridge-freezer<br>Dishwasher<br>Washing machine<br>TV set<br>DVD player<br>Computer<br>None of the above items |

## A-2: PAQ-C ENGLISH

We are trying to find out more about your level of physical activity form the last 7 days (in the last week). This includes sports or dances that makes you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There is no right or wrong answer – this is not a test.
2. Please answer all the questions as honestly and accurately as you can – this is very important.

**1.** Physical activity in your spare time:

Have you done any of the following activities in the past 7 days (last week)? If yes, how many times?

Circle only one circle for each activity

| | NO | 1-2 | 3-4 | 5-6 | 7 times or more |
|---|---|---|---|---|---|
| Skipping | | | | | |
| Rowing/canoeing | | | | | |
| In-line skating | | | | | |
| Tag | | | | | |
| Walking for exercise | | | | | |
| Bicycling | | | | | |
| Jogging or running | | | | | |
| Aerobics | | | | | |
| Swimming | | | | | |
| Baseball softball | | | | | |
| Dance | | | | | |
| Football | | | | | |
| Badminton | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Skateboarding | | | | | |
| Soccer | | | | | |
| Street Hockey | | | | | |
| Volleyball | | | | | |
| Floor hockey | | | | | |
| Basketball | | | | | |
| Ice skating | | | | | |
| Cross-country skiing | | | | | |
| Ice hockey/ringette | | | | | |
| Other | | | | | |

| **2.** In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? **(Check one only.)** | |
|---|---|
| I don't do PE | |
| Hardly ever | |
| Sometimes | |
| Quite often | |
| Always | |

| **3.** In the last 7 days, what did you do most of the time at recess? **(Check one only.)** | |
|---|---|
| Sat down (talking, reading, doing schoolwork) | |
| Stood around or walked around | |
| Ran or played a little bit | |
| Ran around and played quite a bit | |
| Ran and played hard most of the time | |

| **4.** In the last 7 days, what did you normally do at lunch (besides eating lunch)? **(Check one only.)** | |
|---|---|
| Sat down (talking, reading, doing schoolwork) | |
| Stood around or walked around | |
| Ran or played a little bit | |
| Ran around and played quite a bit | |
| Ran and played hard most of the time | |

| **5.** In the last 7 days, on how many days right after school, did you do sports, dance, or play games in which you were very active? **(Check one only.)** | |
|---|---|
| None | |
| 1 time last week | |
| 2 or 3 times last week | |
| 4 times last week | |
| 5 times last week | |

| **6.** In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active? **(Check one only.)** | |
|---|---|
| None | |
| 1 time last week | |
| 2 or 3 times last week | |
| 4 times or 5 times last week | |
| 6 or 7 times last week | |

| **7.** On the last weekend, how many times did you do sports, dance, or play games in which you were very active? **(Check one only.)** | |
|---|---|
| None | |
| 1 time | |
| 2-3 times | |

| | |
|---|---|
| 4-5 times | |
| 6 or more times | |

| **8.** Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the answer that describes you. | |
|---|---|
| **A.** All or most of my free time was spent doing things that involve little physical effort | |
| **B.** I sometimes (1-2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) | |
| **C.** I often (3-4 times last week) did physical things in my free time | |
| **D.** I quite often (5-6 times last week) did physical things in my free time | |
| **E.** I very often (7 or more times last week) did physical things in my free time | |

**9.** Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

| | None | Very little | A little bit | Medium | Often | Very often |
|---|---|---|---|---|---|---|
| Monday | | | | | | |
| Tuesday | | | | | | |
| Wednesday | | | | | | |
| Thursday | | | | | | |
| Friday | | | | | | |
| Saturday | | | | | | |
| Sunday | | | | | | |

| **10.** Were you sick last week, or did anything prevent you from doing your normal physical activities? **(Check one.)** | |
|---|---|
| Yes | |
| No | |
| If Yes, what prevented you? | |

## A-3: PAQ-C AFRIKAANS

| |
|---|
| Ons probeer uitvind wat jou vlak van fisiese aktiwiteit vir die afgelope 7 dae (in die laaste week) was. Dit sluit in sport of dans wat jou laat sweet of jou bene laat moeg voel, of speletjies wat jou laat swaar asem haal, soos "touchers", tout e spring, hardloop, klim, en enige iets anders.<br>Onthou:<br>3. Daar is geen re gen verkeerde antwoorde – dit is nie 'n toets nie.<br>4. Beantwoord asseblief al die vrae so eerlik en akkuraat as wat jy kan – dit is baie belangrik. |
| **11.** Fisiese aktiwiteit in jou vrye tyd:<br>Het jy enige van die volgende aktiwiteite in die afgelope 7 dae (verlede week) dedoen? Indien ja, hoeveel keer?<br>(Kies slegs een) |

| | NO | 1-2 | 3-4 | 5-6 | 7 of meer |
|---|---|---|---|---|---|
| Tou spring | | | | | |
| Roei/ kano | | | | | |
| In lyn skaats | | | | | |
| Jagertjie | | | | | |
| Stap vir oefening | | | | | |
| Fietsry | | | | | |
| Draf of harloop | | | | | |
| Aërobiese oefening | | | | | |
| Swem | | | | | |
| Bofbal of sagtebal | | | | | |
| Dans | | | | | |
| Pluimbal | | | | | |
| Skaatsplank | | | | | |
| Sokker | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Rugby | | | | | |
| Vlugbal | | | | | |
| Hokkie | | | | | |
| Basketbal | | | | | |
| Ysskaats | | | | | |
| Netball | | | | | |
| Tennis | | | | | |
| Krieket | | | | | |
| Ander | | | | | |

| **12.** In die afgelope 7 dae, tydens jou liggaamlike opvoeding (LO) klasse, hoe dikwels het jy baie aktief hard gespeel, gehardloop, gespring, of gegooi? **(Kies slegs een.)** | |
|---|---|
| Ek doen nie LO nie | |
| Selde | |
| Soms | |
| Dikwels | |
| Altyd | |

| **13.** In die afgelope 7 dae, wat het jy die meeste van die tyd gedoen gedurende puose? **(Kies slegs een.)** | |
|---|---|
| Gaan sit (praat, lees, skoolwerk doen) | |
| Rond te staan of loop | |
| Gehardloop of bietjie gespeel | |
| Hardloop en baie gespeel vir ‘ rukkie | |
| Baie gehardloop en gespeel vir meeste van die tyd | |

| **14.** In die afgelope 7 dae, wat het jy gewoonlik gedoen (behalwe middagete eet) by die middagete? **(Kies slegs een.)** | |
|---|---|
| Gaan sit (praat, lees, skoolwerk doen) | |
| Rond te staan of loop | |
| Gehardloop of ‘n bietjie gespeel | |
| Hardloop en baie gespeel vir ‘n rukkie | |
| Baie gehardloop en gespeel vir meeste van die tyd | |

| **15.** In die afgelope 7 dae, op hoeveel dae direk na skool, het jy sport, dans, of speletijies gespeel waar jy baie aktief was? **(Kies slegs een.)** | |
|---|---|
| Geen | |
| 1 keer verlede week | |
| 2 or 3 keer verlede week | |
| 4 keer verlede week | |
| 5 keer verlede week | |

| **16.** In die afgelope 7 dae, hoeveel aande het jy sport, dans, of speletjies gespeel waar jy baie aktief was? **(Kies slegs een.)** | |
|---|---|
| Geen | |
| 1 keer verlede week | |
| 2 of 3 keer verlede week | |
| 4 of 5 keer verlede week | |
| 6 of 7 keer verlede week | |

| **17.** Oor die laaste naweek, hoeveel keer het jy sport, dans, of speletjies gespeel waar jy baie aktief was? **(Kies slegs een.)** | |
|---|---|
| None | |
| 1 time | |

| | |
|---|---|
| 2-3 times | |
| 4-5 times | |
| 6 or more times | |

| **18.** Watter een van die volgende beskryf jou die beste oor die afgelope 7 dae? Lees al vyf stellings voordat jy besluit op die een antwoord wat jy beskryf. | |
|---|---|
| **F.** Alle of meeste van my vrye tyd is bestee aan dinge te doen wat min fisiese inspanning behels. | |
| **G.** Ek het soms (1-2 keer die afgelope week) fisiese dinge in my vrye tyd gedoen (bv. Sport gespeel, gaan hardloop, swem, fietsry of aerobics) | |
| **H.** Ek het dikwels (3-4 keer verlede week0 fisiese dinge in my vrye tyd gedoen | |
| **I.** Ek het heel dikwels (5-6 keer verlede week) fisiese dinge in my vrye tyd gedoen | |
| **J.** Ek het baie dikwels(7 of meer tyd in die vorige week) fisiese dinge in my vrye tyd gedoen | |

