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Food patterns in relation to weight status and body composition of female adolescents in Tshwane

Research proposal for the degree Master of Nutrition

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Date: November 2022

Abstract

Introduction: In South Africa there is a high prevalence of overweight/ obesity among adolescence, which in turn indicates an increased risk of non-communicable diseases (NCDs) in adulthood (DoH, 2016, WHO, 2018). Obesity/overweight is linked to a diet high in saturated fat foods (e.g. fast foods), snacks and/or sugar added foods and beverages (Popkin et al., 2012, Romieu et al., 2017). **Aims:** This cross-sectional study aimed to determine the relationship between food patterns, and weight status (BMI-for-age) and body composition (BC), respectively, of female adolescents (N=91) aged 13 – 19 years attending two private schools in the City of Tshwane. **Methods:** Convenience sampling was used to recruit participants. Weight and height were measured with the Seca mBCA 514 and stadiometer 274, respectively, and used to calculate the body mass index (BMI). World Health Organization reference standards were used to obtain BMI-for-age z-score. Bioelectrical impedance analysis with the Seca mBCA 514 was used to obtain frequency outputs for the calculation of fat mass (FM) and fat free mass (FFM). The rapid eating assessment for patients (REAP) questionnaire was used to assess food patterns and obtain a diet quality score, in total and per food group. The Spearman correlation test was performed to determine the relationship between REAP scores and: FM, FFM, fat mass index (FMI), fat free mass index (FFMI) and BMI-for-age z-score, respectively. **Results:** The mean BMI-for-age z-score was 0.62 (0.37; 0.87), FM was 23.50kg (21.77; 26.32), FFM was 39.03 kg (38.07; 39.98), FMI was 8.95 kg/m^2 (8.26; 10.03), FFMI was 14.79 kg/m^2 and total REAP score was 52.95 (51.62; 54.27). A total of 29.2% was overweight and 8.99% obese. A moderate, statistically significant correlation was found in the overweight category between the REAP score for whole grains/starch consumption and FFM (r=0.51, p=0.01) and FFMI (r=0.47, p=0.02), respectively, and between high sodium consumption and FM (r=0.42, p=0.04). A weak, negative, yet statistically significant correlation was found between the dairy consumption and FFM (r= -0.30, p=0.04) of the black African subgroup. Lastly, a moderate, negative, yet statistically significant correlation was found between the dairy consumption and FFM (r=-0.40, p=0.05) of the overweight category. **Conclusion:** The present findings indicate that participants have a poor-quality diet including a high consumption of fats and oils, sugar, sodium and high fat meat, and a low consumption of fruits and vegetables and whole grains. The BMI-for-age z-scores, FM and FMI indicate that a high percentage of participants were overweight with an increased risk of developing NCDs later in life. The correlation analysis could not be used to draw a meaningful conclusion about the relationship between dietary intake and BMI-for-age z-score, FM, FMI, FFM and FFMI. Future research may need to include a more detailed analysis of dietary intake.

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Concept definitions

- Food patterns generally refer to different types of food groups consumed, quantities per serving, and the frequency at which the food is consumed (Schulze et al., 2018). Food patterns assist individuals consume food according to dietary guidelines/recommendations (USDA, 2014). In this study food patterns include/refers to the consumption of whole/grains, fruits & vegetables, dairy, fats & oils, meats, high sugar foods and high sodium foods respectively and in total.
- Weight status
  - BMI is an index of weight-for-height that is commonly used for overweight and obesity classification in adults (WHO, 2021). In this study, weight status will refer to BMI-for-age z-scores as defined by the WHO: overweight >+1SD, obesity >+2SD and thinness < -2SD (WHO, 2009, WHO, 2020).
- Body composition
  - Fat mass and fat free mass (muscle mass, bone mass, body water) make up total body weight and as a collective these compartments are referred to as body composition (BC) (Kuriyan, 2018, Bienertova-Vaska, 2011). For this study fat mass (FM), fat mass index (FMI), fat free mass (FFM) and fat-free mass index (FFMI) were used when referring to body composition. FFMI and FMI are calculated by dividing the FFM and FM with the height (m) squared, respectively (Shypailo and Wong, 2020).
- Adolescents are defined to be aged between 10 – 19 years (WHO, 2006). For this study only adolescents between the ages of 13 – 19 years were included because the population used was that of high school learners and this is the general age range of high school learners in South Africa.
- Population groups will be referred to as black African, Indian/Asian or white (StatsSA, 2022).

Abbreviations

- BC – Body composition
- BMI – Body Mass Index
- BMI-for age – Body Mass Index for age
- DoH – The Department of Health
- FFM – Fat free mass
- FFMI – Fat free mass index
- FFQ – Food Frequency Questionnaire
- FM – fat mass
- FMI – Fat mass Index
- HEI – Healthy Eating Index
- HSFSA – The Heart and Stroke Foundation in South Africa
- NCDs – Non-communicable diseases
- NDoH – National Department of Health
- REAP – Rapid Eating Assessment for Patients
- SADHS – South Black African Demographic and Health Survey
- SANHANES – South Black African National Examination Survey
- USDA – U.S Department of Agriculture
- WHO – World Health Organization

1. Chapter 1

1.1 Introduction

Overweight and obesity is an increasing health concern globally. In the last decade the number of overweight/ obese people has exceeded the number of those underweight for the first time in history (DoH, 2016). In South Africa, females aged 15 and above, have a higher prevalence of obesity than males (39.2% and 10%, respectively) (Sartorius et al., 2017, DoH, 2016). Overweight/obesity is classified as an accumulation of excess body fat (DoH, 2016, WHO, 2018). Overweight/obesity during adolescent years can result in the development of related non-communicable diseases (NCDs) in adult years (Patton et al., 2016, Corkins et al., 2016). These NCDs include, cardiovascular disease, cancer, chronic respiratory disease and diabetes (DoH, 2016, WHO, 2018). Obesity is responsible for approximately 5% of deaths worldwide and in South Africa (SA) obesity is ranked fifth as a risk factor of early death and years of life lived with disability or disability-adjusted life years (DALYS) (DoH, 2016).

Generally, body mass index (BMI) is used to define obesity or overweight, with a BMI of 30kg/m^2 indicating obesity and a BMI between 25kg/m^2 and 30kg/m^2 indicates overweight in adults (Misra and Dhurandhar, 2019). For children and adolescents, BMI-for-age is the used indicator. The BMI-for-age WHO growth charts use z-scores as cut offs for the different categories. The z-scores between +1 and +2 indicate overweight, between +1 and -1 indicate a healthy weight, smaller than -2 indicate thinness and bigger than +2 indicate obesity (WHO, 2020, WHO, 2009). Although BMI is often used for weight status measurements, it has the limitation of not being able to distinguish between fat mass and muscle mass. This limitation can lead to over estimation of overweight in adolescents (Tyson and Frank, 2018, Simmonds et al., 2015), making it necessary to also consider BC measurements.

Body composition measurements are required to more accurately identify the weight status of adolescents by indication of different body compartments such as fat mass and fat-free mass, which make up the total body weight of an individual. Fat mass is important in determining overweight and obesity, and can be used to overcome the BMI limitation (Bienertová-Vašků, 2011).

Health and wellbeing are crucial during the adolescent stage because of physical and cognitive developments. These developments place an increased requirement of nutrients on the body, thus making nutrition (a healthy diet) an important element in an adolescent’s life. Good nutrition/ a healthy diet can prevent development of chronic diseases. A poor diet that has a high content of energy-dense foods and a low content of nutrient-dense foods can affect optimal development physically and cognitively, causing negative implications for the adult lives of such adolescents (Patton et al., 2016, Corkins et al., 2016).

Food patterns encompass the quantities, proportions, variety of foods and drinks and the frequency at which they are consumed (Schulze et al., 2018). The recommended food patterns to be followed by healthy South Africans aged 5 years and older, are described through the South African Food Based Dietary Guidelines (FBDGs), which will be used as a reference in the study. An incorrect adherence to an aspect that describes food patterns can lead to health issues such as obesity (FBDG-SA, 2013). South African adolescents typically have a frequent consumption of fast foods, fried foods, snacks and sugar added foods/beverages (high energy-dense foods) (Venter and Winterbach, 2010, Shisana et al., 2013, NDoH et al., 2019).

Studies investigating the relationship between food patterns or dietary intake and weight status in South African adolescents are limited, showing that an increased consumption of saturated fats as meals or snacks and sugar added beverages/foods increase the risk of overweight/obesity (Craig et al., 2016, Feeley et al., 2013, Sartorius et al., 2017, Venter and Winterbach, 2010, Sedibe et al., 2018).Available literature shows that such studies were mostly conducted in the United States (Larson et al., 2016, Tripicchio et al., 2019, Cutler et al., 2012) and West Africa (Onyiriuka et al., 2013). These studies showed that fruit and vegetables are associated with a low risk of overweight or obesity and meal skipping and snack/high energy-dense foods consumption are associated with an increase in risk of being overweight or obese (Onyiriuka et al., 2013, Cutler et al., 2012, Tripicchio et al., 2019, Larson et al., 2016).

While these studies contribute useful information towards understanding how some aspects of food patterns affect weight status, they are mainly limited to the American population and weight status, and not body composition per se. It is important to explore all the aspects describing food patterns and to determine the relationship between the food patterns and weight status and body composition, as well as to provide insight into the high prevalence of obesity / overweight among adolescent females in South Africa.

1.2 Problem Statement

In South Africa, there is a high prevalence of obesity and/or overweight among adolescents females, more so than among males (DoH, 2016). Obesity during adolescence may increases the risk of NCDs in adulthood, including cardiovascular disease, cancer, chronic respiratory disease and diabetes (WHO, 2018). The increased prevalence of obesity is associated with a westernised diet and unhealthy food patterns including low-cost calorie-dense foods such as refined carbohydrates, fats and foods with added sugar (Popkin et al., 2012, Romieu et al., 2017). A healthy food pattern according to the FBDGs is advised for children, adolescents and adults to reduce the risk of overweight/obesity and related NCDs (FBDG-SA, 2013).

International research available to understand the association of dietary patterns and weight status of adolescents are limited and focus mainly on; dairy and high calorie snacking, (Nezami et al., 2016, Tripicchio et al., 2019, Onyiriuka et al., 2013, Larson et al., 2016).In addition, South African studies exploring the relationship of dietary patterns on weight status/body composition is limited and those available mostly focus on high fat/energy-dense foods or sugar added foods and beverages (Sedibe et al., 2018, Feeley et al., 2013, Craig et al., 2016).

With the high prevalence of obesity among South African adolescents, in-depth investigation into the association between dietary patterns and weight status/body composition is necessary, as it may provide further insight into understanding the obesity pandemic that affects South African females.

1.3 Aim and objectives

The aim of the study is to determine the relationship between weight status (BMI-for-age z-score) and body composition (BC) on the one hand, and food patterns on the other, of female adolescents aged 13–19 years attending two private schools located in the City of Tshwane metropolitan area.

Objectives:

To assess and describe, female adolescents attending two private school in the city of Tshwane Metropolitan area, according to:

1. Socio demographic background:
    a. Population groups
    b. Age
    c. Gender
2. Weight status including:
    a. Height and weight measurements to determine BMI-for-age z-scores
3. Body composition including:
    a. FM
    b. FMI
    c. FFM

   d. FFMI
4. Food patterns, (quantified using the REAP score) including:
   a. Whole grains/starchy foods
   b. Fruit and vegetables
   c. Dairy
   d. Fats and oils
   e. Meat (poultry, red meat, fish, processed meats)
   f. High sugar snacks and drinks
   g. High sodium processed foods
   h. Total diet quality
5. Determine the relationship between weight status (BMI-for-age z-score), and the REAP score of each food group / pattern and total REAP score, respectively.
6. Determine the relationship between each body composition variable (FM, FMI, FFM and FFMI), and the REAP score of each food group / pattern and total REAP score, respectively.

1.4 Study benefits

There is a limit in South African literature available on the association between dietary patterns and the association they have on the weight status and body composition of adolescent females. This study aims to lessen the limit in widening the scope of dietary patterns previously studied and their relationship on weight status and body composition. This may help direct nutrition interventions, to help reduce overweight and obesity statistics among female adolescents residing in Gauteng.

1.5 Conceptual Framework

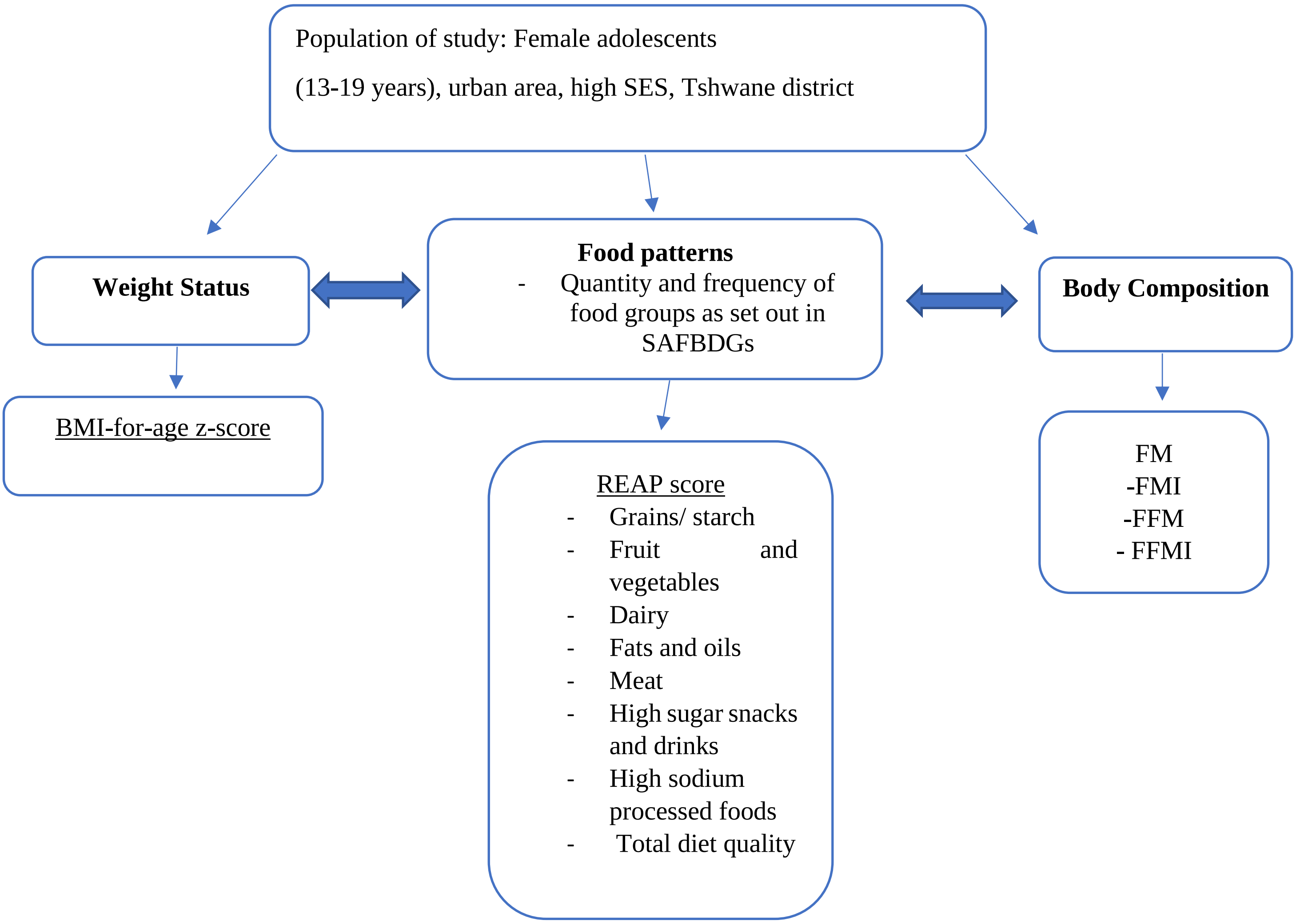

Figure 1: Conceptual framework

2. Chapter Two: Literature Review

2.1 Introduction

Overweight and obesity has been increasing across all populations globally, and in South Africa, obesity has been ranked fifth as a factor for early death and life with disability (DoH, 2016). In South Africa, females aged 15 and above, have a higher prevalence of obesity among them than males (39.2% and10%, respectively) (Sartorius et al., 2017, DoH, 2016). Overweight or obesity during adolescent years can result in the development of related NCDs in adult years (Patton et al., 2016, Corkins et al., 2016).

An accumulation of excess body fat is what leads to obesity. This accumulation of fat can result from poor lifestyle choices, which are characterized by a high intake of energy-dense foods, a low intake of nutrient-dense foods and low to no physical activity/ sedentary behaviour. To avoid being obese or overweight, it is advised that an individual follow a healthy diet (Corkins et al., 2016, Patton et al., 2016, FBDG-SA, 2013).

Obesity is considered a risk factor for development of non-communicable diseases (NCDs). These NCDs include: high blood pressure, diabetes, cardiovascular diseases (e.g., stroke or congestive heart failure) and certain types of cancer (WHO, 2018). In addition, obesity in adolescents can also result in comorbidities such as type 2 diabetes, dyslipidemia, obstructive sleep apnea and steatohepatitis (Kumar and Kelly, 2017). Comorbidities in adolescent years have a negative impact on the health and wellbeing of adolescents. Health and wellbeing are important in adolescent years, as this is when organ growth and cognitive development takes place, and these processes require an increased nutrient intake (WHO, 2018, Patton et al., 2016, Corkins et al., 2016).

Psychologically, obesity can result in stigmatization, altered cognitive performance, low self-esteem, low self-worth, frustration and emotional disorders in adolescents. Low self-esteem and depression may harm the development and transition into adulthood of an adolescent. Studies have suggested that the association between depression and obesity is stronger among female than male adolescents (Elizondo-Montemayor et al., 2017).