**19.** Merk hoeveel kere per dag het jy fisiese aktiwiteit (soos sport, speletjies, dans, of enige ander fisiese aktiwiteit) verlede week vir elke dag gedoen.

| | Geen | Baie min | 'n Bietjie | Partykeer | Dikwels | Baie dikwels |
|---|---|---|---|---|---|---|
| Maandag | | | | | | |
| Dinsdag | | | | | | |
| Woensdag | | | | | | |
| Donderdag | | | | | | |
| Vrydag | | | | | | |
| Saterdag | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sondag | | | | | | |

| **20.** Was jy siek gewees verlede week, of het iets verhoed dat jy jou normale fisiese aktiwiteite te doen? **(Kies een.)** | |
|---|---|
| Ja | |
| Nee | |
| Indien Ja, wat het jou verhoed? | |

# A-4: COMPLETED ISAT FOR SCHOOL A

School Name: (write in print below) A

Technician Initials: A P
Date: 12 / APR / 2019 (Day / Month / Year)

## ISCOLE SCHOOL AUDIT TOOL (ISAT)

School Name: A

Start Time: 2pm    Finish Time: 3pm

### I. SCHOOL BUILT ENVIRONMENT

### A. ACCESS TO THE SCHOOL

1. Please locate each entrance to the school and record its grid reference. Record whether the entrance is accessible by cars, pedestrians, and/or cyclists. (Check all that apply). Then record what mode of transportation the entrance appears to be designed for. (Check all that apply.) Determine if the entrance is an official entrance and check No or Yes. Also, for entrances that open onto a road, please record the speed limit, in miles or kilometers per hour, on the adjacent road and whether roadside parking is available.

| Grid Ref (e.g., A1) | Is entrance accessible by...? (Check all that apply.) | | | Is this entrance designed for use by? (Check all that apply.) | | | Is this an official entrance? | Does the entrance open onto a road? | For each entrance that opens onto a road... | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cars | Peds. | Cycls. | Cars | Peds. | Cycls. | | | Speed limit of adjacent road | Is roadside parking available? |
| 1. Main | ☑ | ☑ | ☑ | ☑ | ☐ | ☐ | ☐N ☑Y ☐Not allowed | ☐N ☑Y → | 60 km ☐Miles/h | ☐N ☑Y |
| 2. Small | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☐N ☑Y ☐Not allowed | ☐N ☑Y → | 60 km ☐Miles/h | ☑N ☐Y |
| 3. Scrol | ☑ | ☐ | ☐ | ☑ | ☐ | ☐ | ☑N ☐Y ☐Not allowed | ☐N ☑Y → | 70 km ☐Miles/h | ☑N ☐Y |
| 4. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 5. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 6. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 7. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 8. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 9. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: ______ Date: ___/___/___

Data Entry Staff Initials: [signature] Date: 12 / 04 / 19

Page 1 of 7 Version 3.0

School Name: (write in print below) A

Technician Initials: A P
Date: 12 / APR / 2019 (Day / Month / Year)

### B. THE SURROUNDING AREA

2. Is the area around the school predominantly...? (Check one.)

Residential ☑ Open fields/ commons/ parks ☐ Business/ retail ☐ A mixture of different land uses ☐

***Are the following visible from any of the entrances?***

| | | Yes | No |
|---|---|---|---|
| 3. | Somewhere where parents can stop and drop children off? | ☑ | ☐ |
| 4. | Somewhere where parents can park their cars? | ☑ | ☐ |
| 5. | A bus stop? | ☐ | ☑ |
| 6. | Cycle lanes: | | |
| | a. Separated from the road? | ☐ | ☑ |
| | b. On the road? | ☐ | ☑ |
| 7. | Pavements/sidewalks: | | |
| | a. On both sides | ☑ | ☐ |
| | b. On one side of the road only | ☐ | ☐ |
| 8. | A marked pedestrian crossing to assist access to the school | ☑ | ☐ |
| 9. | Traffic calming | ☑ | ☐ |
| 10. | Signage: | | |
| | a. School warning signs for road users | ☑ | ☐ |
| | b. Road safety signs | ☑ | ☐ |
| | c. Route signs for cyclists | ☐ | ☑ |
| 11. | Fast food restaurants | ☐ | ☑ |

Remember to refer to the Item Definitions to help keep the study strong!

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: ______ Date: ___/___/___

Data Entry Staff Initials: [signature] Date: 12 / 04 / 19

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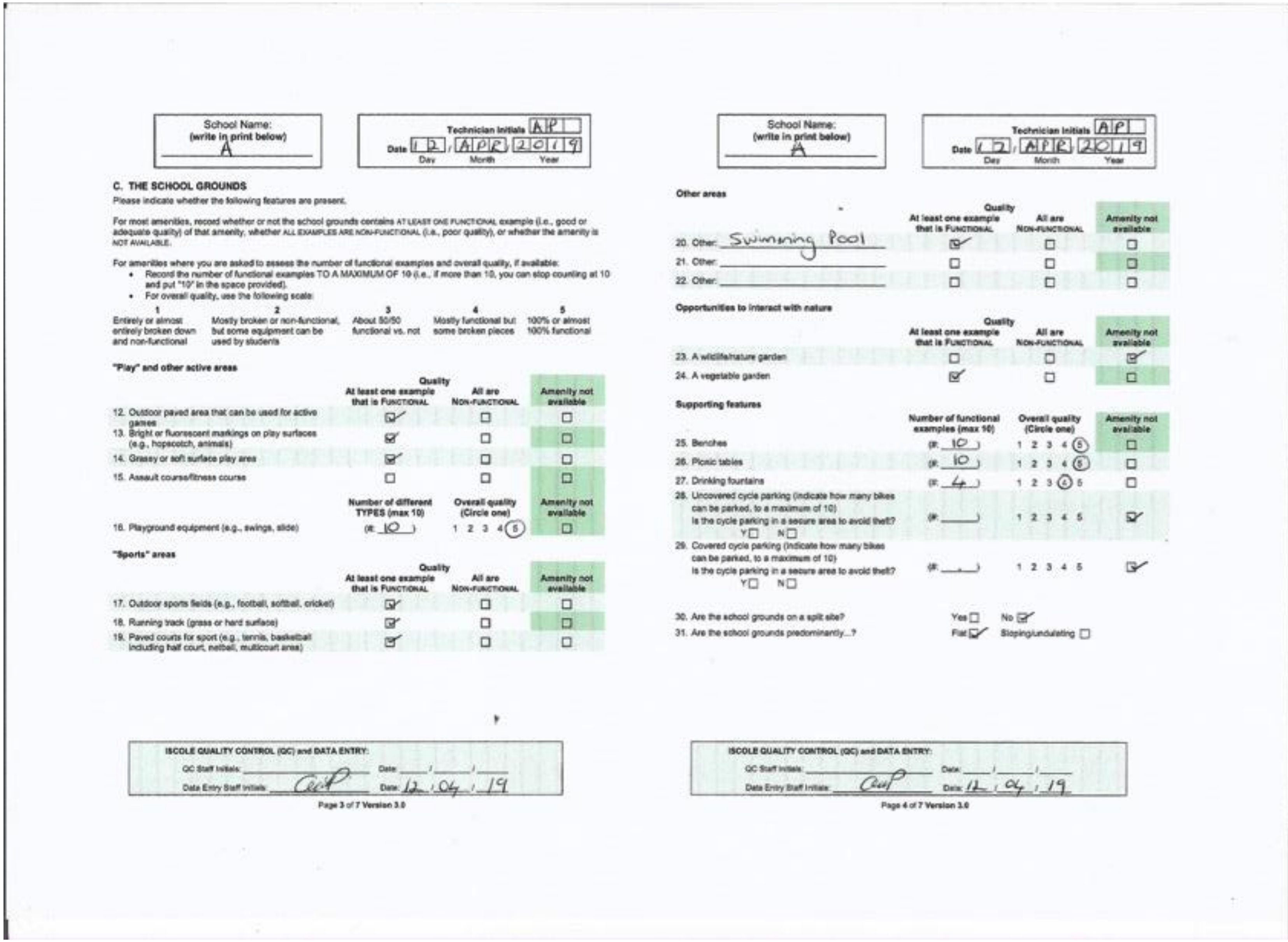