This literature review will provide an explanation of what is meant by weight status, body composition and food patterns and also explore methods of measurement for these three variables. It will also provide available knowledge of the effect of food patterns on the weight status and body composition of female adolescents.

2.2 Weight status and Body composition

Even though 'weight status' is the term often used as an indicator for overweight and health/NCDs, it is actually the fat mass of an individual that is associated with overweight and/NCDs. Weight status is defined by the categories of obese, overweight or healthy and BMI is used to distinguish the difference between these categories (WHO, 2021). BMI is commonly used in adults; however, the National Institute of Health and Care Excellence (NICE) has recommended BMI to be a suitable tool to use for adolescents to classify overweight and obesity (WHO, 2021, Misra and Dhurandhar, 2019, Simmonds et al., 2015).

Fat mass, lean mass, bone mass and body water make up total body weight and as a collective these compartments are referred to as body composition (BC) (Kuriyan, 2018). Fat mass is important when tracking the changes in body weight and determining overweight and/or obesity (Kuriyan, 2018, Bienertova-Vaska, 2011).

2.2.1 Assessment of weight status in adolescents

BMI has been recommended as a practical method to assess weight status in adolescents but, adolescents experience growth and at times this may result in false readings of excess weight. To avoid this problem, BMI is standardized according to age and sex for adolescents to account for growth patterns and is then called BMI-for-age. BMI-for-age is a widely accepted and suitable method to assess thinness, overweight or obesity in adolescents (Simmonds et al., 2015, WHO, 2009).

BMI is determined by calculating the ratio of weight and height, expressed as kg/m^2. BMI-for-age is determined/ calculated the same way as BMI, but to interpret BMI-for-age, specific WHO growth charts are used. The WHO z-scores cut-offs on the charts are as follows (Table 1): overweight >+1 SD, obesity >+2 SD, thinness < -2 SD and -1SD≤ healthy <+1SD (WHO, 2020, WHO, 2009).

Table 1: WHO z-score cut offs for BMI

Weight Category	**Z-score**
Obesity	>+2 SD*
Overweight	>+1SD
Healthy	-1SD ≤ healthy ≤ +1SD
Thinness	< -2SD >

*SD - Standard deviation

Standard deviation (SD) represents the dispersion of data in relation to the mean. The mean in this case would be a healthy BMI which falls along a z-score of zero on the relevant WHO growth chart (NLM, 2022, WHO, 2007). The cut-offs are based on the risk of cardiometabolic morbidity and premature mortality. The z-score classification/ standard deviation is suitable for adolescents because it is able to determine the nutritional status of an individual at extreme ends of the distributions on the growth charts (Adab et al., 2018, WHO, 2020, WHO, 2009).

BMI-for-age measures excess body weight instead of specifically measuring excess fat mass, therefore it can over estimate/under emphasize overweight in adolescents. For instance, a person with strong bones or well-developed muscles, but with a small/low fat mass could have a high BMI (bone and muscle are denser than fat) and be categorized as obese or overweight, when that is not the case. This limitation can therefore be aided by using body composition measurements for fat mass to verify the classification from the BMI-for-age growth charts (Tyson and Frank, 2018, Simmonds et al., 2015). Overweight and obesity are associated with high morbidity and mortality, which makes fat mass a valuable component to add when determining weight status (Kuriyan, 2018, Bienertova-Vaska, 2011). The advantage of BMI is, it is derived from measurements of height and weight which are the two anthropometric measurements commonly collected on children worldwide. These measurements are non-invasive, inexpensive to obtain and are easily understood by health practitioners or researchers and the individuals being measured (Himes, 2009).

2.2.2 Assessment of body composition in adolescents

Body composition is a term used to describe the different body compartments such as; fat mass, lean mass, bone mass and body water, making up the total body weight of a person. Body composition can be separated into two main compartments, namely, FM and FFM. Fat free mass is a combination of all tissues that have no fat in it and consists of muscle, bone, organs and other vital components such as blood and fluids. Fat free mass is made up of 72% water (extracellular and intracellular), 21% protein and 7% minerals, and it forms a structural and functional component of the body. Fat mass on the other hand, is found in organs and in adipose cells which are found under the skin and surrounding organs. Fat mass is made up of 20% water and 80% adipose tissue (Bienertova-Vaska, 2011).

Body composition can be analysed through different methods such as Bioelectrical Impedance (BIA), Dual-Energy X-ray Absorptiometry (DXA), Computed Tomography (CT) or Air Displacement Plethysmography (ADP) (Lee and Nieman, 2013, Kuriyan, 2018). Dual-Energy X-ray determines bone-mineral, bone FFM and the FM of all age groups. The disadvantages are it involves radiation, cannot accommodate large persons and it is expensive. However, it is considered the gold standard for BC measurements. Computed Tomography provides detailed cross-sectional images of the body, differentiating between skeletal muscle, visceral mass or organ mass. One of the disadvantages is that it exposes individuals to high radiation. Air Displacement Plethysmography measures body volume, body density and body fat. Its disadvantage is that it over estimates FM compared to DXA (Kuriyan, 2018, Lee and Nieman, 2013, Andreoli et al., 2016).

Bioelectrical Impedance measures BC by first estimating total body water (TBW) through the resistance of the body to a small alternating current and from that result, the total body FFM is acquired through the use of prediction equations. This method is commonly used for BC assessment in clinical practice and research studies. The advantages of BIA are, it's relatively low in cost compared to DXA, easy and quick to use, non-invasive (no exposure to radiation) and it is commonly used in clinical practice and research studies (higher availability) (Achamrah et al., 2018, Andreoli et al., 2016, Gonzalez et al., 2019, Kuriyan, 2018). The disadvantages of BIA are that it has poor accuracy in detecting the percentage changes in body fat and its possible source of error is dehydration. Despite these disadvantages some systematic reviews show that BIA is a practical and suitable tool to use to measure BC in adolescents when compared to reference methods (e.g., DXA) (Chula de Castro et al., 2018, Talma et al., 2013).

Bioelectrical Impedance has been developed to estimate the BC of adults and so there was a need to test its reliability for adolescents. Thivel et al. (2018) conducted a study to test the reliability of using BIA to estimate BC changes in adolescents (compared to DXA) and their results showed that BIA is reliable to provide an accurate measurement of BC in obese adolescents, however its reliability decreases when having to track changes with increasing body weight. The instrument used for this study was the Tanita MC-780 multifrequency segmental body composition analyzer (Thivel et al., 2018). Chiplonkar et al. (2017) conducted a study among healthy Indian adolescents (5-18 years) testing the validity of BIA against DXA for body fat percentage (%BF, r=0.92), FFM (r=0.98) and FM (r=0.965). Bioelectrical Impedance and DXA were similar in identifying BC values of healthy and overweight adolescents. The study further concluded that BIA and DXA are not interchangeable, however, BIA can be used for population studies, preferably with the addition of ethnic specific references (Chiplonkar et al., 2017).

Bioelectrical Impedance measures the resistance and reactance (impedance) to a small electrical current that passes through the body's water pool. Impedance is based on the concept that the flow of electricity is dependent on tissues of the body that have high electricity conductance. When estimating body fat using BIA, there is an assumption that the body is within normal hydration ranges because a good hydration level/ water level allows for high conductance of electricity. When a person is dehydrated the amount of fat tissue in the body can be overestimated. Dehydration can be a result of low water intake, heavy exercise, increased amounts of perspiration or alcohol use (Lee and Nieman, 2013). This limitation can be prevented by advising patients/ individuals to drink water or avoid alcohol before the day of performing the BIA test (Lee and Nieman, 2013).

Fat mass has lower water levels (10-20%) than FFM (70-75%), therefore the electrical signal passes through FFM with more ease. Impedance, height, weight and body type (gender or age) make it possible to calculate body fat, FFM and other BC values (Kuriyan, 2018, Andreoli et al., 2016, Bienertova-Vaska, 2011).Fat free mass is calculated from TBW assuming that 72 – 73% of the body's FFM is water. To estimate FM the difference between body weight and FFM is calculated. Fat mass includes fat surrounding body organs and the fat cells underneath the skin (Hofsteenge et al., 2015).

Table 2 summarises a list of various BIA FFM equations which have been tested against DXA measurements, for healthy, overweight and obese adolescents. The BIA methods used for these equations were run at a frequency of 50kHz, as this is a standard frequency for body composition tests (de Castro et al., 2018, Steinberg et al., 2019, Wong, 2014). The Kyle and Gray equations were initially derived for use in adults but have been tested among adolescents (obese adolescents) (Steinberg et al., 2019). In addition, the Hamilton equation (Steinberg et al., 2019) and the equation by Hofsteenge et al. (2015), were also developed for a population of obese and severely obese adolescents. Although these four equations had a significant correlation to the DXA standard, they are valid for only obese adolescents.

Equations developed by Deurenberg et al. (1991), Schaefer et al. (1994) and Haroun et al. (2009) were tested among adolescents with various weight statuses and they had significant correlations with DXA equations, with respective r^2 values of 0.97, 0.975, 0.96, The population groups of the adolescent sample used in the Schaefer et al. (1994) and Deurenberg et al. (1991) was not clear, resulting in an uncertainty of appropriateness to use for the study at hand. The adolescent sample tested by Haroun et al. (2009) was of a white population group, which was not appropriate for the study at hand.

Most FFM equations have not been developed/tested for the South African population which places a limit on the equations which can be used for the South African population. In light of this limitation, the Horlick et al. (2002) appears to be the best suited to use for the South African population. This equation was tested for healthy adolescents and a small number of adolescents with HIV. The equation was tested among Americans with different populations groups, which are as follows; white, black, Black African American, Hispanic and non-Hispanic(Horlick et al., 2002).

Table 2: Prediction equations for fat free mass (FFM) based on children and adolescents with a healthy weight and/ or obese

Reference	**Population**	**Equations**	**R^2**
• Wong (2014)	9 – 19 yr Chinese	• FFM= 1.613 + 0.742 x ZI + 0.151 x body weight ZI = height cm^2/ impedance (Ω)	0.95
• (Horlick et al., 2002)	4 – 18 yr Health & HIV infected Asian, Black African American, Hispanic, White	• FFM = (3.474 + 0.459 H^2/R + 0.064W) / (0.769 – 0.009A – 0.016S) S = sex: 1 males, 0 females	0.997
• Deurenberg et al. (1991)	7-15 yr 16-83yr Netherlands	• ≤15y: 0.406*10^4*(Hm^2/Imp)+0.360 • ≥16y:0.340*10^4*(Hm^2/Imp)+15.34H(m)+0.273W -0.127age + 4.56sex – 12.44	0.97
• Hamilton equation (Steinberg et al., 2019)	12 – 18yr Severly obese White	• FM = 47.52 + (0.859 x weight) – (0.0703 x Z) – (0.9722 x RI)	R^2 =0.73
• Schaefer et al. (1994)	3-19yr German	• FFM = 0.65(H^2/Imp) + 0.68age + 0.15	R^2 = 0.975
• Haroun et al. (2009)	5-22yr	• FFM = -2.211 + 1.115(H^2/Imp)	R^2 = 0.96
• (Hofsteenge et al., 2015)	11-18yr Obese Amsterdamn	• FFM = 0.527(H^2/Imp) + 0.306(weight) – 1.862	R^2 = 0.92
• Kyle equation (Steinberg et al., 2019).	20 – 29yr Obese	• FFM = -4.104 + 0.818(H^2/R) + 0.231W + 0.130Reac + 4.229Sex	R^2 =0.78
• Gray equation (Steinberg et al., 2019)	19 – 74yr Obese adolescents Adults	• FFM = 0.00151H^2 – 0.0344R + 0.140W – 0.158Age + 20.387	R^2 =0.92

2.2.2.1 Fat free mass index and fat mass index

FFM and FM are often interpreted in terms of weight and this is not always ideal because for example, in the case that someone has protein malnutrition their FM% will be the same as that of a healthy individual (Shypailo and Wong, 2020). Therefore, more clinically relevant height-normalized indexes, fat-free mass index (FFMI) and fat mass index (FMI), are used to avoid misinterpretation of results among individuals and get a more accurate sense of the individual's FM or FFM. FMI and FFMI are calculated by dividing the FM or FFM by the height squared of the individual, respectively (Shypailo and Wong, 2020, Wells, 2014).

There are various ranges available for the cut off values of FMI and FFMI and Table 3 gives a summary of some of the available ranges. A study done on healthy adolescents in Japan, between the ages of 3 – 11 years made use of a healthy range of FMI 3.2 – 3.8 kg/m^2 and FFMI 12.0 -13.0 kg/m^2 (Nakao and Komiya, 2003). In a study by Oliveira et al. (2016), the same FMI and FFMI ranges used by Nakao and Komiya (2003) were adopted and used on a population of Brazil adolescents (10 – 14years), attending both private and public schools. Another study by (Kyle et al., 2003) on a population of white women from Switzerland, of the ages 15 – 98 years, used the ranges FMI 4 – 8.1 kg/m^2 and FFMI 14.9 – 16.9 kg/m^2 and a study done by Alpízar et al. (2020) on Mexican adolescents (6 – 12 years) proposed a cut off for FMI of 2.1 – 4.1 kg/m^2, however this range requires validation. The ranges suggested by Shypailo and Wong (2020) are specific to ethnicity. These ranges were tested on adolescents in Huston, Texas with different populations groups of black, white and Hispanic.

Table 3: Cut off ranges for fat mass index (FMI) and fat free mass index (FFMI)

Population	Range (Unit = kg/m^2)	Reference
White women in Switzerland 15 - 98 years	FFMI: 14.6 – 16.8 FMI: 3.9 – 8.2	(Kyle et al., 2003)
Mexican adolescents 6 – 19 years	FMI: 2.1 – 5.9	(Alpízar et al., 2020)
Healthy adolescents from Huston, Texas 4 – 19 years B – black W – white H – Hispanic	FFMI (B): 12.56 – 16.58 FFMI (W/H): 12.17 – 15.30 FMI (B): 1.21 – 2.00 FMI (W): 1.13 – 1.97 FMI (H): 1.30 – 2.14	(Shypailo and Wong, 2020)
Healthy adolescents from Japan 3 – 11 years	FFMI: 12.0 – 13.0 FMI: 3.2 – 3.8	(Nakao and Komiya, 2003)

2.2.3 Causal factors for obesity or overweight

An unhealthy diet and low physical activity can lead to a risk of weight gain/ obesity (Cheng et al., 2016, Hruby et al., 2016). An unhealthy diet is one that consists of a high consumption of saturated fats, trans – fats and refined grains (Hruby et al., 2016). Rapid growth and economic changes in low income countries has caused a change from traditional plant-based diets to diets with highly processed foods and beverages which contain less nutrients (Romieu et al., 2017).

Low physical activity also promotes a higher intake of sweets, calorie-dense and high glycaemic index foods, which are considered as part of an unhealthy diet when their consumption is increased. (Cheng et al., 2016). These types of foods are also known as energy dense foods. When a person's energy intake exceeds their energy expenditure, excess energy is stored in their body which then increases their body weight and they are at a risk of being overweight or obese (Romieu et al., 2017).

Adolescents who come from families where the parents have a low/middle education level have a higher risk of overweight/obesity, than those who have parents with a high education level. The prevalence of obesity among adolescents also much higher in a family where both parents are obese. In most cases obese parents create an obesogenic environment for themselves and for their children (Parrino et al., 2016, Birbilis et al., 2013). Another factor that can lead to overweight and obesity, is that in some Black African cultures, being overweight or obese is a trait that is admired and seen as a sign of wealth and a good life (Aigba et al., 2020).

2.3 Food patterns

Food patterns are defined as the type of food and drinks we consume, the quantities and the frequency in which we consume different food and drink items (Schulze et al., 2018). Guidelines for a healthy food pattern for South Africans are promoted through the South African Food Based Dietary Guidelines (SAFBDGs) (Vorster et al., 2013a).

2.3.1 South African Food Based Dietary Guidelines (SAFBDGs)

The SAFBDGs are short recommendations which exist to help consumers in choosing food and beverage combinations that form a diet which meets the nutrient needs of South Africans and lowers the risk of NCDs, including overweight and obesity (Vorster et al., 2013a). These guidelines are based on scientific evidence on the relationship between what South Africans eat and their health, and they are influenced by common health problems in South Africa. These guidelines are used for national and not global use. The Department of Health also created a

Food Guide (Figure 2), that is in line with the SAFDGs, to assist with the implementation of FBDGs in an effort to educate consumers about healthy eating (Vorster et al., 2013a).

Currently the South African FBDGs are as follows (FBDG-SA, 2013):

- Enjoy a variety of foods.
- Be active!
- Make starchy food part of most meals
- Eat plenty of vegetables and fruit every day.
- Eat dry beans, split peas, lentils and soya regularly.
- Have milk, mass or yoghurt every day.
- Fish, chicken, lean meat or eggs can be eaten daily.
- Drink lots of clean, safe water.
- Use fats sparingly. Choose vegetable oils, rather than hard fats.
- Use sugar and foods and drinks high in sugar sparingly.
- Use salt and food high in salt sparingly

Figure 2:The South African Food Guide (Vorster et al., 2013a).

2.3.1.1 Enjoy a variety of foods

A healthy diet is one that includes an intake of a variety of food groups in the recommended amounts. One food item/group does not contain all nutrients, which is why a variety of food groups is recommended to increase the intake of more nutrients. A diet with a low variety can be deficient in nutrients and may result in food insecurity and consequently malnutrition (Steyn, 2013).

2.3.1.2 Starchy foods/grains

Eating starchy foods is a part of the FBDGs to ensure that South Africans consume a sufficient amount of unrefined or minimally processed foods that are rich in starch and non -starch polysaccharides, fibre and micronutrients which can help protect against NCDs (e.g., heart disease, diabetes and cancer). Starchy foods also serve as a main source of energy in a diet (Steyn, 2013, Vorster, 2013, FBDG-SA, 2013).

2.3.1.3 Fruits and vegetables

The consumption of fruits and vegetables increase micronutrients in a diet and helps reduced the risk of many of the nutrition-related diseaes (e.g., cancer and cardiovascular disease) and risk factors that contribute substantially to the burden of disease in South Africa (Naudé, 2013).