School Name: (write in print below) A

Technician Initials AP
Date 12 / APR / 2019 (Day / Month / Year)

**C. THE SCHOOL GROUNDS**

Please indicate whether the following features are present.

For most amenities, record whether or not the school grounds contains AT LEAST ONE FUNCTIONAL example (i.e., good or adequate quality) of that amenity, whether ALL EXAMPLES ARE NON-FUNCTIONAL (i.e., poor quality), or whether the amenity is NOT AVAILABLE.

For amenities where you are asked to assess the number of functional examples and overall quality, if available:

- Record the number of functional examples TO A MAXIMUM OF 10 (i.e., if more than 10, you can stop counting at 10 and put "10" in the space provided).
- For overall quality, use the following scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Entirely or almost entirely broken down and non-functional | Mostly broken or non-functional, but some equipment can be used by students | About 50/50 functional vs. not | Mostly functional but some broken pieces | 100% or almost 100% functional |

**"Play" and other active areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 12. Outdoor paved area that can be used for active games | [x] | [ ] | [ ] |
| 13. Bright or fluorescent markings on play surfaces (e.g., hopscotch, animals) | [x] | [ ] | [ ] |
| 14. Grassy or soft surface play area | [x] | [ ] | [ ] |
| 15. Assault course/fitness course | [ ] | [ ] | [ ] |

| | Number of different TYPES (max 10) | Overall quality (Circle one) | Amenity not available |
|---|---|---|---|
| 16. Playground equipment (e.g., swings, slide) | (#: 10) | 1 2 3 4 (5) | [ ] |

**"Sports" areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 17. Outdoor sports fields (e.g., football, softball, cricket) | [x] | [ ] | [ ] |
| 18. Running track (grass or hard surface) | [x] | [ ] | [ ] |
| 19. Paved courts for sport (e.g., tennis, basketball including half court, netball, multicourt area) | [x] | [ ] | [ ] |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ______ Date: __/__/__
Data Entry Staff Initials: CAP Date: 12 / 04 / 19

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School Name: (write in print below) A

Technician Initials AP
Date 12 / APR / 2019 (Day / Month / Year)

**Other areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 20. Other: Swimming Pool | [x] | [ ] | [ ] |
| 21. Other: ______ | [ ] | [ ] | [ ] |
| 22. Other: ______ | [ ] | [ ] | [ ] |

**Opportunities to interact with nature**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 23. A wildlife/nature garden | [ ] | [ ] | [x] |
| 24. A vegetable garden | [x] | [ ] | [ ] |

**Supporting features**

| | Number of functional examples (max 10) | Overall quality (Circle one) | Amenity not available |
|---|---|---|---|
| 25. Benches | (#: 10) | 1 2 3 4 (5) | [ ] |
| 26. Picnic tables | (#: 10) | 1 2 3 4 (5) | [ ] |
| 27. Drinking fountains | (#: 4) | 1 2 3 (4) 5 | [ ] |
| 28. Uncovered cycle parking (indicate how many bikes can be parked, to a maximum of 10) Is the cycle parking in a secure area to avoid theft? Y[ ] N[ ] | (#: ___) | 1 2 3 4 5 | [x] |
| 29. Covered cycle parking (indicate how many bikes can be parked, to a maximum of 10) Is the cycle parking in a secure area to avoid theft? Y[ ] N[ ] | (#: ___) | 1 2 3 4 5 | [x] |

30. Are the school grounds on a split site? Yes [ ] No [x]

31. Are the school grounds predominantly...? Flat [x] Sloping/undulating [ ]

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ______ Date: __/__/__
Data Entry Staff Initials: CAP Date: 12 / 04 / 19

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School Name:
(write in print below)
A

Technician Initials AP

Date 12 / APR / 2019
Day Month Year

**D. AESTHETICS**

Please indicate whether the following are present:

| | | |
|---|---|---|
| 32. Planted beds containing flowers/ shrubs/ small trees. | None ☐ | Some/ A lot ☑ |
| 33. Trees for sitting under | None ☐ | Some/ A lot ☑ |
| 34. Ambient noise (e.g., traffic, trains, industry) | None ☐ | (Some)/ A lot ☑ |
| 35. Litter | None, very occasional, or very little, localized litter in an otherwise litter-free campus ☑ | Some/ A lot ☐ |
| 36. Murals/ Outdoor art | None ☐ | Some/ A lot ☑ |
| 37. Graffiti | None ☑ | Some/ A lot ☐ |

**E. USEAGE**

Are the school grounds generally suitable for... ?

| | | |
|---|---|---|
| 38. Sport (organized or not) | Not at all ☐ | Somewhat/ Very ☑ |
| 39. Informal games (kickabout, frisbee, etc.) | Not at all ☐ | Somewhat/ Very ☑ |
| 40. General play | Not at all ☐ | Somewhat/ Very ☑ |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ________ Date: ___ / ___ / ___
Data Entry Staff Initials: [signature] Date: 12 / 04 / 19

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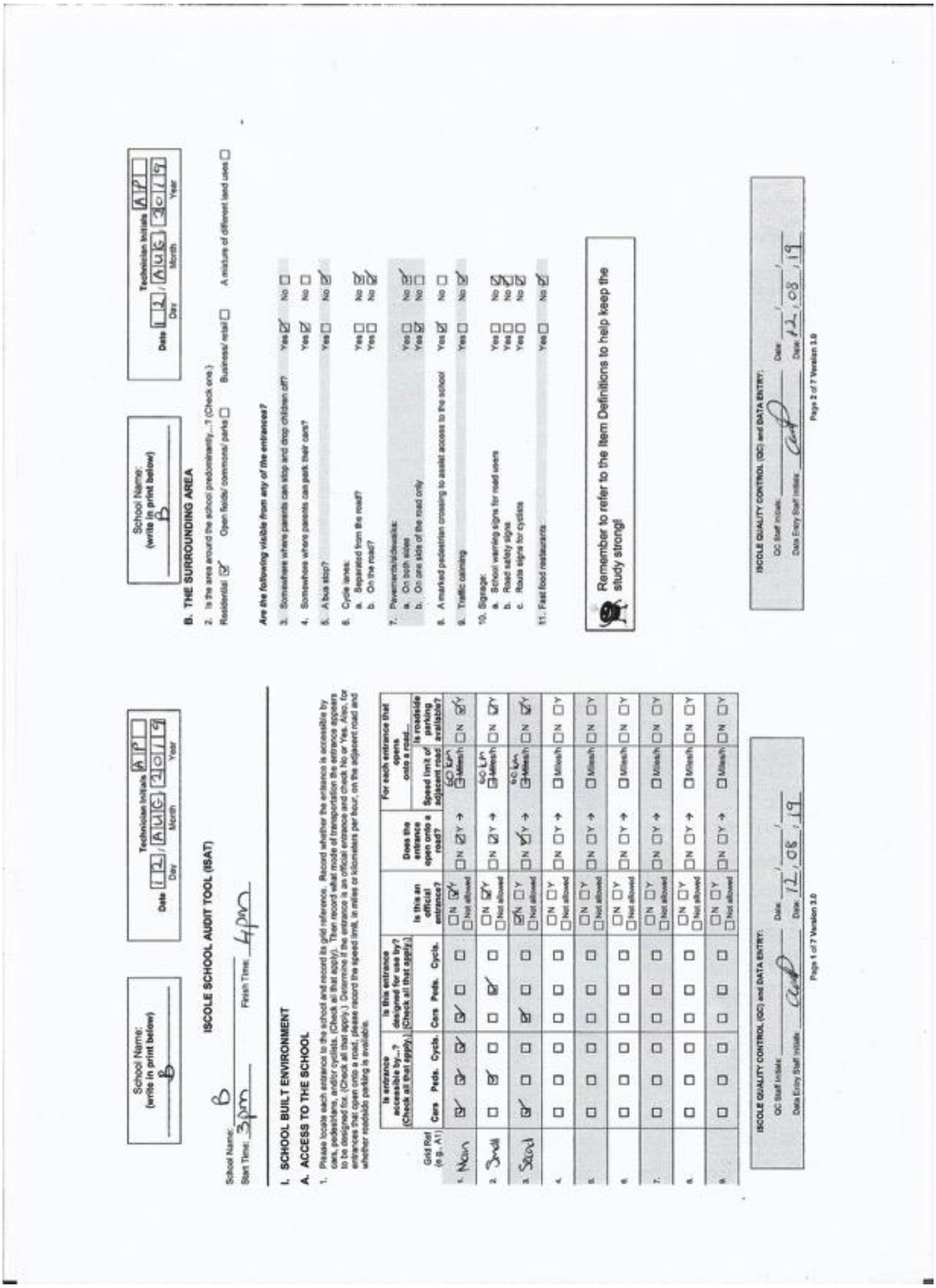
# A-5: COMPLETED ISAT FOR SCHOOL B