2.3.1.4 Legumes

Legumes make part of the guideline because their contribution of protein and micronutrients helps to address undernutrition. Legumes are also ideal to inlcude in diets to reduce the risk of chronic NCDs, for example cardiovascular disease and diabetes (Venter et al., 2013).

2.3.1.5 Dairy

Milk and other diary products have a low sodium-to-potassium ratio and bioactive compounds which aid in protecting individuals against NCD's. The calcium in milk and other dairy products also helps regulate the body weight and bone mineral content in children (Vorster et al., 2013b).

2.3.1.6 Lean meat, Fish, chicken or eggs

Fish, chicken, lean meat or eggs are a source of high quantity and high quality protein, amino acids, B vitamins (B_1, B_2, B_6, B_{12}), naicin, iron and zinc, which are all essential for growth and development (Schonfeldt and Hall, 2013, Vorster et al., 2013b). Research has shown that there is a lack of B vitamins, naicin, iron and zinc in the diets of South Black Africans, hence the inlcusion of these food items in the guidelines (Schonfeldt and Hall, 2013).

2.3.1.7 Water

Considering hydration, water is a crucial nutrient for many bodily functions and an insufficient intake leads to dehydration which is detrimental to health (Van Graan and Bourne, 2013, Venter et al., 2013, Naudé, 2013, Vorster et al., 2013b, FBDG-SA, 2013).

2.3.1.8 Fats and oils

The FBDGs specify vegetable oils rather than hard oils (solid at room temperature) because hard oils mostly don't contain the fatty acids needed for prevention against NCDs in the right amounts/proportions and therefore are not classified as good quality fats. Good quality fats are required for early growth and development, which later in life influence the body's response to NCDs. The quality of fat is determined by the proportion of polyunsaturated fatty acids (PUFA) it contains. Fats and oils also serve as a second source of energy in a diet (Smuts and Wolmarans, 2013).

2.3.1.9 Sugar

Sugar intake can displace food that a rich in micronutrients and so diets rich in sugar can be poor in micronutrient intake. Studies also indicate that high amounts of sugar in diets can increase the risk of diabetes and obesity. Studies suggest that an intake of 10% added sugar to the diet is an acceptable upper limit, hence the guideline instructing a sparing use of sugar between meals (Temple and Steyn, 2013).

2.3.1.10 Salt/sodium

An increased salt intake leads to high blood pressure. Blood pressure is a risk indicator for cardiovascular disease, coronary heart disease and strokes. This is why a sparing use of should of salt is recommended (Wentzel-Viljoen et al., 2013, Temple and Steyn, 2013, Smuts and Wolmarans, 2013).

2.3.2 Factors that may influence food patterns of adolescent girls

Adolescent food patterns/ diet choice behaviours have influences that can be summarised into four categories; intrapersonal, social environment, availability, mass media and advertising (macro-environment). Intrapersonal refers to biological and psychosocial factors. The social environment refers to the influence of peers and family members. Research shows that the peer pressure among females adolescents to purchase fast foods is more prevalent compared to among male adolescents (Van Zyl et al., 2010). The environment which a parent/parents create has a direct influence in an adolescent's food choices. For example, if there is a lot of restriction with food by the parents, an adolescent is most likely to consume a high number of snacks and food high in fat when they are not under parental supervision (Scaglioni et al., 2018).

Availability and access to fast food outlets, school tuckshops, food stores and vendors are external influences on adolescent food choices. The type of food found at these stores end up becoming what adolescents consume the most in a day. In developing countries, there is a positive association between frequent consumption of energy dense foods with urban residents and high socioeconomic status (SES) in adolescents (Steyn, 2010). Media messaging/ advertising has a large influence on adolescents. Most media messages influence a consumption of fast foods and other energy-dense foods and a decreased consumption of fruits and vegetables (Steyn, 2010, Scaglioni et al., 2018).

Other studies have shown that factors that influence adolescent food choices are: sensory (taste, appearance and smell), familiarity of the food, cooking method, food safety, time limitations/ convenience and taste. (Murimi et al., 2016, Van Zyl et al., 2010)

2.3.2 General dietary habits of adolescents in South Africa

Breakfast patterns

Studies have shown a trend of breakfast meal skipping among adolescent females (13 -19 years) in urban areas. This trend increases with age; the older the adolescent, the more likely they are to skip breakfast meals (Tee et al., 2015, Temple et al., 2006). Instead of consuming breakfast at home, they opt to purchase food sold at school vendors. The food purchased at the school vendors are usually unhealthy, high-energy dense foods and snacks (Tee et al., 2015, Sedibe et al., 2014, Feeley et al., 2012).

Fruits and vegetables

When looking at the population of South Africa, the consumption of fruit and vegetables is highest among the white South Africans at 71% and 84% respectively, and the lowest consumption among black South Africans at 46% and 57% respectively (NDoH et al., 2019). The SADHS (2016), showed that among adolescent respondents (n = 1371) 47.2% of them consumed fruit and 53.1% consumed vegetables.

The consumption of fruits and vegetables was high among residents of urban formal areas and low among residents of rural informal areas (Shisana et al., 2013, NDoH et al., 2019). In addition, females were more likely to consume fruits and vegetables than males were. Provincially, fruit and vegetable consumption are highest in the Western Cape. A different study has results showing that Gauteng has the highest percentage of fruit and vegetable consumption (NDoH et al., 2019).

Fruit juice and sugar added foods and beverages

The South African National Health and Nutrition Examination Survey (SANHANES) 2013, used a sugar score based on dietary habits to study the sugar in the diets of the learners. A high sugar score was based on a diet that had high levels of sugar and a low sugar score was based on a diet that had low levels of sugar (Shisana et al., 2013). The study showed that a high sugar score was seen among the age group of 15 – 24 years of age. Learners in urban formal areas had a higher mean sugar score than learners of other areas and low sugar scores were seen in rural formal areas. The highest percentage of high sugar users was seen in Gauteng and the lowest percentage of high sugar users was seen in the Eastern Cape. In addition, the highest rate of high sugar users were white people and the lowest rate of high sugar users were Indians (Shisana et al., 2013).Looking at school dietary patterns, females have more items in their lunch box as compared to the males, and some of the popular items in these lunch box were fruit and a fruit juice (Sedibe et al., 2014, Feeley et al., 2012).

Fast foods, fried foods, processed meats and snacks

Many adolescents in South Africa have a typical food intake of high-fat products, with fast foods or snacks as a use for meals (Venter and Winterbach, 2010). Studies have shown that adolescents consume an energy-dense diet frequently, which is poor in essential micronutrients (Steyn, 2010). There is a suggestion that adolescents from urban middle to upper socioeconomic areas have a lack of knowledge on dietary fat and they in turn consume diets that do not use fats sparingly (Venter and Winterbach, 2010).

Typically, adolescents in South Africa consume fast foods, fried foods, processed meats and snacks with added salt two to three times a week. They follow a diet high in fat over a diet with low-fat choices or desirable fat content. The high consumption of snacks is influenced by an increased viewing of television. The following foods are an example of what adolescents consume weekly; hot dogs, frankfurters, hamburgers, bacon, potato chips, corn chips, sweet biscuits fried chicken, red meat, cold cuts, doughnuts and mayonnaise (NDoH et al., 2019, Feeley et al., 2013, Venter and Winterbach, 2010, Steyn, 2010). The highest prevalence of high fat food consumption among adolescents is in Gauteng and the lowest prevalence in the Eastern Cape. In addition, high fat prevalence is higher among white adolescents, followed by black Africans and then Indians (Shisana et al., 2013).

In conclusion, typical food patterns of adolescents in South Africa include a consumption of vegetables more than fruits, and a frequent consumption of fast foods, fried foods, snacks and sugar added foods/beverages (high energy-dense foods) (Venter and Winterbach, 2010, Shisana et al., 2013, NDoH et al., 2019). Studies also show that skipping of breakfast meals at home is common among adolescents, and this increases the consumption of high energy-dense food or snacks from school vendors or tuckshops (Tee et al., 2015). This increased consumption of high-energy dense foods may lead to an increase in body fat leading to overweight and obesity and the lack of nutrient-dense foods may lead to nutrient deficiencies in the adolescent's body, interfering with the rate of growth and development (Corkins et al., 2016, Patton et al., 2016).

2.3.3 Assessment of food patterns

Dietary intake/food pattern is usually assessed for the purpose of comparing the average nutrient intakes among groups, ranking individuals intake within a group and estimating an individuals intake. Measurement/ assessment techniques are divided into two categories, namely, daily food consumption methods and recall/average food consumption methods. The daily food consumption methods include food records and 24-hour recalls. The average food consumption methods inlude diet history and food frequency questionnaires (Lee and Nieman, 2013).

Table 4 summarizes the different methods for assessing food patterns. The 24-hour recall is a subjective method that requires individuals to answer questions about their food and beverage consumption 24 hours before taking the assessment. It's disadvantages are that it may not be representative of the individuals usual intake. For a valid assessment of usual intake it needs to be done more than once(Rankin et al., 2010). Food records are a detailed recording of the time of consumption, type and quatity of food and beverage consumed over a period of time. The disadvantage with this method is that, it becomes a burden and leads to inaccurate record. A diet history records food intake over a long period, assessing usual intake over seasonal changes but has the disadvantage of being time consuming (Lee and Nieman, 2013, Shim et al., 2014).

A food frequency questionnaire (FFQ) is composed of a list of food groups or food items and the respondent/ individual has to indicatethe frequency and amount at which they consume each item over a specified period of time. The advantages of an FFQ is that it can be specific toa population, it assess usual diet intake, it is time efficient and cost effective as it does not require a trained interviewer. The disadvantages are that it uses close ended questions, it must be culturally sensitive to avoid under reporting and it is reliant on the respondent's memory (Shim et al., 2014, Lee and Nieman, 2013, Rankin et al., 2010). Despite these disadvantages, a systematic study done by Rankin et al. (2010) shows that an FFQ is a valid and reproducible method to use for dietary assessment among adolescents and it provides more of a comprehensive assement in a short time frame and can be used for large papulation groups (Shim et al., 2014).

Table 4: Different dietary assessment methods (Shim et al., 2014, Rankin et al., 2010)

	24-hour Recall	**Food Record**	**Diet History**	**Food Frequency Questionnaire (FFQ)**
Methods	A subjective measure of food consumed over a period of time	Record of time of consumption, type and quantity of food and beverage consumed	Measures diet intake over a long period of time (e.g a year)	Measures the frequency and amount at which a list of food items is consumed
Advantages	Open ended questions, can be used for a diverse group of people	Easy to use for individuals who mostly eat meals at home	Detailed usual intake	Can be specified for a population, usual diet intake, cost effective
Disadvantages	Time consuming, recall bias	A burden to individuals, record bias	Time consuming, nutrient intake over estimation	Close ended questions, reliant on respondents memory

The REAP is considered an FFQ often used in practice and research to perform a dietary assessment by assessing the intake of different food groups. It is a tool/method that is low in cost, has a good representation of usual dietary intake and it has a good response rate from learners. The REAP is written at a sixth-grade literacy level, has 27 questions and was initially developed to help primary care givers to assess dietary intake and physical activity of patients (Gans et al., 2006). In more recent years, the REAP has been shown to be applicable outside of a clinical setting. In a study based in London, the REAP was used to determine the diets of university students, among other factors to describe their lifestyles (Aceijas et al., 2017).

Validation and reliability of the REAP was tested among medical students and consumers of which majority where high school graduates (atleast 18 years). With the general consumer, the REAP was tested against an FFQ developed by the Fred Hutchinson Cancer Research Center. Correlation tests resulted in a r-value of 0.86 ($P<.0001$), the REAP was significantly correlated with the nutrients of food groups of the FFQ (Gans et al., 2006). In the same study, the REAP was tested for validity against the Health Eating Index (HEI), using a study population of second year medical students from Brown University. Results showed that the REAP correlated well with the HEI overall scores ($r=0.49$, $p=.0007$)(Gans et al., 2006, Johnston et al., 2018).

The HEI is regarded as the gold standard/ premier tool for assessing and scoring diet quality because it closely follows the Dietary Guideline for Americans (Johnston et al., 2018)..
The REAP tool has a scoring system which helps to determine if an individuals dietary intake is of a high quality or a low quality. The scoring system has points allocated to each question and the total of all the points per question will give a score ranging between 27 – 81 points. A high score indicates a high-quality diet and a low score indicates a low-quality diet (Johnston et al., 2018).

2.4 Food patterns related to weight status and body composition

2.4.1 Weight status

Studies show that there is a positive association between an increased BMI z-score/ increased risk of overweight or obesity, and the consumption of high energy-dense snacks. These types of snacks are ones with high levels of sugar, saturated fat and sodium (Larson et al., 2016, Tripicchio et al., 2019).For a low risk of overweight/obesity, a consumption of healthy snacks which are high in fibre, vitamins or proteins and low in fat is advisable, because they contribute nutrient requirements for growth and development in adolescents (Tripicchio et al., 2019, Cutler et al., 2012).

Fruits and vegetables have a high content in fibre and water, which play a role in satiety promotion and decreasing the total energy intake in consumption by displacing energy-dense foods. Fruits and vegetables are associated with a low risk for overweight/obesity and regarded as obesity preventing (Du et al., 2010, Schwingshackl et al., 2015).

Lastly, a pattern/habit of meal skipping, any meal of the day, leads to hunger and overeating among adolescents. This then results in adolescents purchasing a lot of high energy-dense foods (high fat, low fibre), which result in increased levels of adiposity or increased risk of overweight/ obesity (Stoner et al., 2019, Onyiriuka et al., 2013, Ambrosini et al., 2012).

2.4.2 Body Composition

Just as with weight status, energy-dense foods/ultra-processed foods are also related to body composition. When specifically looking at body fat, increased energy intake adds to higher levels of body fat, which then result in overweight or obesity in adolescents. Examples of energy-dense foods/ultra-processed foods include; snacks, sweets, convenience foods, fast foods/ fried food, sugar sweetened beverages/ soft drinks, confectionaries and ready-to-eat meals (Krebs et al., 2007, Costa et al., 2018).

Consuming breakfast foods has been found to have a slight negative association to body composition variables (FM, FMI), meaning consuming breakfast does not result in an increase of FM and FMI. Consuming breakfast may lead to an overall lower intake of energy because a consumption of rich fibre foods and low energy-dense foods, may increase energy expenditure to an improvement in energy and vigour (Onyiriuka et al., 2013, Stoner et al., 2019). However, not consuming breakfast/skipping breakfast correlates with overweight or obesity because skipping leads to increased hunger and over eating of energy dense foods (Stoner et al., 2019).

2.5 Conclusion

Weight status is the state of an individual's body weight as healthy, overweight or obese, and BMI is a method used to distinguish between these three characteristics (WHO, 2021, Misra and Dhurandhar, 2019, Simmonds et al., 2015). Body composition refers to the compartments of body weight known as fat mass, lean mass, bone mass and body water. (Kuriyan, 2018, Achamrah et al., 2018).

Obesity in adolescents can be caused by an unhealthy diet and low physical activity. An unhealthy diet is one that consists of a high consumption of saturated fats, trans-fats and refined grains. An increased consumption of high-energy dense foods is associated with an increase in BMI and body fat, which results in obesity/overweight (Costa et al., 2018, Hruby et al., 2016, Tripicchio et al., 2019).

Food patterns refer to the type of food and drinks one consumes, the quantities and the frequency in which one consumes the different foods and drinks (Schulze et al., 2018). Healthy food patterns for South Africans are promoted through the SAFBDGs. The SAFBDGs are short recommendations designed to help consumers choose food and beverage combinations which meet the nutrient needs of South Africans (Patton et al., 2016, Corkins et al., 2016, FBDG-SA, 2013).

Female adolescent food patterns/dietary choices are influenced by peers and family members, media and advertising (social environment) and obesogenic environments (e.g., food vendor or school tuckshops) (Van Zyl et al., 2010, Scaglioni et al., 2018). Generally, adolescent females from urban areas skip breakfast meals at home for meals purchased at food vendors, have a high intake of high energy-dense foods, have a high sugar consumption and have a good consumption of fruits and vegetables (Tee et al., 2015, NDoH et al., 2019, Shisana et al., 2013, Venter and Winterbach, 2010).

3. Chapter Three: Methodology

3.1 Study design

The design was a cross-sectional observational study. A cross-sectional study describes the prevalent situation at a single point in time and can be used to determine a relationship between the variables of interest in a sample (Singh, 2007).The advantage of using this type of study is that it is suitable to estimate the prevalence of a disease in a population (Sedgwick, 2014). In terms of this study, the prevalent disease in the population was obesity. To understand this prevalence, the relationship between food patterns and weight status, as well as food patterns and body composition was studied. A disadvantage of this type of study design is that it was prone to no-response bias if the learners who took part in the study differed from those who did not participate (Sedgwick, 2014).

3.2 Study setting and population

3.2.1 Study setting

The study was performed in two private schools within the City of Tshwane in the Gauteng Province. Both schools were situated in an urban affluent area and therefore considered homogenous in terms of geographical location.

School A and school B were both private schools situated in affluent urban areas of Tshwane. Generally, children in these types of schools, in this type of area can be assumed to be from families of medium to high socio-economic classes and therefore considered to have similar lifestyles. In addition, the school grounds were similar in having big, well-kept grounds, a variety of academic subjects and a wide selection of sports and cultural activities. With these similarities, school A and school B were said to have a homogenous population.

School A accommodated 150 learners per grade in the school, of which 385 of the learners were females in grade 8 to grade 12. School B accommodated a total of 407 learners, with 111 of them being in boarding school and 296 of them day students.