School Name: (write in print below) B

Technician Initials AP

Date 12 / AUG / 2019 (Day, Month, Year)

ISCOLE SCHOOL AUDIT TOOL (ISAT)

School Name: B

Start Time: 3pm Finish Time: 4pm

I. SCHOOL BUILT ENVIRONMENT

A. ACCESS TO THE SCHOOL

1. Please locate each entrance to the school and record its grid reference. Record whether the entrance is accessible by cars, pedestrians, and/or cyclists. (Check all that apply). Then record what mode of transportation the entrance appears to be designed for. (Check all that apply.) Determine if the entrance is an official entrance and check No or Yes. Also, for entrances that open onto a road, please record the speed limit, in miles or kilometers per hour, on the adjacent road and whether roadside parking is available.

| Grid Ref (e.g. A1) | Is entrance accessible by...? (Check all that apply.) Cars | Peds. | Cycls. | Is this entrance designed for use by? (Check all that apply.) Cars | Peds. | Cycls. | Is this an official entrance? | Does the entrance open onto a road? | For each entrance that opens onto a road... Speed limit of adjacent road | Is roadside parking available? |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Main | ☑ | ☑ | ☑ | ☑ | ☐ | ☐ | ☐N ☑Y ☐Not allowed | ☐N ☑Y → | 60 km ☐Miles/h | ☐N ☑Y |
| 2. Small | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☐N ☑Y ☐Not allowed | ☐N ☑Y → | 60 km ☐Miles/h | ☐N ☑Y |
| 3. Second | ☑ | ☐ | ☐ | ☑ | ☐ | ☐ | ☑N ☐Y ☐Not allowed | ☐N ☑Y → | 60 km ☐Miles/h | ☐N ☑Y |
| 4. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 5. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 6. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 7. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 8. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |
| 9. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐N ☐Y ☐Not allowed | ☐N ☐Y → | ☐Miles/h | ☐N ☐Y |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: ______ Date: __/__/__

Data Entry Staff Initials: [signature] Date: 12 / 08 / 19

Page 1 of 7 Version 3.0

School Name: (write in print below) B

Technician Initials AP

Date 12 / AUG / 2019 (Day, Month, Year)

B. THE SURROUNDING AREA

2. Is the area around the school predominantly...? (Check one.)

Residential ☑ Open fields/ commons/ parks ☐ Business/ retail ☐ A mixture of different land uses ☐

*Are the following visible from any of the entrances?*

| | Yes | No |
|---|---|---|
| 3. Somewhere where parents can stop and drop children off? | ☑ | ☐ |
| 4. Somewhere where parents can park their cars? | ☑ | ☐ |
| 5. A bus stop? | ☐ | ☑ |
| 6. Cycle lanes: a. Separated from the road? | ☐ | ☑ |
| b. On the road? | ☐ | ☑ |
| 7. Pavements/sidewalks: a. On both sides | ☐ | ☑ |
| b. On one side of the road only | ☑ | ☐ |
| 8. A marked pedestrian crossing to assist access to the school | ☑ | ☐ |
| 9. Traffic calming | ☐ | ☑ |
| 10. Signage: a. School warning signs for road users | ☐ | ☑ |
| b. Road safety signs | ☐ | ☑ |
| c. Route signs for cyclists | ☐ | ☑ |
| 11. Fast food restaurants | ☐ | ☑ |

Remember to refer to the Item Definitions to help keep the study strong!

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: ______ Date: __/__/__

Data Entry Staff Initials: [signature] Date: 12 / 08 / 19

Page 2 of 7 Version 3.0

School Name:
(write in print below)
B

Technician Initials AP
Date 12 / AUG / 2019
Day Month Year

## C. THE SCHOOL GROUNDS

Please indicate whether the following features are present.

For most amenities, record whether or not the school grounds contains AT LEAST ONE FUNCTIONAL example (i.e., good or adequate quality) of that amenity, whether ALL EXAMPLES ARE NON-FUNCTIONAL (i.e., poor quality), or whether the amenity is NOT AVAILABLE.

For amenities where you are asked to assess the number of functional examples and overall quality, if available:

- Record the number of functional examples TO A MAXIMUM OF 10 (i.e., if more than 10, you can stop counting at 10 and put "10" in the space provided).
- For overall quality, use the following scale:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Entirely or almost entirely broken down and non-functional | Mostly broken or non-functional, but some equipment can be used by students | About 50/50 functional vs. not | Mostly functional but some broken pieces | 100% or almost 100% functional |

**"Play" and other active areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 12. Outdoor paved area that can be used for active games | ☑ | ☐ | ☐ |
| 13. Bright or fluorescent markings on play surfaces (e.g., hopscotch, animals) | ☑ | ☐ | ☐ |
| 14. Grassy or soft surface play area | ☑ | ☐ | ☐ |
| 15. Assault course/fitness course | ☑ | ☐ | ☐ |

| | Number of different TYPES (max 10) | Overall quality (Circle one) | Amenity not available |
|---|---|---|---|
| 16. Playground equipment (e.g., swings, slide) | (#: 10) | 1 2 3 4 (5) | ☐ |

**"Sports" areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 17. Outdoor sports fields (e.g., football, softball, cricket) | ☑ | ☐ | ☐ |
| 18. Running track (grass or hard surface) | ☑ | ☐ | ☐ |
| 19. Paved courts for sport (e.g., tennis, basketball including half court, netball, multicourt area) | ☑ | ☐ | ☐ |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ______ Date: __/__/__
Data Entry Staff Initials: ap Date: 12 / 08 / 19



School Name:
(write in print below)
B

Technician Initials AP
Date 12 / AUG / 2019
Day Month Year

**Other areas**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 20. Other: Swimming Pool | ☑ | ☐ | ☐ |
| 21. Other: ______ | ☐ | ☐ | ☐ |
| 22. Other: ______ | ☐ | ☐ | ☐ |

**Opportunities to interact with nature**

| | Quality: At least one example that is FUNCTIONAL | All are NON-FUNCTIONAL | Amenity not available |
|---|---|---|---|
| 23. A wildlife/nature garden | ☑ | ☐ | ☐ |
| 24. A vegetable garden | ☐ | ☐ | ☑ |

**Supporting features**

| | Number of functional examples (max 10) | Overall quality (Circle one) | Amenity not available |
|---|---|---|---|
| 25. Benches | (#: 10) | 1 2 3 4 (5) | ☐ |
| 26. Picnic tables | (#: 10) | 1 2 3 4 (5) | ☐ |
| 27. Drinking fountains | (#: 5) | 1 2 3 (4) 5 | ☐ |
| 28. Uncovered cycle parking (indicate how many bikes can be parked, to a maximum of 10) Is the cycle parking in a secure area to avoid theft? Y☐ N☐ | (#: ___) | 1 2 3 4 5 | ☑ |
| 29. Covered cycle parking (indicate how many bikes can be parked, to a maximum of 10) Is the cycle parking in a secure area to avoid theft? Y☐ N☐ | (#: ___) | 1 2 3 4 5 | ☑ |

30. Are the school grounds on a split site? Yes ☐ No ☑
31. Are the school grounds predominantly...? Flat ☑ Sloping/undulating ☐ (playgrounds = flat)

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:
QC Staff Initials: ______ Date: __/__/__
Data Entry Staff Initials: ap Date: 12 / 08 / 19

School Name:
(write in print below)
D

Technician Initials A P
Date 12 / AUG / 2019
Day Month Year

## D. AESTHETICS

Please indicate whether the following are present:

| | | |
|---|---|---|
| 32. Planted beds containing flowers/ shrubs/ small trees. | None ☐ | Some/ A lot ☑ |
| 33. Trees for sitting under | None ☐ | Some/ A lot ☑ |
| 34. Ambient noise (e.g., traffic, trains, industry) | None ☑ | Some/ A lot ☐ |
| 35. Litter | None, very occasional, or very little, localized litter in an otherwise litter-free campus ☑ | Some/ A lot ☐ |
| 36. Murals/ Outdoor art | None ☐ | Some/ A lot ☑ |
| 37. Graffiti | None ☑ | Some/ A lot ☐ |

## E. USEAGE

Are the school grounds generally suitable for... ?

| | | |
|---|---|---|
| 38. Sport (organized or not) | Not at all ☐ | Somewhat/ Very ☑ |
| 39. Informal games (kickabout, frisbee, etc.) | Not at all ☐ | Somewhat/ Very ☑ |
| 40. General play | Not at all ☐ | Somewhat/ Very ☑ |

ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: ________ Date: ___/___/___

Data Entry Staff Initials: Aop Date: 12 / 08 / 19

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## A-6: AERIAL MAP OF SCHOOL A

## A-7: AERIAL MAP OF SCHOOL B

## A-8: DATA COLLECTION SHEET

Date of assessment: ____________ Time of assessment: _______

Location of assessment: _____________________

| **Section A: Participant Information** | | | | | |
|---|---|---|---|---|---|
| Age (years) | 6 | 7 | 8 | 9 | |
| Date of birth | 2010 | 2011 | 2012 | | |
| Sex | M | F | | | |
| Population group | Black | Whit e | Coloure d | Indian/ Asian | Other |
| Nationality | | | | | |
| **Section B: Nutritional Intake** | | | | | |
| Did you eat supper last night? *Het jy gisteraand geëet?* | Yes / *Ja* | No / *Nee* | | | |
| Did you get up during the night to eat or drink something? *Het jy deur die nag opgestaan om te eet of te drink?* | Yes /*Ja* Can you explain / *Kan jy verduidelik:* | No / *Nee* | | | |
| Did you eat or drink anything this morning (before school, on your way to school or at school)? *Het jy enigiets vanoggend geëet of gedrink?* | Yes /*Ja* Can you explain / *Kan jy verduidelik:* | No / *Nee* | | | |
| Did you drink coffee this morning? | Yes /*Ja* | No / *Nee* | | | |

| | | |
|---|---|---|
| *Het jy vanoggend koffie gedrink?* | | |
| **Section C: Health Information** | | |
| Did you sleep well last night?<br><br>*Het jy lekker geslaap gisteraand?* | No / *Nee*<br><br>Can you explain / *Kan jy verduidelik:* | Yes / *Ja* |
| Did you do any activities (sport, walking, cycling) this morning?<br><br>*Het jy vanoggend enige aktiwiteite (sport, stap, fietsry) deelgeneem?* | Yes / *Ja*<br><br>Can you explain / *Kan jy verduidelik:* | No / *Nee* |
| Do you have an injury (e.g. broken arm)?<br><br>*Het jy 'n besering (bv. gebreekte arm)?* | Yes / *Ja*<br><br>Can you explain / *Kan jy verduidelik:* | No /<br><br>*Nee* |
| Are you ill or do you feel sick?<br><br>*Is jy siek of voel jy sleg?* | Yes / *Ja*<br><br>Can you explain / *Kan jy verduidelik:* | No / *Nee* |
| Do you take any pills or medicine?<br><br>*Neem jy  pille of medisyne?* | Yes / *Ja*<br><br>Can you explain / *Kan jy verduidelik:* | No / *Nee* |

| | | | |
|---|---|---|---|
| **Section D: Anthropometric Measurements** | | | |
| Weight (kg): | 1: | 2: | Ave: |
| Height (cm): | 1: | 2: | Ave: |
| BMI: | | | |

## ANNEXURE B

# Informed consent and child assent forms

## B-1: PARENTAL INVITATION LEAFLET AND INFORMED CONSENT FORM

### TITLE OF THE STUDY: FACTORS RELATED TO RESTING ENERGY EXPENDITURE AND PHYSICAL ACTIVITY OF 6-9-YEAR OLD CHILDREN IN TWO PRIMARY SCHOOLS IN THE CITY OF TSHWANE METROPOLITAN AREA

Dear Parent

We invite your child to participate in a research study. This information leaflet will help you to decide if you want your child to participate. Before you allow your child to take part, you should fully understand what is involved. If you have any questions that this leaflet does not fully explain, please do not hesitate to contact the researcher.

The participation of your child will be an invaluable source of information to contribute to future health interventions of South African children in our fight against overweight/obesity. Your permission is an important part in this and will be greatly appreciated.

**Nature and purpose of the study:**

Many South African children struggle to maintain a healthy weight or are at risk of gaining weight when they become older. To help prevent this, dietitians need to know how much energy a person’s body needs to stay alive, support growth and live healthily. International studies have suggested that it is possible that this amount of energy is different for various population and socio-economic groups, and studies at the University of Pretoria have confirmed this for adults. No such studies have been done on South African children, yet the rising prevalence of overweight and obesity in our children challenge us to analyse all contributors to the problem.

The aim of this study is to determine what the energy required by the human body to maintain basic body functions is, and whether it is different between the 6-8-year old children (that is before they enter puberty) attending two identified schools in the City of Tshwane. The study will also determine activity levels, that may influence total energy requirements, and possible differences between these children in this age group.

**Explanation of the procedure:**

The study will involve the measurement of the energy required to stay alive. The primary researcher and a research assistant appointed by the University of Pretoria will perform all measurements. First the participating children will be asked to complete a questionnaire with the assistance of the researcher or assistant, regarding their involvement in physical activities. They will then be weighed, their height will be measured, and the amount of fat and muscle will be measured with a scale with electrodes under the feet and hands (see picture below).

To measure the amount of energy required to stay alive, participants will be asked to lie down for 20 minutes, with a clear, see-through hood over their head that measures the air breathed (see picture below).

To keep the participant relaxed and comfortable, an audio CD with an age-appropriate short story will be played. Each participant will then be asked to wear a pedometer (i.e. a step-counting device) for 7 consecutive days to measure their involvement in physical activity. After the 7 days, the pedometer will be collected, and the children will be asked to complete the same questionnaire with the assistance of the researcher or assistant, regarding their involvement in physical activities.

Measurements must be taken early in the morning, before the start of school, since participants will be required to fast overnight and skip breakfast. A one-hour session (i.e. 6.30-7.30am) will be required for measuring three children. A venue at the

University of Pretoria, or at your child's school will be used where the measurements will be performed.