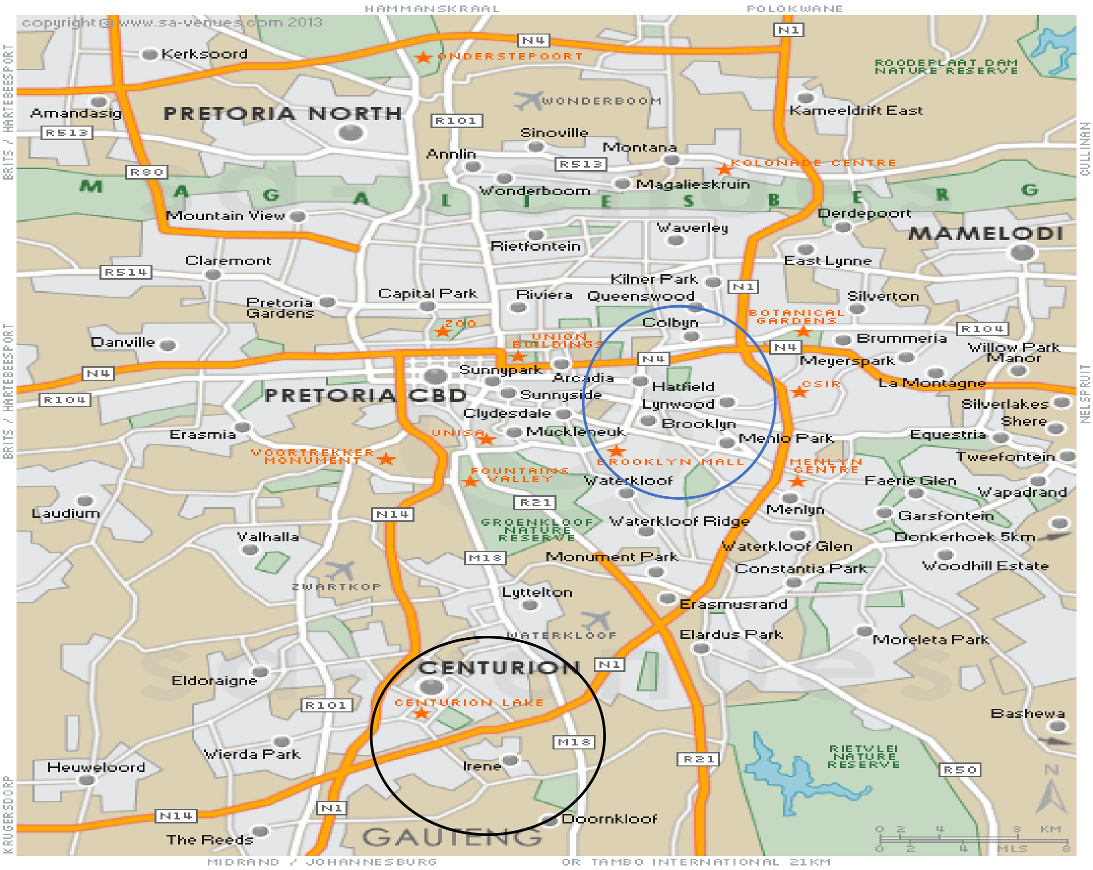

Figure 3: A map of the City of Tshwane – The area for School A is represented by the black circle and the area for School B is represented by the blue

3.2.2 Study population

The study population included learners in the selected schools A and B, registered in grade 8 to grade 12 during the 2021/2022 academic year. Learners included are females between the ages 13 – 19 years (Table 5).

Table 5: Inclusion and exclusion criteria

Inclusion criteria	**Exclusion criteria**
13 -19 years old and born in 2003 – 2009	Children/parents/guardians not willing/giving consent to take part in the study
Enrolled for gr 8-12 at the selected schools during the 2021/2022 academic year	Children who were ill at the time of data collection
Girls	Height <110cm, to enable BIA assessment with the SECA mBCA
Able to stand without assistance	

3.3 Sample size and sampling and recruitment procedures

The Internal Statistical Consultation Services of the University of Pretoria was contacted for the calculation of the sample size. A recommendation from the consultation services was given to have a sample of 60 – 80 participants.

3.3.1 Sampling and recruitment procedure

A convenience sampling approach was used and recruitment continued until the desired sample size was reached. Convenience sampling is a type of sampling that includes/uses people in a population that are willing to participate, are available at any given time and are easily accessible geographically. The disadvantage is that this method is likely to be biased and the advantages are that it is easy to use, affordable and participants are readily available (Etikan et al., 2016), which was needed for this study.

The disadvantage of this method did not affect this study due to the fact that the population outline of the study was specific and recruitment was done in similar areas, accommodating the inclusion criteria (Table 5). Therefore, the sample population being biased was not a concern.

The school heads were approached to be involved in the study by opening up their school/ giving access to their learners for recruitment. A meeting was held with the schools to explain the purpose, aims and objectives of the study. Once the school principals agreed in writing to take part in the study, dates were set in which the learners of the school were addressed during their assembly period, in order to invite them to participate in the study.

During this address, an explanation of who the researchers were, what the study was about and what was required from participants was explained to the students. In addition to speaking to the learners of the school, communication was sent to the parents or legal guardians of the learners on the school's communication system (D6). Communication sent through the D6 was in the form of an invite letter briefly explaining what the study was about, what to expect and the benefits of the study. The letter of invite which went out to the parents included a link, which when clicked led to consent and assent forms (Appendix B).

The link on the invite letter led to a detailed explanation of what the study was about, the measurements to be taken, how the learners could take part and what was required of them, as well as minimal risks involved (Appendix B). On this link, parents could complete the consent form (Appendix B) and booked a day and time frame for measurements to be taken, on behalf of their children. All consent (filled in by parents only) and assent (filled in by learners only) forms completed via this link were emailed to the researcher using the given email address in the forms. Alternatively, participants and parents\guardians completed a printed copy of the consent and assent forms, and brought them to the school on the days set aside for data collection, or, those who were over 18 years (matriculants) completed a consent form on site.

In addition to speaking to the learners and sending out an email to the parents/ legal guardians, the same poster (Appendix D) was distributed and put up on notice boards around the schools. This served as another form of recruitment and reminder to the learners about the study. This study happened alongside a study done by the Department of Human Nutrition. Even though data collection and procedures of the study varied, recruitment was combined, with separate consent/assent forms used and different aims and data sets for each study.

The sampling and data collection period at School A took place between September – November 2021 and at School B between March – May 2022.

3.4 Data Collection

3.4.1 Measurement instruments

3.4.1.1 Weight status and body composition

The instruments of measurement which were used for the study were the SECA 274 stadiometer (Figure 4) and the SECA mBCA 514 (Figure 5). The SECA stadiometer was used to measure the learner's height in centimetres (cm). The SECA mBCA was used to measure the learner's weight in kilograms (kg) and measure the learners body composition (BC). With the height measurement from the stadiometer, the SECA mBCA was able to calculate the BMI-for-age z score of the learners(seca, 2020b).

SECA mBCA is a bioelectrical impedance analysis (BIA) instrument. The use of BIA to measure body composition was tested again Dual-X-ray absorptiometry (DXA) and results showed that BIA is reliable to provide accurate measurements of body composition in adolescents who are healthy and have a normal amount of body fluid (Thivel et al., 2018, Bosy-Westphal et al., 2013).

SECA instruments have been validated against standard methods used to measure adolescent body composition. These standard methods are 3C and 4C models based on D_2O dilution and DXA. The validation tests showed the correlation between SECA results and the standard method results to have no error, therefore SECA instruments are suitable to use for adolescent body composition measurements (seca, 2020b).

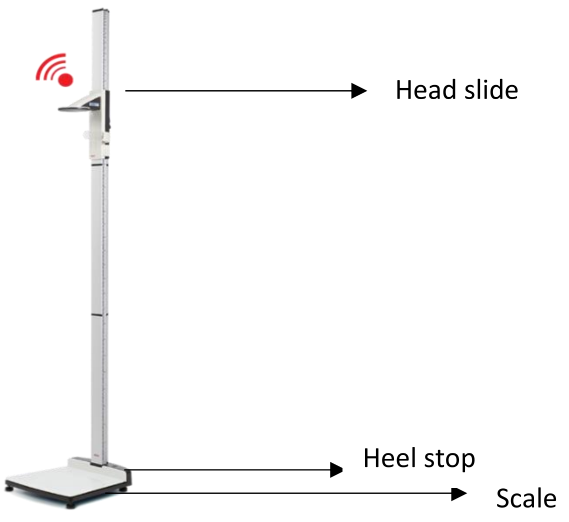

Figure 4: SECA 274 stadiometer

Figure 5: SECA mBCA 515

Figure 6: The correct posture on SECA mBCA 514 (left image) and SECA 274 stadiometer (right image).

In addition, a pre-checklist (Appendix E) was created in order to be aware of the participants' hydration levels (Lee and Nieman, 2013) prior to BIA tests, in order to use it as a reference when analysing BIA outputs.

3.4.1.2 Food patterns

To assess the food patterns of the learners the Rapid Eating Assessment for Participants (REAP) questionnaire was used. The REAP consists of 27 questions, which helps assess the intake of whole grains, calcium- rich foods, fruit and vegetables, fat, saturated fat, cholesterol, sugary beverages, sodium, alcoholic beverages, meat/poultry/fish and dairy (Gans et al., 2006, Kurka et al., 2014, Johnston et al., 2018). For the purpose of this study these groups were re-grouped/ summarised into six food groups to match those of the SAFBDGs (FBDG-SA, 2013). These six groups were: whole grains, fruits and vegetables, fat (included saturated fat and cholesterol), meat/poultry/fish, dairy and snacks/sugary beverages and foods.

Some of the food examples used in the questionnaire were adjusted to be relevant to common foods in South Africa and the units of measurement used were grams (g) and millilitres (ml). Some of the food examples used in the REAP such as Wheaties or Grape Nut are grain cereals which were not found in South Africa. These examples were replaced with grain cereals which are available in South Africa, such as Weet-bix or All-bran flakes (Appendix A).

3.4.2 Methods/ procedures

All procedures were done at school A and school B in a room allocated by the schools. All necessary instruments were transported to the schools. Parents of the learners were contacted to agree on a date and time for testing. This was done during the afternoons after school, starting from approximately 2 pm.

The learners came into the measurement room one at a time and once measured (approx. 3mins), they went back to being seated outside the room to complete the REAP questionnaire on their smart cell phones (approx. 10 min). A Qualtrics link or QR code to scan was provided on which they accessed the REAP. Printed copies of the REAP questionnaire were available for those learners who did not have access to smart cell phones. Each student was issued with a number which was used as their identity for the REAP questionnaire and their measurements. (COVID-19-related protocols were adhered to, refer to section 3.7)

3.4.2.1 BMI-for-age z-scores and body composition

The weight status of learners was determined using BMI-for-age z-scores (A detailed protocol of how measurements were taken to follow below). A SECA 274 stadiometer (Figure 4) was used to measure the height of the learners and a SECA mBCA 514 (Figure 5) was used to measure the weight and give the calculated body mass index.

Both devices were switched on to activate wireless functions before use. A USB was connected to the display head of the SECA mBCA to store all learner files. A learner/ patient file was created on the SECA mBCA 514. The leaner file included the age and population group of the leaners, which was used to describe the population when discussing results. The description SECA mBCA provided for the population groups were; African, Caucasian and Southeast Asian. For the purpose of this study the descriptions used will be; black African, white and Indian/Asian, respectively, according to the classification used by Statistics South Africa StatsSA (2022). Once the device was switched on, a user pin was entered and then the learner tab selected to create a learner file.

<u>Height and weight measurement</u>

The following method was taken from the SECA 274 stadimeter manual (seca, 2020a), and these measurements are similar to the standard protocol stated in the National Health and Nutrition Examination Survey, anthropometry measurement manual (CDC, 2007). The measurements were done by the researcher.

- ✓ Learners came wearing light clothing (sport uniform) in order to reduce interference with measurements. Learners were expected to wear a face mask at all times.
- ✓ Stadiometer was used first
- ✓ Head slide (Fig. 4) was moved up to make space for the learner to step onto the scale. To move the head slide, keep the break button pressed.
- ✓ The learner was to remove their shoes and socks (bare footed) and step onto the stadiometer, underneath the head slide. The learner’s back was towards the head slide.
- ✓ The learner’s heels were against the heel stop and their back and head was straight against the vertical surface of the stadiometer and their arms were placed on the sides of their body (CDC, 2007).
- ✓ Head slide was pushed down to touch the patient’s head.
- ✓ Frankfurt measure was pulled out of the head slide. The patient’s Fankurt horizonal (looking straight ahead) matched with the three lines on the Fankurt measure pulled out of the head slide.
- ✓ The height appeared in ‘cm’ on the display screen. The reading was to the nearest first decimal.

- ✓ Enter button was selected to send the height wirelessly to the SECA mBCA 514
- ✓ To set the head slide display screen to zero, the arrow key at ***hold/zero*** was pressed until the message "ZERO" appeared in the display.
- ✓ Stadiometer was sanitized after each learner used it.
- ✓ Next, the learner stepped onto the SECA mBCA 514 bare foot. The hands and feet of the learners were clean before stepping onto the scale. The researcher ensured that the learner places their feet and hands correctly on the electrodes (Fig.6).
- ✓ Hands were extended but not strained (Fig. 5). The learner placed their hands on the corresponding electrodes on the left and right side. The hand electrodes had finger spacers that fell in between the middle finger and ring finger on both sides.
- ✓ If the learner was not in the correct position, the display screen would highlight the areas with an error in red and if the position was correct, it was indicated with a green light.
- ✓ Once on the scale, the learner stood still to allow for an accurate measure of weight. They remained still until the measurement was complete (approximately 3 seconds).
- ✓ The weight was recorded automatically in 'kg'. Once the weight display and hold value stopped flashing, the measurement was complete.
- ✓ The learner could stay on the machine for the BIA.

<u>Body composition</u>

The following methods were taken from the SECA mBCA 514 user manual (seca, 2020b) and the measurement taking was done by the researcher.

- ✓ The 'bia' tab was activated. Once the "self-test running" was no longer on display the bioimpedance was available.
- ✓ "Continue" was selected
- ✓ On the display screen, the learner should be selected as part of the group of bioimpedance measurements.
- ✓ The learner stepped back onto the mBCA machine and placed their hands and feet onto the electrodes (Fig. 5).
- ✓ The feet were placed that the toes were on the front electrodes and the heals on the rear/back electrodes. Arms were stretched out but not strained and the hands placed onto the corresponding hand electrodes on the right and left (Fig. 6). These electrodes were the same on the left and right. The hand electrodes had finger spacers which were in between the middle finger and the ring finger.

- ✓ The learner was to stand still during measurement. There was a 3 second countdown to the start of the measurement on the display screen. The actual measurement will last for a duration of 15 seconds.
- ✓ Once the measurement was done, the researcher selected ‘continue’ on the display screen to proceed to evaluation.
- ✓ Once completed, the save button was selected and learner files were sent to the USB on the display head.

3.4.2.2 Food patterns

The REAP was completed online via Qualtrics software programme (Qualtrics, 2022) . All learners received a Qualtrics link which took them to the REAP. Learners used their cell phones/smart phones to access the form. There learners filled in a participation code given to them by the researcher, before filling in the REAP.

The REAP was scored to allow for statistical analysis. These scores represented the diet quality with the higher scores indicating a higher quality. Response of ‘usually/often’ received 1 point, ‘sometimes’ received 2 points, ‘rarely/never’ and ‘does not apply to me’ received 3 points (Johnston et al., 2018).

REAP questions were grouped according to the SAFBDGs as illustrated in table 6. Food groups were reported according to the SAFBDGs, therefore the REAP questions were categorised into these food groups to know which question represented a specific food group. The following table 6 is a list of food groups that were analysed and the REAP questions pertaining to each food group. Question 25 was removed from the questionnaire because alcohol is not applicable to the study population.

Table 6: A table of the food groups to be studied and the REAP question numbers relative to the groups

Food groups as per SAFBDGs	**REAP question numbers allocated to the relevant food group**
Whole grains/starchy	3
Fruit and vegetables	4 & 5
Dairy	6 – 8
Fats and oils	14 - 18
Meat (poultry/red meat/fish/processes meats)	9 - 13
High sugar snacks and drinks	19 - 22
High sodium processed foods	23 & 24

A total score was calculated ranging from 27 to 81 (Johnston et al., 2018) per questionnaire. This score indicated the quality of the diet. The total score was reached by adding the points awarded to each response per question, using the point system by Johnston et al. (2018).The total score was determined to assess the overall food pattern quality. Scores above the median indicated a good quality diet and scores below the median indicated a poor quality diet (Fawcett, 2012), these scores were used to classify good vs poor quality. The median was calculated using the score range of 27 – 81, to be a median of 54. A poor quality diet is one that has a high content of energy-dense foods and a low content of nutrient-dense foods (Corkins et al., 2016). A good quality diet is one that meets all of the SAFBDGs (FBDG-SA, 2013). These guidelines are explained in Chapter 2 of this document.

The points scored per food group (by adding points from each question pertaining to a food group) will also be analysed to observe which food groups were consumed the most among the sample. Frequency graphs will be developed to see which food groups had the most points for 'usually/often', 'sometimes' and 'rarely/never'. The mean REAP score for each food group will also be added to provided more detailed information to use to discuss food patterns.

3.4.3 Variables

REAP

- Grains/starchy foods
- Fruit and vegetables
- Dairy
- Fats and oils
- Meat (poultry/red meat/fish/processed meat)
- High sugar snacks and drinks
- High sodium processed foods
- Total REAP score

Stadiometer, mBCA, BMI-for-age z-score

- Height (m)
- Weight (kg)
- BMI-for-age z-score

BIA

- FFM
- FFMI
- FM
- FMI

Data collection took 6 – 8 weeks, with approximately 25 learners being assessed per week.

3.5 Data management and analysis

3.5.1 BMI-for-age z-scores and body composition

The BMI-for-age z-score was automatically calculated by the SECA mBCA 514(seca, 2020b), using the WHO references standards for 5 – 19 years (WHO, 2007). According to WHO reference standards, > +1SD is the cut off for overweight, >+2SD the cut off for obese and > +3SD the cut off for severely obese. The cut off for thinness is < -2SD and sever thinness is <-3SD (WHO, 2009).The range for a healthy weight is -2SD > BMI < +1SD (WHO, 2007). These results were exported from the seca instrument to excel.

The outputs from the BIA included; impedance (Z), resistance (®), reactance (X_c) and phase angle (ϕ) (seca, 2020b), but for this study not all outputs were used, only the height(H), resistance (R) and weight (W) were used for calculations. The following equation was chosen to use for FFM calculations:

FFM = (3.474 + 0.459H^2/R + 0.064W)/(0.769 - 0.009A -0.0165) (Horlick et al., 2002)

Although this equation was not developed for the South African population (Horlick et al., 2002), the population groups involved are similar to those that can be found in South Africa, making this equation the most suitable to use for the study.

The FM was calculated by subtracting the FFM from the body weight (Bienertova-Vaska, 2011). The FMI and FFMI were then calculated, and these values were used for analysis. The following equations were used for their calculation:

FMI = FM(kg)/ height squared (m^2) or FFMI = FFM(kg)/ height squared (m^2) (Wells, 2014).

The standard ranges for FMI and FFMI chosen for use are those developed by (Shypailo and Wong, 2020)(Table 3). Although the reference ranges by Shypailo and Wong (2020) were not developed using a South African population, the assumption was made that the black and white population referred to in that study, can represent the South African black and white population, because the black population in America is described to have African decent (African

American) and the same terms (black and white) are used to describe population groups in South Africa (StatsSA, 2022).

3.5.2 Food patterns

REAP results were exported from Qualtrics onto excel and the REAP score per category was calculated, as well as the total REAP score. Those scores were then used for the correlation analysis between each food group, total REAP and BMI-for-age z-scores, as well as the relationship between the food groups, total REAP and FM, FMI, FFM and FFMI.

3.5.3 Statistical analysis

The Internal Statistical Consultation Services, Department of Statistics of the University of Pretoria was approached for assistance with data analysis.

Statistical analysis was performed using R software (version 4.1.3; http://www.r-project.org/). Statistical relationships between the variables were tested using the Spearman correlation test, and a significance level of 5% was tested. It was observed that this significance level was very stringent on the data, resulting on a small number of significant relationships. Therefore, in addition, a significance level of 10% was explored, although due to a loss in statistical power results will be interpreted with caution. This test is a nonparametric measure of the strength and direction of association that exists between two variables measured (statistics, 2021). The mean values were used to analyse the relationships. The correlation coefficient (r) was described according to the following categories (Mindrila and Balentyne, 2017):

- $r < 0.3$ none or very weak relationship
- $0.3 < r < 0.5$ weak relationship
- $0.5 < r < 0.7$ moderate relationship
- $r > 0.7$ strong relationship

The correlation coefficient (r), p-value, values for BMI-for-age z-scores and body composition variables (FM, FMI, FFM, FFMI) were reported to two decimal places.

The relationships were determined between:

- Weight status (BMI-for-age z-scores) and REAP score for each food group, respectively and for the total REAP
- Body composition variables (FM, FFM, FMI, FFMI) and REAP score for each food group, respectively and for the total REAP score.

An illustration of how these relationships were studied is in Table 7 and 8.

Table 7: This illustrates each relationship that will be tested per food group. BMI-for-age z-scores relationship with each REAP score variable will be tested.

Relationship between mean measured BMI-for-age z-score and each REAP score variable	
BMI-for-age z-score	Grain/starches (total score of question…)
	Fruit & vegetable (total score of question…)
	Dairy
	Fats and oils
	Meat (poultry/red meat/fish/processed meat)
	High sugar snacks and drinks
	High sodium processed foods
	Total diet quality

Table 8: This table illustrates the relationship which will be studied between FM and each food group of the REAP.

Relationship between mean measured FM and each food pattern variable	
FM	Grain/starches (total score of question…)
	Veg & Fruit (total score of question…)
	Dairy
	Fats and oils
	Meat (poultry/red meat/fish/processed meats)
	High sugar snacks and drinks
	High sodium processed foods
	Total diet quality

3.5.1 Budget and funding

The digital, wireless, SECA 274 stadiometer, SECA mBCA 514, and medical gloves were provided by the Department of Human Nutrition, University of Pretoria (UP). This study was self-funded, but the equipment was transported by the Department of Human Nutrition to the venues.

Table 9: Equipment used

Item	Sponsor
Thermometer for screening	Department of Human Nutrition (UP)
Sanitiser	Department of Human Nutrition (UP)
Digital, wireless SECA 274 stadiometer	Department of Human Nutrition (UP)
SECA mBCA 514 (version 1.4.292.4928)	Department of Human Nutrition (UP)
Medical gloves	Department of Human Nutrition (UP)

3.6 Pilot study

A pilot study was done using learners, similar to the stated study population. These learners were selected from a group of students I tutored form different private schools in Tshwane. They filled in the REAP (which was adapted to be applicable in South Africa) in order to test the understanding of the questions and functionality of the questionnaire link. The REAP was completed online, by providing the learners with a Qualtrics link which they used to access the REAP.

3.7 Ethical considerations

Participating schools were contacted and they granted permission for the study to take place at their school with their learners. The permission letters have been attached in the appendix (Appendix C). Participation was voluntary and learners chose to leave the study at any given moment.

Ethics was applied for through the Faculty of Natural and Agricultural Science ethical committee. Approval letter NAS154/2021 is attached in Appendix F.

<u>COVID-19 care</u>

<u>Data collection took place during the COVID-19 lock down in 2021 and 2022 post lock down, and the following safety protocol was followed to prevent the spread of the disease:</u>

- Only one student at a time was taken into the assigned room to allow for social distancing.

- Learners and researchers had masks on at all times.
- Each learner sanitised their hands before being measured and all measurement instruments were sanitised after each leaner was measured.
- The researcher had on latex gloves at all times during measurements.
- When filling in the REAP questionnaire, learners were seated outside the measurements room, socially distanced, using their personal smart phones or filling in a paper REAP.
- For learners filling in the physical form, they were required to used their own pen.

4. Chapter Four: Results

4.1 Introduction

This chapter includes results related to the weight status, body composition and food patterns of the sample. Data was categorised according to population groups to add further insight into the characteristics of the sample and allow for appropriate interpretation in relation to available reference standards and national anthropometric data.

4.2 Sample distribution and characteristics

A total sample of 91 participants were included in the total sample. However, due to instrumental error (e.g., missing BMI z-score calculations and missing R-value for FFM/FM/FMI/FFMI calculations) and incomplete REAP questionnaires, only 79 number of complete data sets were available. Nevertheless, all available data for each variable were included in the analysis. The number of participants included for each variable is illustrated in Figure 7.

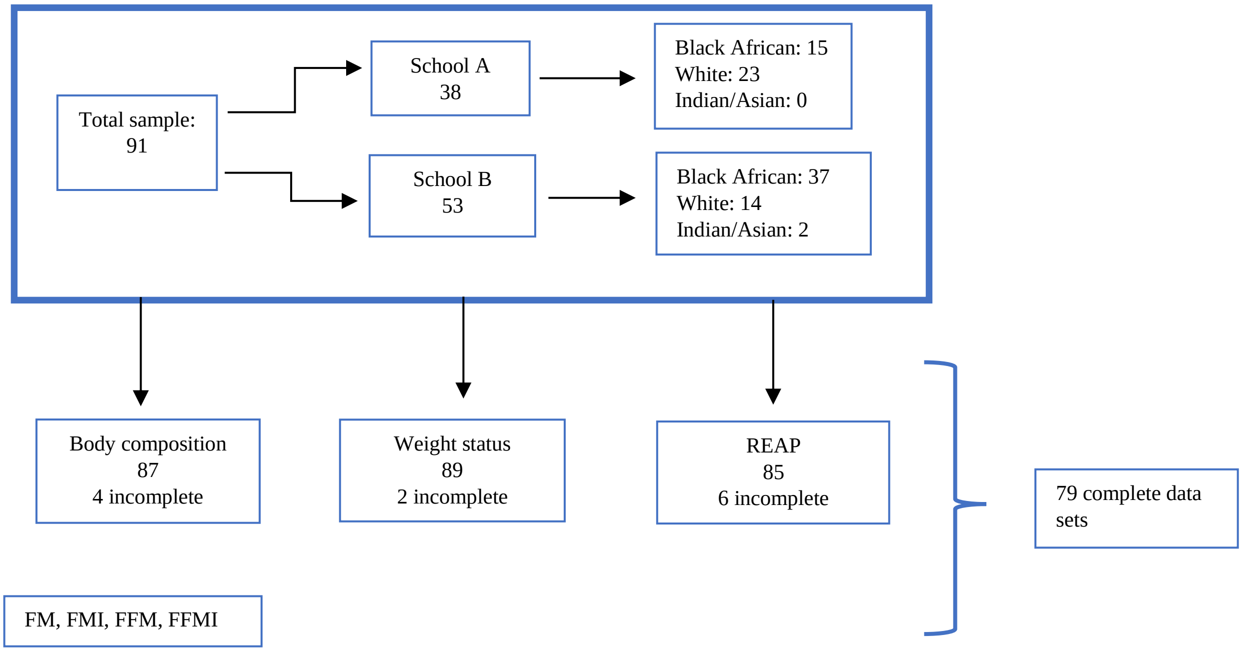

Figure 7: Illustration of sample numbers

Table 10 summarises the characteristics of the sample according to age, weight and height. The mean age of the sample was 16.3 years, the mean weight was 62.34 kg and the mean height of 162.46 cm (Table 10).

Table 10: Description of the sample according to age, weight and height (N=91)

Variable	Mean	SD[a]
Age (years)	16.29	1.53
Weight (kg)	62.34	12.61
Height (cm)	162.46	6.49

[a]SD – standard deviation

4.3 Weight status

Table 11 summarises the weight status expressed as the mean BMI-for-age z-score for the total sample and categorised according to population groups. For the total sample the mean BMI-for-age z-score was 0.62 (0.37; 0.87) (Table 11).

Table 11: BMI for-age z-score

	Mean	*CI*[a]
Total sample (N=89)	0.62	(0.37;0.87)
Black African (n= 52)	0.86	(0.50;1.22)
White (n =35)	0.30	(-0.00;0.60)
Indian/Asian (n= 2)	0.00	(-0.12;0.12)

[a]95% confidence interval (CI) around the mean

Table 12 summaries the frequency and percentage distribution of participants per BMI-for-age category for the total sample and per population group. More than half of the participants (60.97%) were within the healthy weight category.

Table 12: The frequency and percentage distribution of participants per weight category

		Black African (n= 52)	White (n= 37)	Indian/Asian (n= 2)	Total sample (N= 89)	Proportion of the total sample (%)
BMI-for-age categories	**Healthy**	29 (32.58%)	25 (28.09%)	0 (0%)	54	60.67%
	Obese	5 (5.62%)	3 (3.37%)	0 (0%)	8	8.99%
	Overweight	15 (16.85%)	9 (10.11%)	2 (2.25%)	26	29.21%
	Thin	1 (1.12%)	0 (0%)	0 (0%)	1	1.12%

4.4 Body composition

Table 13 summarises the mean values of FM, FMI, FFM and FFMI of the total sample and categorised according to population groups. The mean FM for the total sample was 23.50 kg

(21.77;2632), the mean FMI was 8.95kg/m^2 (8.26;10.03), the mean FFM was 39.03 kg (38.07;39.98) and the mean FFMI was 14.79kg/m^2 (14.17;15.07).

Table 13: Body composition of the sample

			Population groups					
	Total sample		Black African		White		Indian/Asian	
	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI
FM N=88	23.50	(21.77; 26.32)	25.56	(22.74; 28.62)	20.47	(18.23; 25.63)	19.23	(14.89;23.57)
FMI N=88	8.95	(8.26;10.03)	9.98	(8.85; 11.21)	7.39	(6.62; 9.26)	7.72	(7.41; 8.03)
FFM N=87	39.03	(38.07; 39.98)	38.21	(36.99; 39.33)	40.38	(39.24; 42.13)	32.90	(25.04; 40.76)
FFMI N=88	14.79	(14.17; 15.07)	14.87	(14.39; 15.27)	14.71	(13.46; 15.31)	13.20	(12.49; 13.90)

FM, fat mass; FMI, fat mass index; FFM, fat free mass; FFMI, fat free mass index

[a]95% confidence interval (CI) around the mean

4.5 REAP scores for the sample

Table 14 summarises the total REAP score per category of the population groups and weight status. The REAP score of the total sample was 52.94 (51.62; 54.27). Figure 8 illustrates the distribution graph of the REAP score with a solid black line indicating the median score of 54. Forty-seven participants had a REAP score below the median, and 38 above the median.

Table 14: Total REAP score per category

			Population groups						Weight status category					
	Total sample		Black African		White		Indian/Asian		Healthy		Overweight		Obese	
	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI	Mean	[a]95%CI
REAP scores	52.94	(51.62; 54.27)	52.35	(50.47;54.24)	53.11	(51.09;55.13)	59.50	(53.15;65.85)	53.30	(51.39;55.13)	51.77	(49.41;53.62)	52.57	(46.12; 59.02)

[a]95% confidence interval (CI) around the mean

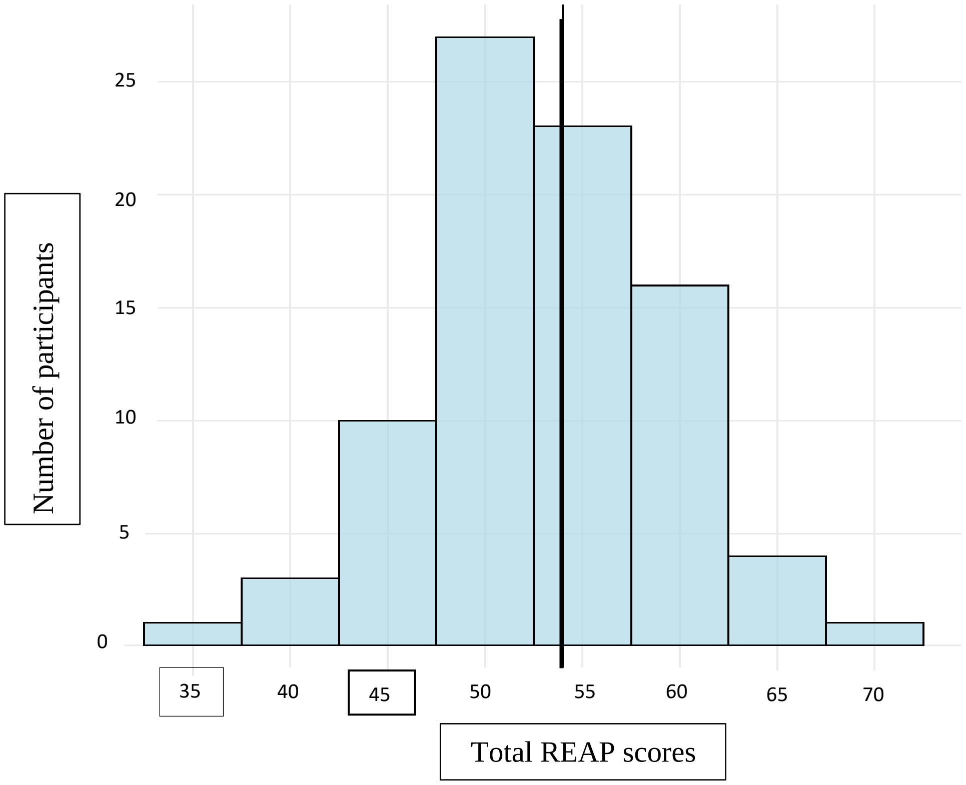

Figure 8: The distribution of total REAP scores, with a bold solid line representing the median score of 54. (N=85)

Figures 9 – 15 illustrates the consumption frequency of each food group. Figures 13, 11, 10, 9 and 15, indicates that the grains/starch, dairy, fats & oils, meat, and high sodium groups, have the most picked consumption response of “usually”. In the fruits and vegetables group (Figure 12) grains/starch group (Figure 13), and the high sugar food group (figure 14), the most picked response was “sometimes”.