**Risk and discomfort involved**

Participants will be asked to remove their shoes and socks when height, weight and body fat and muscle measurements are taken. They will need to lie and breathe normally for 20 minutes with a clear hood over their head to measure the oxygen inhaled and carbon dioxide exhaled. The hood will not cause any health or safety risk but may provide some discomfort. The participants will be observed and comforted by the researcher or research assistant during the entire procedure. Participants will then need to wear a waist belt with a matchbox size pedometer attached, for 7 days. Parents will be required to each day cover the pedometer with provided masking tape, record the number of steps taken and send and SMS to the researcher with the number of steps taken.

Although the procedures do not involve any health or safety risks, a school nurse or the school's designated first aider will be contacted in the event of any medical emergency. Please also provide your contact details and an alternative contact number in the provided space below.

The study has received written approval from the Research Ethics Committee of the Faculty of Health Science at the University of Pretoria. A copy of the approval letter is available if you wish to have one.

Participation is entirely voluntary, and no compensation will be provided. However, a small breakfast (with consideration of possible food allergies and with your permission) will be provided after the measurement. Your child will also be asked to provide their permission prior the measurements.

All information will be kept strictly confidential. Once we analysed the information, no one will be able to identify the children. Research articles and reports will not include any information that may identify the children.

**Contact details:**

Please do not hesitate to contact me, Adeline Pretorius, Registered Dietitian, or the principle supervisor (Prof F Wenhold: friede.wenhold@up.ac.za), should you require any further information.

**Consent to participate in this study**

I confirm that the person asking my permission for my child to take part in the study has informed me about the nature, process, risks, discomforts and benefits of the study. I have also received, read and understood the above written information (Information Leaflet and Informed Consent) regarding the study. I am aware that the results of the study, including personal details, will be anonymously processed into research reports. Participation of my child is willingly. I have had time to ask questions and have no objections for my child to participate in this study. I understand that there is no penalty should my child wish to discontinue with the study and the withdrawal will not affect me or my child in any way. If my child decided to withdraw, I will be given the option that information and data collected for my child to be either destroyed or to be used for results of the study.

Please note that should your child not meet all the criteria that we require, they may not be able to participate in the study. However, they will still receive a record of all the measurements taken, they will be provided with the breakfast snack and would have the option of wearing the pedometer for 3 days

I have received a signed copy of this informed consent agreement.

Child's name ____________________________________________ (please print)

Parent's/Guardian's name_________________________________ (please print)

Parent's/Guardian's signature______________________ Date ____________________

Parent's/Guardian's cell phone number: _____________________________________

Alternative contact person: Name: _________________ Tel no: ___________________

Witness's name __________________________________________ (please print)

Witness's signature ______________________________ Date ____________________

**B-2: ASSENT FORM FOR CHILDREN TAKING PART IN THE RESEARCH STUDY**

**FACTORS RELATED TO RESTING ENERGY EXPENDITURE AND PHYSICAL ACTIVITY OF 6-9-YEAR OLD CHILDREN IN TWO PRIMARY SCHOOLS IN THE CITY OF TSHWANE METROPOLITAN AREA.**

We wish to know if you would like to be part of a research study where we will take certain measurements from you. We are asking you, because many children in South Africa struggle to maintain a healthy weight. When children gain more weight than is good for their health, they may become unhealthy when they grow up. If we take certain measurements from many different children, it will help us to understand what we can do to prevent children to gain too much weight when they become grown up.

Today we will do different kind of tests on you. We will first ask you to answer a few questions about the sports and activities that you do. We will then measure your weight, height and the amount of fat and muscle in your body (see picture 1 below). After that, we will measure the amount of oxygen you breathe (see picture 2 below). You will feel no pain and there will be someone next to you all the time.

Picture 1

Picture 2

After these measurements, we will ask you to wear a step-counter for seven days, when we will collect the step-counter and ask you to answer the questions about sports and activities again.

If you do not want to take part today or if you decided not to carry on, no-one will force you to carry on. No-one will be cross or upset with you if you don’t want to. You don’t have to give us an answer now. You can take some time and look at this form and the pictures before you decide.

If you sign this form at the bottom, it will mean that you have read this paper and that you would like to be in this study.

Participant Name: ___________________________

Signature: _________________________________ Date:___________________

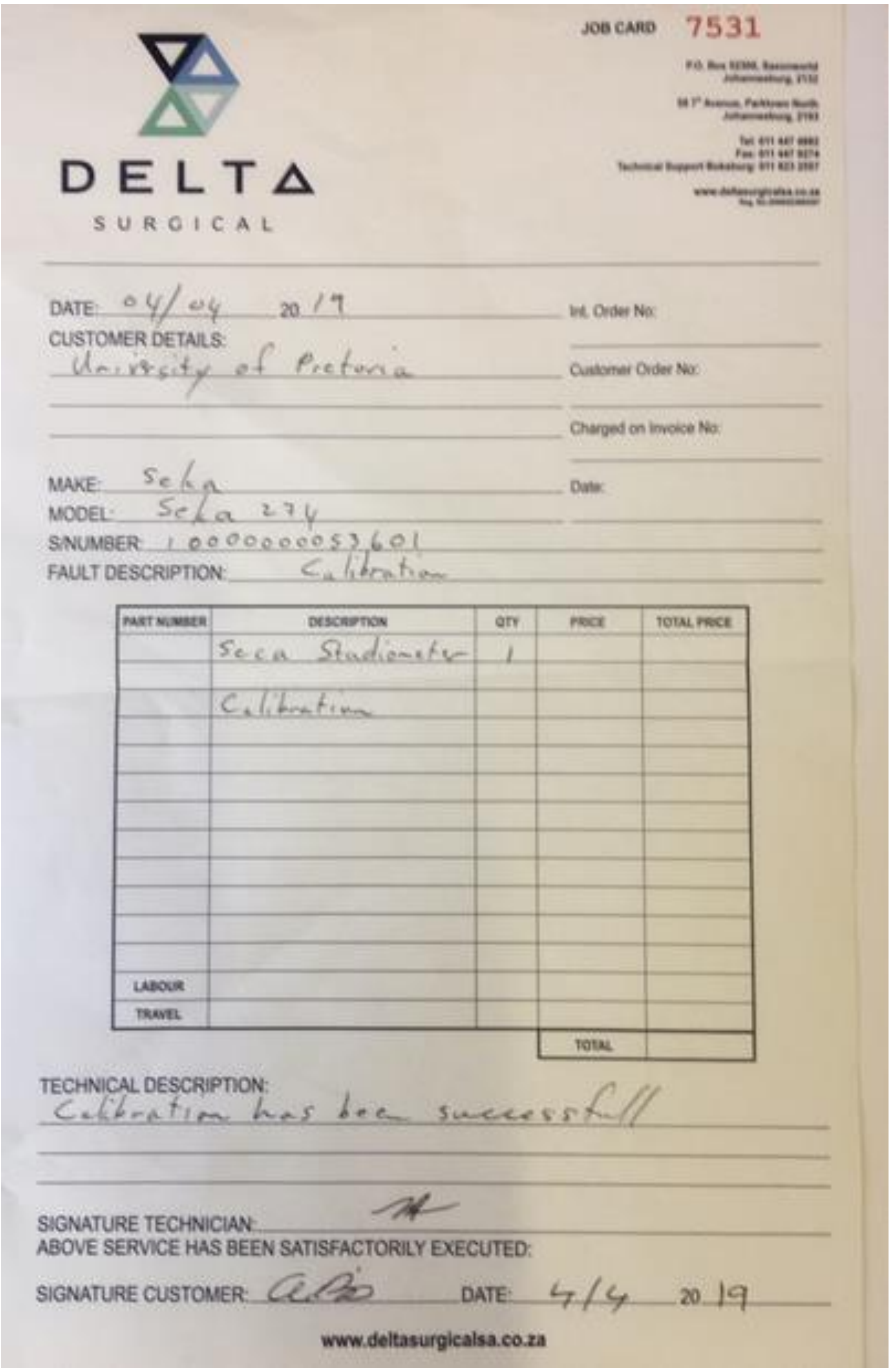
Witness Name: _____________________________

Signature: _________________________________ Date: ___________________

# ANNEXURE C

## Calibration and service certificates

## C-1 CALIBRATION CERTIFICATE FOR SECA 274 DIGITAL STADIOMETER



DELTA SURGICAL

JOB CARD 7531

www.deltasurgicalsa.co.za

DATE: 04/04 20 19

Int. Order No:

CUSTOMER DETAILS:

University of Pretoria

Customer Order No:

Charged on Invoice No:

MAKE: Seka

Date:

MODEL: Seka 274

S/NUMBER: 10000000053601

FAULT DESCRIPTION: Calibration

| PART NUMBER | DESCRIPTION | QTY | PRICE | TOTAL PRICE |
|---|---|---|---|---|
| | Seca Stadiometer | 1 | | |
| | | | | |
| | Calibration | | | |
| LABOUR | | | | |
| TRAVEL | | | | |
| | | | TOTAL | |

TECHNICAL DESCRIPTION:

Calibration has been successfull

SIGNATURE TECHNICIAN:

ABOVE SERVICE HAS BEEN SATISFACTORILY EXECUTED:

SIGNATURE CUSTOMER: DATE: 4/4 20 19

www.deltasurgicalsa.co.za

## C-2 CALIBRATION CERTIFICATE FOR SECA mBCA 514

DELTA
SURGICAL

PO Box 52300
Saxonwold
2132
58 7th Avenue
Parktown North
Johannesburg
2193
Tel:+27 11 447 4882
Fax:+27 11 447 8274
Reg no 2008/023802/07
(F048D)

# CERTIFICATE OF CALIBRATION

Cerificate Number: 7531

Institution: University of Pretoria

Location: University

Model: SECA 514 MEDICAL BODY COMPOSITION ANALYSER

ProductSN 10000000057056

Next Service Date: 04/04/2021

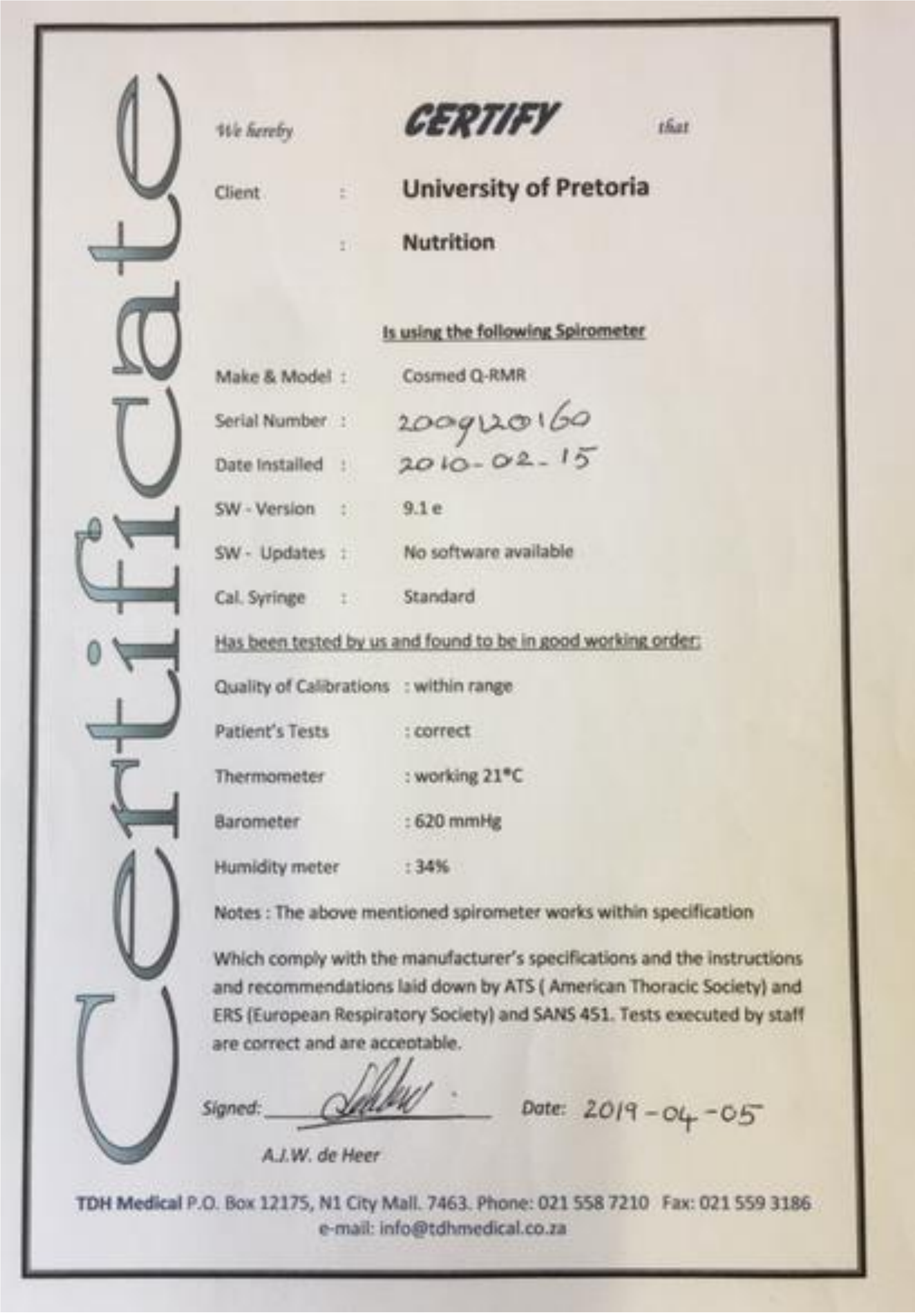
Service Engineer

04/04/2019

Date of Calibration

seca SAMARIT SCHMITZ Dr. Mach Baumanometer

## C-3 QUARK RMR SERVICE CERTIFICATE



Certificate

*We hereby* **CERTIFY** *that*

Client : **University of Pretoria**

: **Nutrition**

Is using the following Spirometer

Make & Model : Cosmed Q-RMR

Serial Number : 200912016O

Date Installed : 2010-02-15

SW - Version : 9.1 e

SW - Updates : No software available

Cal. Syringe : Standard

Has been tested by us and found to be in good working order:

Quality of Calibrations : within range

Patient's Tests : correct

Thermometer : working 21°C

Barometer : 620 mmHg

Humidity meter : 34%

Notes : The above mentioned spirometer works within specification

Which comply with the manufacturer's specifications and the instructions and recommendations laid down by ATS ( American Thoracic Society) and ERS (European Respiratory Society) and SANS 451. Tests executed by staff are correct and are acceptable.