Figure 9: Meat frequency

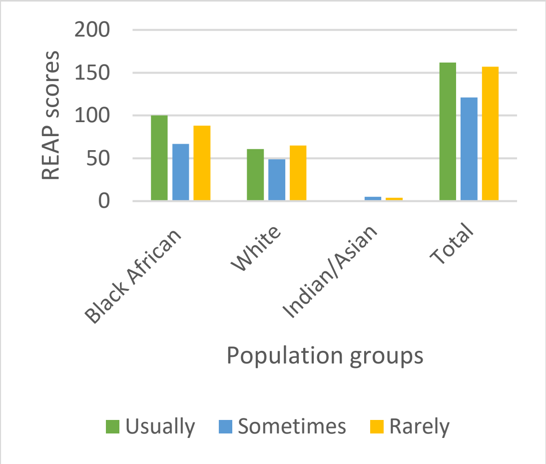

Figure 10: Fats & oils frequency

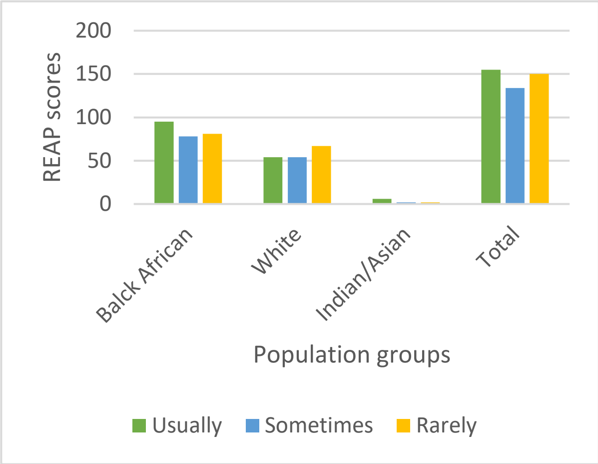

Figure 13: Dairy frequency

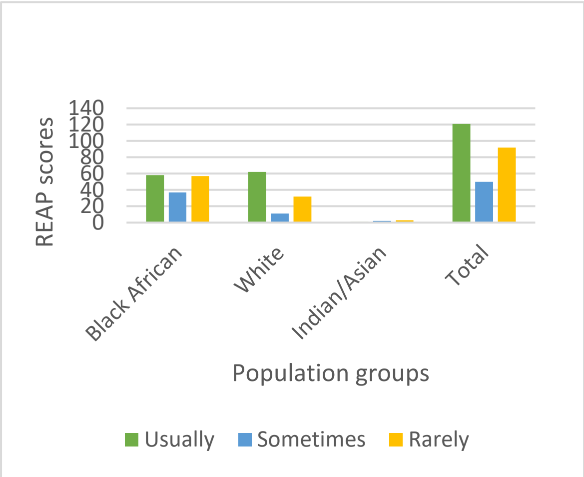

Figure 14: Fruits and vegetables frequency

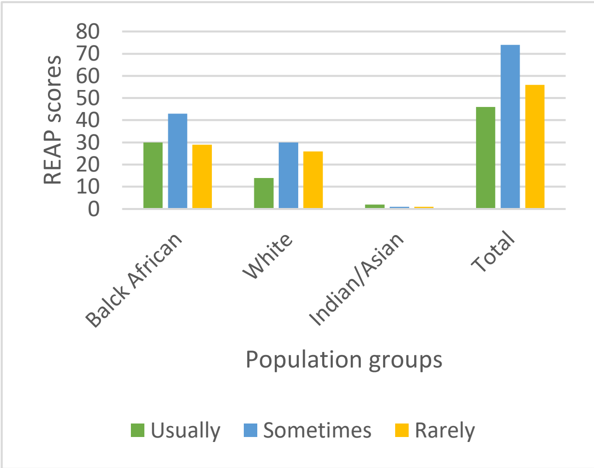

Figure 11: Grains/ starch frequency

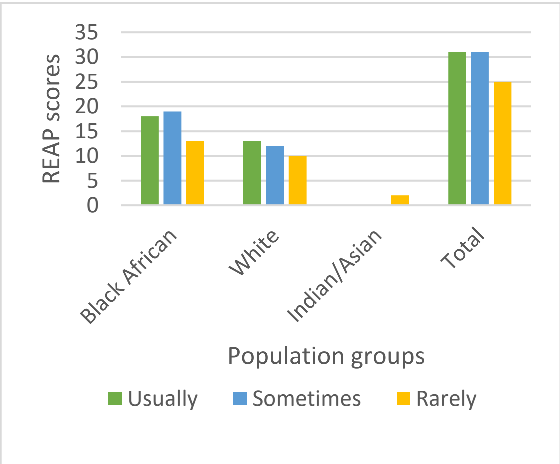

Figure 12: High sugar frequency

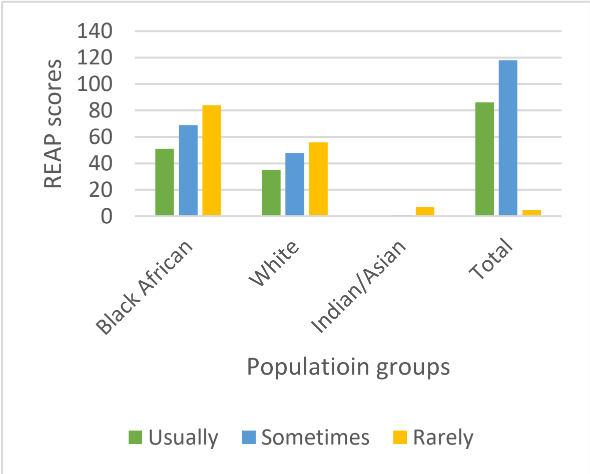

Figure 15: High sodium frequency

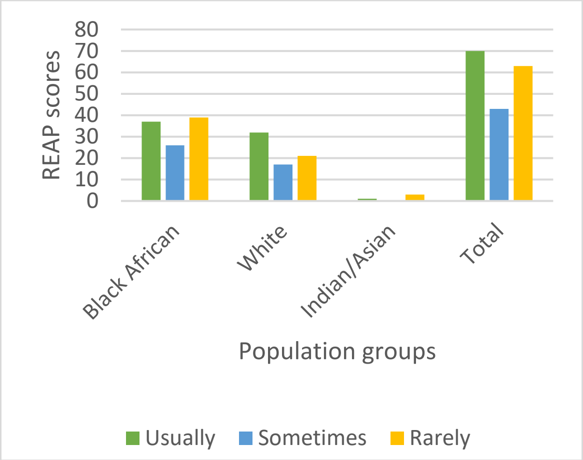

Table 15 summarises the mean REAP scores per food group. The highest mean is in the meat group (9.91) and the lowest mean in the whole grains/starch group (1.92).

Table 15: REAP scores per food group

Variables	Mean REAP score per food group	95% CI
Whole grains/starch	1.92	(1.74; 2.10)
Fruit & vegetables	4.15	(3.89; 4.41)
Dairy	5.65	(5.31; 6.00)
Fats & oils	9.83	(9.31; 10.35)
Meats	9.91	(9.40; 10.42)
High sugar	8.71	(8.28; 9.13)
High sodium	3.90	(3.62; 4.17)

[a]95% confidence interval (CI) around the mean

4.6 The relationship between REAP score, and, weight status and body composition, respectively

Tables 16 – 23 present the correlation analysis performed between the total REAP score, and BMI-for-age z-scores and BC variables, respectively, and, REAP score per food group and BMI-for-age z-scores and BC variables, respectively, presented for the total sample and each population group. A correlation analysis could not be performed for the Indian/Asian population group due to only two participants belonging to this category, making it less than feasible to perform a correlation analysis. Likewise, the obesity and thinness\underweight participants were not analysed as part of the weight group.

Table 16 represents the correlation analysis between the total REAP score and, weight status and BC variables, respectively. There were no significant correlations using a significance of P<0.05, however using a lower statistical power (P<0.1), significance was found between the overweight category and FFMI (r=0.37, P=0.07), which was a weak, positive correlation. Although not significant, all correlations with FM are negative except between the white group and FM.

Table 16: Correlation between the total REAP score per category and, weight status and BC variables, respectively

Variables	Total Sample (N = 85)		Per population group				Per weight category			
			Black African (n = 48)		White (n = 35)		Healthy (n = 46)		Overweight (n = 24)	
	^b^r	^c^P	^b^r	^c^P	^b^r	^c^P	^b^r	^c^P	^b^r	^c^P
BMI-for-age z-score	-0.02	0.84	-0.10	0.48	0.19	0.32	0.16	0.29	0.15	0.48
FM	-0.10	0.37	-0.14	0.34	0.01	0.94	-0.02	0.87	-0.10	0.63
FMI	-0.05	0.63	-0.13	0.37	0.10	0.60	0.09	0.54	-0.10	0.63
FFM	-0.11	0.34	-0.10	0.50	-0.07	0.70	-0.13	0.38	0.22	0.31
FFMI	0.02	0.85	-0.06	0.69	0.25	0.18	0.08	0.58	0.37	0.07

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index

[b]r = Spearman correlation coefficient

[c]P = statistical significance of correlation

In tables 17 – 23, the total REAP scores categorised according to food groups are presented. Table 17 represents the correlation analysis between the whole grains/starchy food group REAP score and, weight status and BC variables, respectively. A positive, moderate, significant correlation was found within the overweight group REAP score and the FFM (r= 0.51, P= 0.01), and a weak, positive, significant relationship between the overweight group REAP score and FFMI (r= 0.47, P= 0.02). Although not significant, almost all relationships were negative, except for BMI-for-age, FM and FFM of the white population group and BMI, FFM and FFMI of the overweight group.

Table 17: Correlation between the REAP score per category of the whole grains/starchy food group and, weight status and BC variables

			Per population group				Per weight category			
Variables	**Total sample (N = 85)**		**Black African (n = 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	[b]r	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**
BMI-for-age z-score	-0.11	0.33	-0.04	0.80	0.06	0.75	-0.07	0.62	0.14	0.52
FM	-0.15	0.20	-0.12	0.44	0.10	0.60	-0.07	0.63	-0.18	0.40
FMI	-0.15	0.18	-0.04	0.79	-0.06	0.77	-0.07	0.64	-0.23	0.27
FFM	0.11	0.36	$-4e^{-04}$	0.99	0.14	0.46	0.01	0.93	0.51	0.01
FFMI	-0.08	0.46	0.09	0.53	-0.06	0.77	-0.17	0.25	0.47	0.02

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
[b]r = Spearman correlation coefficient
[c]P = statistical significance of correlation

Table 18 represents the correlation analysis of the REAP score of fruits and vegetables and, the weight status and BC variables, respectively. There were no significant correlations found, however, even though not significant, all correlations associated with the FM, except for total sample REAP score and FM, are negative correlations.

Table 18: Correlation between the REAP score per category of the fruits and vegetables group and, weight status and BC variables

			Per population group				Per weight category			
Variables	**Total sample (N = 85)**		**Black African (n= 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	[b]r	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**
BMI-for-age z-score	0.01	0.91	0.03	0.76	-0.01	0.97	0.07	0.65	0.26	0.21
FM	0.09	0.42	-0.09	0.54	-0.05	0.77	-0.13	0.39	-0.14	0.52
FMI	-0.04	0.72	- 0.01	0.93	0.02	0.89	-0.06	0.68	0.17	0.42
FFM	0.04	0.71	- 0.00	0.98	-0.04	0.85	0.12	0.45	0.02	0.92
FFMI	0.08	0.46	0.10	0.51	0.03	0.89	0.08	0.56	0.28	0.19

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
[b]r = Spearman correlation coefficient
[c]P = statistical significance of correlation

Table 19 represents the correlation analysis between the REAP score for the dairy group and, weight status and BC variables, respectively. A negative, weak, significant correlation was found between the black African group REAP score and FFM (r= -0.30, P= 0.04).

Table 19: Correlation between the REAP score per category of the Dairy food group and, weight status and BC variables

			Per population group				**Per weight category**			
Variables	**Total sample (N = 85)**		**Black African (N = 48)**		**White (N = 35)**		**Healthy (N = 46)**		**Overweight (N = 24)**	
	[b]r	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**
BMI-for-age z-score	0.00	0.99	-0.02	0.88	- 0.00	0.98	0.04	0.81	0.24	0.26
FM	-0.04	0.74	-0.11	0.44	- 0.01	0.94	0.06	0.70	-0.24	0.27
FMI	0.02	0.85	-0.07	0.65	0.00	0.96	0.12	0.44	0.17	0.44
FFM	-0.19	0.10	-0.30	0.04	0.15	0.43	-0.04	0.80	-0.40	0.05
FFMI	-0.05	0.68	-0.13	0.37	0.14	0.44	0.02	0.87	-0.01	0.96

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
[b]r = Spearman correlation coefficient
[c]P = statistical significance of correlation

Table 20 represents the correlation analysis between the REAP score of the fats and oils group and, weight status and BC variables, respectively. There were no significant correlations.

Table 20: Correlation between the REAP score per category of the fats and oils food group and, weight status and BC variables

			Per populations group				**Per weight category**			
Variables	**Total sample (N = 85)**		**Black African (n = 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	[b]r	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**
BMI-for-age z-score	0.06	0.58	-0.03	0.81	0.22	0.24	0.14	0.35	-0.13	0.53
FM	-0.02	0.86	-0.05	0.76	0.02	0.91	-0.09	0.55	-0.17	0.43
FMI	-0.01	0.93	-0.07	0.65	0.10	0.59	-0.02	0.88	-0.31	0.14
FFM	0.07	0.53	0.01	0.96	-0.01	0.95	-0.02	0.91	0.20	0.34
FFMI	0.13	0.26	0.04	0.79	0.21	0.27	0.20	0.19	0.17	0.44

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
[b]r = Spearman correlation coefficient
[c]P = statistical significance of correlation

Table 21 represents the correlation analysis between the REAP score of the meat group and weight status and BC variables, respectively. There were no significant correlations using a significance of P<0.05, however using a lower statistical power (P<0.1), significance was found. Negative, weak, significant relationships were found between the total sample REAP scores and FFM (r= -0.20, P= 0.07), as well as between the white population group REAP scores and FFM (r= -0.32, P= 0.09).

Table 21: Correlation between the REAP score per category of the meat food group and, weight status and BC variables

			Per population group				Per weight category			
Variables	**Total sample (N = 85)**		**Black African (n = 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	br	**cP**	**br**	**cP**	**br**	**cP**	**br**	**cP**	**br**	**cP**
BMI-for-age z-score	-0.14	0.21	-0.15	0.33	-0.08	0.70	-0.12	0.44	-0.08	0.72
FM	-0.13	0.25	-0.16	0.29	0.02	0.92	-0.04	0.77	-0.17	0.43
FMI	-0.13	0.26	-0.18	0.22	0.04	0.83	-0.00	0.99	-0.25	0.24
FFM	-0.20	0.07	-0.16	0.27	-0.32	0.09	-0.23	0.11	0.02	0.93
FFMI	-0.17	0.14	-0.16	0.28	-0.14	0.48	-0.17	0.26	0.02	0.93

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
br = Spearman correlation coefficient
cP = statistical significance of correlation

Table 22 represents the correlation analysis between the REAP scores of the high sugar food group and, weight status and body composition variables, respectively. There were no significant correlations using a significance of $P<0.05$, however using a lower statistical power ($P<0.1$), significance was found between the healthy weight group REAP scores and the BMI-for-age z-score as a positive, weak correlation ($r=0.26$, $P=0.08$).

Table 22: Correlation between the REAP score per category of the high sugar food group and, weight status and BC variables

			Per population group				Per weight category			
Variables	**Total sample (N = 85)**		**Black African (n = 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	br	**cP**	**br**	**cP**	**br**	**cP**	**br**	**cP**	**br**	**cP**
BMI-for-age z-score	-0.06	0.61	-0.05	0.71	0.04	0.82	0.26	0.08	0.16	0.46
FM	-0.13	0.27	- 0.07	0.64	-0.16	0.40	0.09	0.56	0.11	0.62
FMI	-0.08	0.50	-0.04	0.79	-0.09	0.63	0.16	0.29	0.29	0.16
FFM	-0.15	0.18	-0.07	0.65	-0.16	0.41	-0.15	0.31	0.13	0.55
FFMI	- 0.01	0.94	-0.06	0.70	0.18	0.35	0.09	0.55	0.27	0.19

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
br = Spearman correlation coefficient
cP = statistical significance of correlation

Table 23 represents the correlation analysis of the high sodium food group REAP scores and, weight status and BC variables, respectively. There was a positive, moderate, significant correlation between the overweight group REAP scores and the FM (r=0.42, P=0.04). This was the only significant correlation for this food group.

Table 23: Correlation between the REAP score per category of the high sodium food group and, weight status and BC variables

			Per population group				**Per weight category**			
Variables	**Total sample (N = 85)**		**Black African (n = 48)**		**White (n = 35)**		**Healthy (n = 46)**		**Overweight (n = 24)**	
	[b]r	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**	**[b]r**	**[c]P**
BMI-for-age z-score	0.17	0.88	-0.14	0.37	0.23	0.24	0.10	0.49	0.13	0.56
FM	0.03	0.81	-0.06	0.69	0.16	0.40	0.05	0.74	0.42	0.04
FMI	0.02	0.86	-0.12	0.40	0.20	0.31	0.09	0.57	0.19	0.37
FFM	-0.05	0.64	0.06	0.67	-0.05	0.80	-0.04	0.80	-0.01	0.98
FFMI	-0.02	0.81	-0.12	0.43	0.18	0.36	0.09	0.56	-0.12	0.59

BMI, body mass index; FM, fat mass; FMI, fat mass index; FFM, fat free mass: FFMI, fat free mass index
[b]r = Spearman correlation coefficient, [c]P = statistical significance of correlation

5. Chapter Five: Discussion of results

5.1 Introduction

This chapter will discuss the results of the study in the context of existing literature of the weight status, body composition and food patterns of female adolescents.

5.2 Sample profile

To reach the sample size of 91, the sample was selected among two different schools, with the aim of attaining a homogenous group of adolescents. Attaining a homogenous group was important because demographics such as socio-economic status (SES) or location (e.g., urban or rural) can affect food patterns or BC and weight status, therefore having a sample with similar backgrounds was necessary to have an accurate analysis of results. For example, urban adolescents tend to show a higher prevalence of overweight and obesity than rural adolescents due to the rapid urbanisation of food environments, transport, infrastructure and an increased access to a variety of foods (Wrottesley et al., 2019). Food patterns of those living in rural communities are usually low in diversity compared to diets of those living in urban communities, and individuals from a low SES tend to have less knowledge about healthy food compared to those from a higher SES (Wrottesley et al., 2019). Both schools were situated in affluent urban areas of the City of Tshwane, they were private schools and participants were in grade 8 – 12, providing a similar age range from both schools. The prevalence of overweight and obesity in South Africa starts within this age group and it is a sensitive age group because overweight and obesity prevalence during this age results in development of NCDs in adulthood (DoH, 2016, Patton et al., 2016, Corkins et al., 2016), hence the decision to focus on this age group.

The study sample included three population groups; black African, white and Indian/Asian. Although the study was not designed to include various population groups, South Africa is considered a rainbow nation accommodating various population groups including; black African, coloured, Indian/Asian and white (StatsSA, 2022). It was therefore expected that the sample would include various populations. Due to various body compositions standard ranges being specified per population group (Shypailo and Wong, 2020, Wells, 2014), it was necessary to categorise into population groups. Using one reference for different population groups may not be accurate, for example, some females who appeared to require intervention due to a low FFMI, in the Shypailo and Wong (2020) study, when analysed using the white/Hispanic population group FFMI references, they were classified not to be at a risk. This shows that separate reference standards according to population groups are necessary, otherwise a neutral reference standard may lead to clinical implications for individuals(Shypailo and Wong, 2020).