*Signed:* ____________ *Date:* 2019-04-05

*A.J.W. de Heer*

**TDH Medical** P.O. Box 12175, N1 City Mall. 7463. Phone: 021 558 7210 Fax: 021 559 3186
e-mail: info@tdhmedical.co.za

# ANNEXURE D

## Supplementary information

# D-1: SUPPLEMENTARY PAQ-C STATISTICAL ANALYSIS

## RELATIONSHIP BETWEEN AVERAGE STEPS/DAY AND AVERAGE OF EACH PAQ-C CATEGORY (N = 94)[a]

| Variable | Population | r[b] | P-value[c] |
|---|---|---|---|
| PAQ-C 1 Average | **Black African** | 0.0251 | 0.8641 |
| | **White** | 0.2434 | 0.1071 |
| PAQ-C 2 Average | **Black African** | -0.0750 | 0.6086 |
| | **White** | 0.0632 | 0.6802 |
| PAQ-C 3 Average | **Black African** | 0.2051 | 0.1574 |
| | **White** | 0.2481 | 0.1004 |
| PAQ-C 4 Average | **Black African** | 0.1969 | 0.1751 |
| | **White** | 0.2531 | 0.0935 |
| PAQ-C 5 Average | **Black African** | 0.0185 | 0.8996 |
| | **White** | 0.3306 | 0.0265 |
| PAQ-C 6 Average | **Black African** | 0.0600 | 0.6822 |
| | **White** | -0.1445 | 0.3436 |
| PAQ-C 7 Average | **Black African** | 0.0479 | 0.7438 |
| | **White** | 0.1966 | 0.1955 |
| PAQ-C 7 Average | **Black African** | 0.1139 | 0.4360 |
| | **White** | 0.1727 | 0.2567 |
| PAQ-C 7 Average | **Black African** | 0.1340 | 0.3586 |
| | **White** | 0.2574 | 0.0878 |

[a] Black African n = 48; white n = 40

[b] Spearman’s product-moment correlation

[c] Level of statistical significance

## ANNEXURE E

# Ethical and financial considerations

# E-1: ETHICS APPROVAL CERTIFICATE 14 MARCH 2019

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

14 March 2019

**Approval Certificate**
**New Application**

**Ethics Reference No.: 757/2018**
**Title: Factors related to resting energy expenditure and physical activity of 6-8-year old children in two primary schools in the City of Tshwane Metropolitan area**

Dear Ms A Pretorius

The **New Application** as supported by documents received between 2019-03-06 and 2019-03-13 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-03-13.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-03-14.
- Please remember to use your protocol number (757/2018 ) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

**Ethics approval is subject to the following:**

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

**Yours sincerely**

**Dr R Sommers**
MBChB MMed (Int) MPharmMed PhD
**Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

*The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)*

Research Ethics Committee
Room 4-60, Level 4, Tswelopele Building
University of Pretoria, Private Bag X323
Arcadia 0007, South Africa
Tel +27 (0)12 356 3084
Email deepeka.behari@up.ac.za
www.up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

# E-2: ETHICS CERTIFICATE WITH AMENDED TITLE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

**Institution:** The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

16 March 2020

**Approval Certificate**
**Amendment**

**Ethics Reference No.: 757/2018**

**Title: FACTORS RELATED TO RESTING ENERGY EXPENDITURE AND PHYSICAL ACTIVITY OF 6-9-YEAR OLD CHILDREN IN TWO PRIMARY SCHOOLS IN THE CITY OF TSHWANE METROPOLITAN AREA.**

Dear Ms A Pretorius

The **Amendment** as supported by documents received between 2020-02-25 and 2020-03-11 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2020-03-11.

Please note the following about your ethics approval:

- Please remember to use your protocol number (757/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

**Ethics approval is subject to the following:**

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

**Yours sincerely**

**Dr R Sommers**
MBChB MMed (Int) MPharmMed PhD
**Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

*The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).*

Research Ethics Committee
Room 4-60, Level 4, Tswelopele Building
University of Pretoria, Private Bag x323
Gezina 0031, South Africa
Tel +27 (0)12 356 3084
Email: deepeka.behari@up.ac.za
www.up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

## E-3: SCHOOL A APPROVAL LETTER

2 April 2019

Dear Mrs Pretorius

**RE: CONTACTING GR 1-3 LEARNERS AT THE AFTERCARE CENTRE OF [redacted]**

Further to our previous communication, I am pleased to confirm that you can use an allocated venue at the aftercare centre [redacted] during the second quarter of 2019, for the completion of a physical activity questionnaire with grade 1-3 learners who took part in a research study conducted at the University of Pretoria. I am also aware that an observational questionnaire about the school's food and physical activity environment would need to be completed by yourself while being engaged with the project.

Although the school provides permission to use the premises of the aftercare centre, it is the researcher's responsibility to contact the parents and their children to obtain the required consents/assent to participate in the research study and for any additional arrangements.

Kind regards

[redacted]

## E-4: SCHOOL B APPROVAL LETTER

**15 July 2019**

Dear Mrs Pretorius

**RE: CONDUCTING A RESEARCH STUDY AT [redacted]**

Further to our previous communication, I would like to inform you that [redacted] agreed to the participation of our school in the research study to determine the resting energy expenditure and physical activity levels of grade 1-3 pupils.

We confirm that you can use an allocated venue on the premises of the school during the third quarter of 2019 between 6h30 and 7h30 in the mornings before school starts.

You can contact the parents via an invitation letter to explain the procedure and measurements. Both parents and children would need to provide their consent/assent for the participation in the study.

Kind regards

[redacted]

..........................................

## E-5: FINANCIAL REPORT

| Date | Description | | TOTAL AMOUNT |
|---|---|---|---|
| 2019/03/20 | Transport of equipment | | **R4 807,69** |
| 2019/10/30 | Research assitants | | **R7 243,50** |
| 2019/04/02 | Quark anti-bacterial filters; permatube | | **R6 888,90** |
| 2019/03/29 | Disposable items e.g. battery for Quark RMR, cleaning wipes, masking tape | | **R1105,55** |
| 2019/10/08 | Printing & Stationary | | **R675,73** |
| 2019/03/16 | Space tent | R308,00 | **R1 828,50** |
| 2019/04/04 | Strecher/bed for RMR measurement & sationary (paper) | R750,98 | |
| 2019/04/11 | Waist bands and buckles to attach pedometers | R309,50 | |
| 2019/04/11 | Thermometer | R89,90 | |
| 2019/04/26 | Double electrical plug & breakfast snack | R199,54 | |
| 2019/04/27 | 2 point plug & stationary | R60,08 | |
| 2019/05/30 | Waist bands and buckles to attach pedometers | R110,50 | |
| 2019/09/01 | SMS Airtime minutes | | **161,42** |
| 2019/10/10 | Breakfast snack | | **R3 171,87** |
| 2020/09/07 | ICD Conference attendance and presentation | | **R4 700,00** |
| 2020/12/10 | Editing and printing costs of thesis doucment | | **R10 000,00** |
| **TOTAL EXPENDITURE TO DATE** | | | **R40 583,16** |
| | | | **≈$2 700** |

## ANNEXURE F

# - Additional reports -

# F-1: TURNITIN ORIGINALITY REPORT

Document Viewer

## Turnitin Originality Report

Processed on: 13-Dec-2020 07:17 SAST
ID: 1473511960
Word Count: 46945
Submitted: 1

Thesis By Adeline Pretorius

| Similarity Index | Similarity by Source | |
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https://adaevidencelibrary.com/vault/2440/web/EE_Non-CriticallyIll_JAND20151.pdf

<1% match (publications)
Stephen Heung-sang Wong. "Validity of Bioelectrical Impedance Measurement in Predicting Fat-Free Mass of Chinese Children and Adolescents", Medical Science Monitor, 2014

<1% match (Internet from 04-Jun-2016)
http://www.ncbi.nlm.nih.gov

<1% match (Internet from 30-Jun-2009)
http://www.abdn.ac.uk

<1% match (publications)
Susan Fullmer, Sue Benson-Davies, Carrie P. Earthman, David C. Frankenfield et al. "Evidence Analysis Library Review of Best Practices for Performing Indirect Calorimetry in Healthy and Non–Critically Ill Individuals", Journal of the Academy of Nutrition and Dietetics, 2015

<1% match (Internet from 31-Mar-2015)
http://jap.physiology.org

<1% match (Internet from 23-Nov-2019)
http://zakboekdietetiek.nl

## F-2: REPORT FROM LANGUAGE EDITOR


*Alexa Barnby*

*Language Specialist*

Editing, copywriting, indexing, formatting, translation

BA Hons Translation Studies; APEd (SATI) Accredited Professional Text Editor, SATI

Mobile: 071 872 1334

Tel: 012 361 6347 alexabarnby@gmail.com


11 December 2020

To whom it may concern

This is to certify that I, Alexa Kirsten Barnby, an English editor accredited by the South African Translators' Institute, have edited the doctoral thesis titled "Factors related to resting energy expenditure and physical activity of 6–9-year-old children in two primary schools in the City of Tshwane Metropolitan Area" by Adeline Pretorius.

The onus is on the author, however, to make the changes and address the comments made.