The Indian/Asian population group only had two participants for representation out of the whole sample, for that reason analysis could not be done for this group. The South African population distribution for Indian/Asian females is 2.5% (StatsSA, 2022), therefore it was expected that the total sample would have a small representation of the Indian/Asian population group.

5.3 Weight status

According to the BMI-for-age z-score outcomes, the total sample had a mean of 0.62 (0.37; 0.87) which falls into the category of a healthy weight status. The percentage distributions of the weight status category show 60.67% of healthy weight individuals, 8.99% of obese individuals and 29.2% of overweight individuals. According to WorldObesity (2016), the prevalence of obesity and overweight among females aged 2 – 14 years is 7.1% and 16.5%, respectively. The prevalence of obesity and overweight among females aged 15 – 24 years is 15% and 24%, respectively (WorldObesity, 2016). In relation to the statistics by World Obesity of the two age groups, one can deduce that the obesity and overweight percentages (8.99% and 29.2%) of this study sample are high and are reflective of the obesity/overweight problem among adolescents. These results add perspective to the predicted obesity prevalence of 50% among South African women in 2030 (WorldObesityFederation, 2022).

The disadvantage of high obesity or overweight prevalence in adolescence is a life with comorbidities such as type 2 diabetes or the risk to develop NCDs in adulthood (WHO, 2018, Kumar and Kelly, 2017). Looking at the population groups, in the overweight category (Table 12), the black African population group has more participants (16.85%) who are overweight than the white and Indian/Asian population group (10.11% and 2.25%, respectively). The same pattern is also observed for the obese category. These patterns are also reflected in national data with black South African women having a higher prevalence of overweight and obesity than other population groups (Negash et al., 2017). A probable explanation to this pattern is the cultural perception among the black African population that a larger body size is a sign of happiness and wealth and a smaller body size or underweight is associated with unhappiness or sickness, creating a barrier towards weight loss (Prioreschi et al., 2017).

Other factors from the literature review that could explain the rate of obesity and overweight in the sample, are home environments where both parents are obese (obesogenic environment), or that coming from a home with parents of a low/middle education level increases the risk of overweight/obesity (Parrino et al., 2016, Birbilis et al., 2013). However, the economic or educational backgrounds of the adolescents' parents was not studied, nor was the weight status of the parents' studied, therefore these factors cannot be concluded as possible explanations to the overweight and obesity prevalence among this population.

It is important to note that BMI has a limitation of not specifically measuring fat mass (Tyson and Frank, 2018, Simmonds et al., 2015) and so it is possible that a healthy weight status is not an accurate description of the sample.

5.4 Body Composition

Body composition measurements were used as a secondary tool to evaluate obesity/overweightness of the sample. To determine obesity, both FM and FMI were used to reduce the chance of misinterpretation (Shypailo and Wong, 2020, Wells, 2014) . The difference between the FM value and the FMI value, is the inclusion of height with the FMI value. FMI is the fat mass relative to the individual's height, which helps to get a more accurate sense of an individual's fat mass (Shypailo and Wong, 2020, Wells, 2014). Although FMI is seen as a more effective diagnostic tool compared to FM, due to height-normalization (Alpízar et al., 2020), it was expected that FM and FMI would show similar results in terms of overweight or obesity categories, because the inclusion criteria for the sample required participants to be healthy, therefore assuming no underlying diseases (e.g. protein malnutrition) would affect the outcomes of FM vs FMI (Shypailo and Wong, 2020, Wells, 2014). However, when comparing between the population groups, differences between FM and FMI or FFM and FFMI are expected, because FMI and FFMI eliminates differences caused by height (Kyle et al., 2003, Heymsfield et al., 2016).

In this sample, the black African group had FM and FMI values higher than the standard/healthy range for African Americans, outlined by Shypailo and Wong (2020), but the FFM and FFMI values are lower than the standard/healthy range (Table 24). The white population group showed outcomes of FM and FMI higher than standard/healthy range specific for white adolescents, but the FFM and FFMI average values are within the standard range (Table 24). Both population groups have above standard ranges of FM/FMI. These findings may explain that the higher BMI may indeed be an indication of higher levels of obesity of this sample and in accordance with literature indicating that female adolescents have a prevalence of obesity among them (DoH, 2016, Shypailo and Wong, 2020). This high prevalence of obesity or overweight among female adolescents starts with puberty, seeing that female experience high levels of fat/weight gain from the onset of puberty (De Oliveira et al., 2016, Wrottesley et al., 2019). In addition, the increased rate of urbanisation in diet (high-energy dense/ ultra-processed foods) and activity changes, affects the prevalence of overweight and obesity among South African urban adolescents (Wrottesley et al., 2019, Tripicchio et al., 2019, Costa et al., 2018).

With a closer look at table 24, the standard ranges of the black African group have a higher upper range than those of the white group, which agrees with some studies showing that body composition values differ per population groups and the black population tends to have more fat mass than white population groups (Micklesfield et al., 2010, Heymsfield et al., 2016, Shypailo and Wong, 2020).

Table 24: A summary of the standard values of FM, FMI, FFM & FFMI and the values of the same variables from the research population

	Black African		**White**	
Variables	**Standard (Shypailo and Wong, 2020)**	**Mean values of the sample**	**Standard (Shypailo and Wong, 2020)**	**Mean values of the sample**
FM	18.9 – 22.6	25.56	15.6 – 21.6	20.47
FMI	1.73 – 2.00	9.98	1.61 – 1.97	7.39
FFM	41.4 – 44.6	38.21	38.9 – 42.1	40.38
FFMI	15.28 – 16.58	14.87	14.34 – 15.30	14.71

BMI-for-age z-scores shows the population to be of a health weight but FM calculations shows the population to have above the healthy range of FM, this difference confirms that BMI has a limitation of only being able to measure excess body weight as opposed to excess fat mass (Tyson and Frank, 2018, Simmonds et al., 2015), resulting in inaccurate classifications of weight status. Using body composition as an additional tool for measurement, was beneficial in order to verify the outcomes of BMI. The reason for the BMI outcomes to show the population to have a healthy weight status could be due to the fact that they have a below healthy range of muscle mass/FFM, causing their total body weight to appear healthy.

5.3 Total food pattern and per food group, and their association to weights status and BC variables

The majority (55.3%) of this sample has been found to have a poor-quality diet and less than half (44.7%) had a good quality diet. Generally, poor quality diets consist of low-quality foods, which include ultra-processed foods and/ high energy-dense foods (Harvard, 2022) and in South Africa, the typical food patterns of adolescents include high energy-dense foods (fried foods, snacks, confectionaries etc) (Venter and Winterbach, 2010, NDoH et al., 2019) and this is reflected through the study sample's diet results. REAP score results, showed the sample to consume mostly fried foods, high salted snacks/processed foods and meat (specifically, high fat options and processed meats), often in high quantities. They also consume fewer whole grains and dairy products, while choosing the full cream or regular fat options of dairy as opposed to low fat. This observed pattern is contradictory to the SAFBDGS (FBDG-SA, 2013).

Research shows that urban female adolescents are more likely to buy food from school tuckshops than bring their own meals from home. School tuckshops mainly sell high-fat foods and snacks and so the habit of buying food at the tuck shop frequently can result in a poor quality diet (Sedibe et al., 2018). Most school tuck shops sell unhealthy food options than healthy, limiting the choice of learners (Faber et al., 2014). In instances where the tuck shop provides healthy and unhealthy food options, research shows that learners are still more likely to purchase the unhealthy food choices (Mindrila and Balentyne, 2017). Peer pressure to buy high-fat/snack foods is high among females (Van Zyl et al., 2010), which adds on to the use of tuckshops in school.

After performing correlation analysis, the only significant correlation found (using the lower statistical power), was between the total REAP of the overweight group (BMI Z-score >+1SD) and the FFMI, which was positive (Table 16). This contradicts existing evidence: A high REAP score indicates a good quality diet and, typically overweight individuals do not have a good quality diet (Venter and Winterbach, 2010). A good quality diet shows consumption of all food groups in the recommended amounts by the SAFBDGs (FBDG-SA, 2013) and the opposite of that would be a poor quality diet consisting mainly of high fat foods/ high energy dense foods (Harvard, 2022). A good quality diet limits frequent consumption of high fat foods/ obesogenic food which controls fat mass gain (Sedibe et al., 2018).

Good quality diets are not typically associated with overweight/obese people, which then raises the question why the significant relationship is under the overweight group. The limitation of using an FFQ to assess food patterns is that it is not a sensitive tool which can be caused by under reporting due to the respondents memory or not being culture specific (Shim et al., 2014, Lee and Nieman, 2013) as it was used for different population groups. Therefore, correlation analysis was not highly reliable.

5.3.1 Whole Grains/starch

Whole grains are grains from cereal which still contain all their components after milling, if milled and the starch foods referred to are minimally processed. Whole grain products add additional micronutrients to the diet and dietary fibre (Vorster, 2013). Examples include; whole grain bread, whole grain cereal (e.g., All bran or weet-bix), oats, rice or potatoes (Vorster, 2013). The SAFBDGs indicate that whole grains should be included in the diet daily as part of most meals. The recommended intake is 10 servings per day of whole grains/ starchy foods. One serving is the equivalent of one slice of bread / 35 – 40g (Vorster, 2013). The majority of the sample indicated that they consume less than three servings of whole grains/ starchy foods per day, which is less that the recommended intake. In addition, the mean REAP score for this food group was 1.92 (Table 15), which supports the samples' low consumption of whole grains/starchy foods.

According to literature, the black African group has the lesser consumption of grains/starch compared to the white group. Previously (2005 – 2010), there was a challenge to encourage South Africans to eat more whole grains, even more so the white population groups who generally had a lower intake of total carbohydrates (Vorster, 2013). In more recent years, this did not change among adolescents. Wrottesley et al. (2019) shows that adolescents in urban areas had dietary habits consisting of refined/processed carbohydrates rather than whole grain carbohydrates, which is partly the result of the rapid nutrition transition, seeing a decrease in healthy/recommended total carbohydrates intake (e.g. whole grains and minimally processed starch) and an increased intake in unhealthy carbohydrates (e.g. highly processed, added sugars, fast foods) (Vorster, 2013, Wrottesley et al., 2019).

Results of this study agree with research over the years, showing that the consumption of whole grain foods among adolescents may be insufficient. Some of the barriers of whole grain consumption are lack of availability, lack of knowledge and dislike of taste (Kamar et al., 2016). Lack of knowledge referred to not knowing which terms are used for whole grain products when purchasing and not knowing the benefits of consuming whole grains (Kamar et al., 2016). Consumption of whole grain products could be improved through an increase in education about the benefits of whole grain products and which products qualify as whole grain products, as well as availability of whole grain products in schools (Kamar et al., 2016).

Looking at the whole grains/starch food group correlation analysis, two significant relationships were found. Among the overweight group, when the consumption of grains/starch increases, so does the FFM and FFMI. Through this we see that there are no significant correlations between grains/starch consumption and fat mass but rather FFM/muscle mass. Literature shows there is not yet a significant correlation between whole grains consumption/carbohydrate consumption and weight (Dinu et al., 2020). However, whole grains have multiple effects such as contributing dietary fibre, micronutrients, lowering blood cholesterol etc, all these benefits collectively maintain an optimal body weight and reduces the risk of NCDs (Vorster, 2013).

5.3.2 Fruits and vegetables

The SAFBDGs recommends for plenty of fruits and vegetables to be consumed daily, which according to WHO is at least 400g (1 serving = 80g) of fruits and vegetables per day (Naudé, 2013). Consuming plenty of fruits and vegetables increases dietary diversity and micronutrient intake (Naudé, 2013). The majority of the sample indicated "sometimes" consuming less than 3-4 servings (240g – 320g) of vegetables or less than 2-3 servings (160 – 240g) of fruits per day in an average week (Figure 12), a mean REAP score of 4.15 (Table 15). This does not meet the recommendation given by WHO (Naudé, 2013), the desired outcome according to the WHO recommendation should have been rarely consuming below 2-3 or 3-4 servings of fruits and vegetables, respectively.

Between the black African and the white group, the black African group shows a better consumption of fruits and vegetables than the white group. South African literature shows fruits and vegetables consumption to be high among adolescents in urban areas (Shisana et al., 2013, NDoH et al., 2019). This could be due to access and availability to fruits and vegetables in urban areas (NDoH et al., 2019) . However, according to literature adolescents who are of the black African population group, have a lower consumption of fruit and vegetable than that of the white population group (NDoH et al., 2019), and this is opposite to the pattern of this population. This increase/ good consumption of fruit and vegetables could also be due to parental influence on availability of foods in the household. Research has shown that consumption of fruit and vegetables while watching TV has an overall increase on fruit and vegetable consumption in adolescents (Pearson et al., 2017), which could be a habit/pattern among this sample.

No significant correlations were found for the fruit and vegetables food group. Although not significant, we see an increase in fruits and vegetables consumption being associated with a low/ decrease in FM for most of the groups (Table 18). Fruits and vegetables are a source of fibre and so an increased consumption leads to increased satiety reducing the overall energy intake of an individual (Schwingshackl et al., 2015, Du et al., 2010).Secondly, an increased consumption of fruits and vegetables is seen as a health conscious act, which consequently reduces the intake of high-fat food products and high-sugar food products (Collese et al., 2017). High-fat and high-sugar products are linked to obesity (Collese et al., 2017), therefore an increased intake of fruits and vegetables reduces the risk of obesity (Mellendick et al., 2018).

5.3.3 Dairy

Dairy provides majority calcium in adolescent diets and helps prevent against osteoporosis (Vorster et al., 2013b, Phillips et al., 2003). A study done in the United Kingdom shows that diary consumption has been decreasing among adolescents over the past recent years, due to the belief that dairy adds to the risk for obesity (Green et al., 2015). Contrastingly, a study done in South Africa shows dairy consumption to have increased over the years, possibly due to the shift to a more westernized diet (Ronquest-Ross et al., 2015). The sample of our study usually consumes less than two to three servings of dairy a day (Figure 11), with a mean REAP score of 5.65 (Table 15)), usually choosing full cream/regular fat options. The recommended intake in South Africa is 400 – 500 ml low-fat milk per day (Vorster et al., 2013b), our study sample does not meet this recommendation.

In a more recent South African study, the Ronquest-Ross et al. (2015) study, urban adolescents were reported to have a decrease in dairy consumption (Wrottesley et al., 2019), which supports our study sample findings. The low intake seen in our study may be due to similar reasons as seen in the United Kingdom study (Green et al., 2015). Not meeting the recommended intake puts adolescents at a risk of low calcium and decreased bone health (Vorster et al., 2013b).

We found that, although not statistically meaningful, an increase in dairy consumption in the overweight group was associated with a decrease in FFM, and that among the Black African group an increase of dairy consumption is associated with a decrease in FFM (Table 19). Relationships between FFM and dairy consumption are not known as yet, however research has shown there to be no significant associations or a possible inverse association between dairy consumption and BMI or body fat (Nezami et al., 2016, Dougkas et al., 2019, Moreno et al., 2015). Dairy is a good source of protein and so it could promote physical growth in adolescents, by supporting linear/bone growth (Nezami et al., 2016). Bone mass makes a part of FFM (Kuriyan, 2018), therefore one would assume an increased consumption of dairy would have a correlation with an increase in FFM values instead of a decrease. Again, a more reliable tool to determine the exact dairy intake of adolescents would need to be used to determine whether a real relationship with BC or BMI might exist.

5.3.4 Fats and oils

Good types of fats and oils (polyunsaturated and monounsaturated fatty acids) are beneficial for growth and development, whereas poor types of fats and oils add to fat mass (trans fatty acids and saturated fatty acids) (Smuts and Wolmarans, 2013, Feeley et al., 2013). Good types of fats prevent bad/poor cardiovascular health, prevent degenerative disease and promote neurodevelopment (Smuts and Wolmarans, 2013). The guideline for total fat intake is 68g (Smuts and Wolmarans, 2013).

Questions from the REAP questionnaire which have been grouped together to represent the fats and oils group, also include questions on snacks and fried food consumption. The use of regular fats and oils in cooking or as condiments (non-low-fat options), the consumption of fried foods and the consumption of regular snacks (e.g., potato chips), is usual among our study sample, with a mean REAP sore of 9.83 (Table 15). These results agree with literature, as South African adolescents have been described to have a high consumption of fried foods and often opt for high fat products over low-fat products or vegetables oils (Venter and Winterbach, 2010, Steyn, 2010, NDoH et al., 2019, Feeley et al., 2013). In addition, adolescents have a high consumption of snacks in place of meals (Venter and Winterbach, 2010). Snacking while watching TV has increased the consumption of snacks among adolescents (Larson et al., 2016), and furthermore, a lack of nutrition knowledge results in a dietary pattern of high snack or fats and oils consumption (Steyn, 2010).

The questions grouped together for the fats and oils food group assessed the consumption of snacks and fried foods as well. An unexpected outcome was to find no significant relationships between the consumption of fats and oils and the weight status and BC variables. Although not significant, there are negative r-values between all groups (except the white group) and FM and FMI. An increase in REAP score for the fats and oils group indicates a use of good/healthy fats. Therefore, the observed negative r-value indicate that a consumption of healthy fats is related to a decrease in FM. Research has shown that a high consumption of high fat/energy-dense snacks and saturated fats has an, association with increased BMI z-scores and increased FM (Larson et al., 2016), thereby supporting the results of this study. A possible explanation to the absence of a significant relationship between BMI and FM, could be due to missing/ incomplete questions of the REAP affecting the scores and analysis and the REAP score not being sensitive enough to detect a meaningful relationship.

5.3.5 Meat

Meat/ animal products provide macro- (protein and fat) and micronutrients (vitamin B1,2,6,12, calcium, iron and zinc) to the body. Without an adequate amount of protein intake from animal sources, there may be an increase in fat mass but not length/height among individuals (Schonfeldt and Hall, 2013). The recommended intake of meat according to the SAFBDGs is: two to three servings of fish per week, four eggs per week and 90g/day of lean meat (Schonfeldt and Hall, 2013).

The sample of our study indicated that they usually (Figure 9) consume 224g of meat per day and they choose high-fat meats or regular processed meats over lean meats or low-fat processes meats, which resulted in a mean REAP score of 9.91 (Table 15). The REAP questionnaire was limiting as it did not separate meat and fish consumption to allow for separate comparison of the two to the SAFBDGs recommendations. However, a consumption of 224g of meat per day is much higher than the recommended amount of 90g per day (Schonfeldt and Hall, 2013). Research shows that due to urbanization, people consume more meat products high in fat content, more so in urban areas (Schonfeldt and Hall, 2013, Venter and Winterbach, 2010), which supports findings within this study's sample. The choice of consuming high fat food products often/regularly increases the risk of overweight and/or obesity, affecting the growth and development of adolescents, as these high fat options do not provide enough nutrients required for the growth and development of adolescents (Tripicchio et al., 2019, Romieu et al., 2017, Hruby et al., 2016). Including meat in diet, specifically low fat/lean cuts, is beneficial because its bioavailability of iron and zinc is higher than in plant sources and low levels of iron and zinc in South African diets is an issue (Schonfeldt and Hall, 2013).

The meat food group had inverse relationships (using the lower statistical power of 10%) between the consumption of the total sample and FFM and more specifically between the White population group consumption and FFM (Table 21). A higher consumption of meat (high in fat) and processed meats was related to lower FFM (Table 21). Research shows that an increased consumption of lean meat accompanied by increased intakes of fruits and vegetables, results in desired levels of lipids\adiposity in adolescents (Bradlee et al., 2014). Opposite to research, this sample has an increased consumption of high fat meat and a low consumption of fruits and vegetables (Figure 4.4), and consequently undesired levels of fat mass, hence, although not significant, the negative r-value between a high consumption of high fat meat and FM/FMI (Table 21).

The benefit of consuming lean meat is that it provides protein to the body which helps with skeletal muscle build. This is beneficial as it will prevent against disease such as sarcopenia in adulthood (Giromini and Givens, 2022).

5.3.6 High sugar

The SANHANES 2013, has shown adolescents from urban formal areas, among the ages of 15 – 24 years to have a high consumption of sugar (Shisana et al., 2013). Results of this study shows the sample's adolescents to usually consume high sugar foods and beverages (Figure 14), with a mean REAP score of 8.71 (Table 15). The SAFBDGS advise a sparing use of sugar high foods and beverages, which is not adhered to among this population (Temple and Steyn, 2013). This outcome is not preferred, as a high consumption of sugar can displace the consumption of food rich in micronutrients (Temple and Steyn, 2013).

When individuals considered to have a healthy BMI, consume more high sugar products, their BMI z-score also increases. There was a positive relationship between the sugar REAP score of healthy individuals and BMI z-scores, only significant when using a lower statistical power of 10%. This result of the study, is in agreement with research showing high levels of sugar increases BMI z-score (Tripicchio et al., 2019, Larson et al., 2016). Consuming high sugar snacks or an increased consumption of sugar snacks increases an individual's calory intake and subsequently, increases the risk of adiposity/ body weight, resulting in an increase in BMI (Tripicchio et al., 2019).

5.3.7 High sodium

Lastly, this sample has a high consumption of sodium (salt) (Figure 15), with a mean REAP score of 3.90 (Table 15). Once again, prevalence of consumption was seen mostly among the Black African population. This agrees with studies describing adolescents to typically have a high consumption of high salty snacks (Feeley et al., 2013, Venter and Winterbach, 2010). The recommended consumption or use of salt by the SAFBDGs is less than 5g per day. The high consumption of overall salt has been seen to be increased by the consumption of snacks in front of the television (Larson et al., 2016).

In this study, an increased intake of high sodium foods (e.g., frozen meals, canned soap, table salt) relates to an increase in FM among the group classified as overweight, in accordance with findings from Feeley et al. (2013), Steyn (2010) and Venter and Winterbach (2010). With this food group, significance is only noticed for the overweight group. The reason for this could be because overweight or obese adolescents are more susceptible to the characteristic of over snacking, increasing their risk of adiposity (Tripicchio et al., 2019).

5.3.8 Conclusion

Majority of the food groups tested among our sample, show a pattern that does not adhere to the recommendations stipulated by the SAFBDGs. The consumption of the fats & oils, meat, high sugar and high sodium food groups are above recommended intakes and the whole grains/starch, dairy and fruits & vegetables food groups are below the recommended intake. A low-quality diet is generally associated with an increased risk of overweight/obesity (Tripicchio et al., 2019, Larson et al., 2016), however, the results of this study did not always conform with existing evidence. In some cases, e.g., fruits and vegetables with BMI z-scores or BC variables, a significant relationship was not present. It should be noted that even though the REAP tool is suggested as a reliable tool to assess food patterns, it may not have been sensitive enough to determine the exact eating habits of this adolescent population.

6. Chapter Six: Conclusion

The sample group used for this study were adolescent females (13 -19 years), attending private schools in urban, affluent areas of Tshwane. BMI z-score results indicated 60.67% of the sample to have a healthy weight, 29.21% overweight and 8.99% obese and fat mass results indicated that the population had a FM above the healthy range for both Black African and White population groups, highlighting the limitation of using BMI as the only tool to determine weight categories. Fat free mass/FFMI showed the Black African group to have a below standard range FFM/FFMI but the White group has an FFM/FFMI within standard range.

The majority of the sample had an overall poor-quality diet. When analysing each food group, all of the food group patterns did not reflect the stipulated recommendations of the SAFBDGs. This sample consumed over the recommended amounts for the fats & oils group, high sugar group, high sodium group and the meat group. They also consumed below the recommended amount for the dairy, whole grains/starch and the fruits & vegetables group. This resulted in an overall classification of a poor-quality diet.

Correlation analysis was performed using a statistical power of 5%, however this resulted in a few significant relationships for discussion. A statistical power of 10% was then considered, although lower in power, to allow for further discussion of the data. Although not reliable, significant relationships between consumption and weight status and body composition variables, were only found within the dairy, meat, whole grains/starch, high sugar and high sodium food groups. Significant relationships were not found in the fruit & vegetables group and the fats and oils group.

An increased consumption of whole grains in overweight individuals is associated with an increase in FFMI, however no significant correlations have yet been found between whole grains/ carbohydrate consumption and weight (Dinu et al., 2020). In the study, an increased consumption of dairy in overweight and Black African individuals was associated with a decrease in FFM, however research has shown there to be no significant associations between dairy consumption and BMI or body fat (Nezami et al., 2016, Dougkas et al., 2019). The study also showed an increased consumption of high fat meat in the total sample is associated with a decrease in FFM, however this was using the lower statistical power (10%). A consumption of lean meats (not high fat) provides protein to the body, building skeletal muscle and therefore resulting in a positive relationship with FFM (Giromini and Givens, 2022). An increased consumption of high sugar foods in healthy individuals of the study, is associated with an increase in BMI. High sugar consumption increases calory intake and subsequently, increases body weight (Tripicchio et al., 2019). Lastly, an increased consumption of high sodium products in overweight individuals is associated with an increase in FM. High sodium consumption is usually associated with increased snacking, which has been found to increase the risk of adiposity (Tripicchio et al., 2019).

A high percentage of the study sample were overweight and/or obese and their observed food pattern supports overweight/obesity, placing them at an increased risk of developing NCDs later in life. The correlation analysis could not be used to draw a meaningful conclusion about the relationship between dietary intake and weight status and BC.

Recommendations

Therefore, I would recommend that future research may need to include a more detailed analysis of dietary intake to study the relationship between dietary intake and weight status and body composition, as well as measure the activity levels of the study sample to incorporate or eliminate factors of activity that influence weight status and body composition. More research can be done in the private school setting as there is limited research in that setting. The use of BMI as a weight measurement should be accompanied by body composition measurements to accommodate for limitations of the BMI, or more research can be done into creating a tool that is easily accessible, easy to use, with small to no limitations for calculating weight status in large population studies. A larger study sample than that of this study may also allow for stronger correlation analysis.

Strengths and limitations

The use of BMI and BC analysis proved to be beneficial in having a thorough understanding of the populations weight categories. Most of the food group patterns being high among the Black African group could be due to the fact that most of the recruits were Black African than Caucasian, causing a limitation in the population analysis. Not looking into the physical activity levels of the population served as a disadvantage as we could not rule out the effects of physical activity on body composition, leaving the possibility that some relationships observed are related to physical activity more than food patterns. The REAP only assessed food patterns according to an average week, therefore the possibility of over reporting or under reporting due to memory was possible when answering the REAP. Lastly, time constraints caused by the

COVID-19 lockdown restrictions in 2021 affected the recruitment procedure placing a limit on the number of participants recruited.

7. Chapter Seven: References

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Appendices

Appendix A

TOPIC	In an average week, how often do you:	Usually/ Often	Sometimes	Rarely/ Never	Does not apply to me
MEALS	1. Skip breakfast?	❍	❍	❍	
	2. Eat <u>4 or more</u> meals from sit-down or take out restaurants?	❍	❍	❍	
GRAINS	3. Eat <u>less than 3 servings</u> of whole grain products a day? **Serving** = 1 slice of 100% whole grain bread; 1 cup whole grain cereal like All bran or Weet-bix, muesli, high fiber cereals, oats, 3-4 whole grain crackers, ½ cup brown rice or whole wheat pasta	❍	❍	❍	
FRUITS & VEGETABLES	4. Eat <u>less than 2-3 servings</u> of fruit a day? **Serving** = ½ cup or 1 med. fruit or ¾ cup 100% fruit juice	❍	❍	❍	
	5. Eat <u>less than 3-4 servings</u> of vegetables/potatoes a day? **Serving** = ½ cup vegetables/potatoes, or 1 cup leafy raw vegetables	❍	❍	❍	
DAIRY	6. Eat or drink <u>less than 2-3 servings</u> of milk, yogurt, or cheese a day? **Serving** = 1 cup milk or yogurt; 57g cheese	❍	❍	❍	
	7. Use <u>2% (reduced fat</u>**)** or <u>full cream milk</u> instead of skim (non-fat) or 1% (low-fat) milk?	❍	❍	❍	Rarely use milk ❍
	8. Use <u>regular cheese</u> (like Feta, Cheddar, Swiss, Gouda, Mozzarella) instead of low fat or part skim cheeses as a snack, on sandwiches, pizza, etc.?	❍	❍	❍	Rarely eat cheese ❍
MEATS/CHICKEN/TURKEY	9. Eat red meat, pork or chicken <u>more than 2 times a</u> week?	❍	❍	❍	
	10. Eat more than 224g (see sizes below) of red meat, chicken, turkey, pork or fish <u>per day</u>? ***Note**: 84g of meat or chicken is the size of a deck of cards or ONE of the following:*	❍	❍	❍	Rarely eat meat, chicken, turkey or fish

	1 regular hamburger, 1 chicken breast or leg (thigh & drumstick), or 1 pork chop. 11. Choose <u>higher fat red meats</u> like ribeye steak, T-bone steak, hamburger, ribs, etc. instead of lean red meats like sirloin steak, shank cuts or loin steak. 12. Eat the <u>skin</u> on chicken and turkey or the <u>fat</u> on meat? 13. Use <u>regular processed meats</u> (like polony, salami, corned beef, hotdogs, sausage or bacon) instead of low-fat processed meats (like roast beef, turkey, lean ham; low-fat cold cuts/hotdogs)?	❍ ❍ ❍	❍ ❍ ❍	❍ ❍ ❍	❍ Rarely eat meat ❍ Never eat meat, or poultry ❍ Rarely eat processed meats ❍
FRIED FOODS	14. Eat <u>fried foods</u> such as fried chicken, fried fish, fried potato chips, fried chicken feet, vetkoek?	❍	❍	❍	

TOPIC	In an average week, how often do you:	Usually/ Often	Sometimes	Rarely/ Never	Does not Apply to me
SNACKS	15. Eat regular potato chips, corn chips (e.g., Doritos, Fritos, Big Korn Bites, Nachos), crackers, regular popcorn, nuts, biltong instead of pretzels, low-fat chips or low-fat crackers, air-popped popcorn (e.g., Jumping Jack or Hoppity Poppity)?	❍	❍	❍	Rarely eat these snack foods ❍
FATS AND OILS	16. Use regular salad dressing & mayonnaise instead of low-fat or fat-free salad dressing and mayonnaise?	❍	❍	❍	Rarely use dressing/mayo ❍
	17. Add butter, margarine or oil to bread, potatoes, rice or vegetables at the table?	❍	❍	❍	
	18. Cook with oil, butter or margarine instead of using non-stick sprays or cooking without fat?	❍	❍	❍	Rarely cook ❍
SWEETS	19. Eat sweets, cake, cookies, pastries, donuts, muffins, and chocolate instead of low fat or fat-free sweets?	❍	❍	❍	Rarely eat sweets ❍
	20. Eat regular ice cream instead of sherbet, sorbet, low fat or fat-free ice cream, frozen yogurt, etc.?	❍	❍	❍	Rarely eat frozen desserts ❍
	21. Eat sweets, cake, cookies, pastries, donuts, muffins, chocolate more than 2 times per day.	❍	❍	❍	Rarely eat sweets ❍
SOFT DRINK	22. Drink 473ml or more of fizzy drinks, fruit drink/punch? ***Note***: 1 can = 330ml Examples of fizzy drinks: Coke, Sprite, Pepsi, Cool-time, Kingsley	❍	❍	❍	
SODIUM	23. Eat high sodium processed foods like canned soup or pasta, frozen/packaged meals, chips?	❍	❍	❍	
	24. Add salt to foods during cooking or at the table?	❍	❍	❍	
ACTIVITY	25. Do less than 30 total minutes of physical activity 3 days a week or more? (Examples: walking briskly, gardening, golf, jogging, swimming, biking, dancing, etc.)	❍	❍	❍	
	26. Watch more than 2 hours of television or videos a day?	❍	❍	❍	

Do you….	Yes	No
27. Usually shop and prepare your own food?	❍	❍
28. Ever have trouble being able to shop or cook?	❍	❍
29. Follow a special diet, eat or limit certain foods for health or other reasons?	❍	❍

30. **How willing are you to make changes in what, how or how much you eat in order to eat healthier? (Circle the number that best describes how you feel)**

Very willing				**Not at all willing**
5	**4**	**3**	**2**	**1**

Appendix B

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PARENTAL OR LEGAL GUARDIAN INFORMATION AND INFORMED CONSENT

We thank you for your time. This study forms part of two research projects being undertaken. Please find the details below.

Study titles:

1. Vitamin D status, weight status and body composition of female adolescents attending a private school in Tshwane (Gauteng, South Africa).
2. The relationship between food patterns, weight status and body composition of female adolescents attending a private school in Tshwane, South Africa.

Principal Investigator: Veronica Wessels and Ntsepase Matete

Supervisor: Dr Z White and Dr A Pretorius

Institution: University of Pretoria

Telephone number/s: 066 092 5922 (Veronica) or 076 525 7384 (Ntsepase)

Email address: upstudy21@gmail.com

All the information will be discussed below. Should you have any questions or require any clarification please don't hesitate to contact the researchers using the above listed contact details.

Dear Parent or Legal Guardian

1. INTRODUCTION

Allow us to introduce the researchers. Veronica Wessels and Ntsepase Matete are master's students at the University of Pretoria, in dietetics and nutrition, where their focus is research in female adolescents.

We invite your child to participate in a research study. This information document will help you to decide if your child may want to participate and if you consent for them to participate. Before you agree that your child may take part, you should fully understand what is involved. If you have any questions that this document does not fully explain, please do not hesitate to contact the researchers.

2. THE NATURE AND PURPOSE OF THIS STUDY

There are two research projects fulfilling 6 purposes, which are:

1. Identifying how much vitamin D is in different teenager's bodies.
2. Identifying how many teenagers are deficient in vitamin D.
3. Identifying how much fat-free mass and fat mass are in teenagers' bodies.
4. Identifying how does your fat mass relate to your vitamin D status.
5. Identifying what the typical food intake of a teenager is.
6. Identifying how a teenager's food intake is related to their fat-free and fat mass.

Please note: All information will be kept confidential (private). Only you and the researcher will know your fat and vitamin D results. Your name and information will not be made available to anyone or published on any platform. We as researchers are bound by the Protection of Personal Information (POPI) act and strictly adhere to this.

3. EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS.

The following will be assessed:

- Height – making use of a height meter
- Weight, body fat mass and fat-free (lean) mass – using specialised equipment (SECA mBCA 514)
- Vitamin D status through a finger prick
- Eating patterns through a 10-minute questionnaire

4. POSSIBLE RISK AND DISCOMFORT INVOLVE

There are no risks involved in participating in the study. Some of the procedures may cause minimal discomfort (finger prick) and take some of your child's time.

5. POSSIBLE BENEFITS OF THIS STUDY

The results will provide you and your child with information related to their vitamin D status and body composition.

You and your child will also be invited to join a virtual webinar hosted by dietitians on "Healthy Eating during Exams". The link will be provided on the day of your assessment.

The study results may help us to improve our knowledge on body composition and vitamin D statuses in female adolescents attending a private school in Tshwane (Gauteng, South Africa).

6. YOUR CHILD'S RIGHTS AS A PARTICIPANT?

Your child's participation in this study is entirely voluntary. Your child can refuse to participate or stop at any time during the study without giving any reason. Your child's withdrawal will not affect his/her treatment/access to any health care.

7. ETHICS APPROVAL

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4-59, Telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors in biomedical research involving humans. A copy of the Declaration may be obtained from the investigator should you wish to review it.

8. COMPENSATION

You will not be paid to take part in the study. However, you will not be liable for any costs. This specialised vitamin D test cost around R1000.00 and the adolescent body composition costs between R300.00-R600.00. Because this assessment forms part of a study it will be free of charge.

9. CONFIDENTIALITY

All information about your child will be kept strictly confidential. Once we have analysed the information no one will be able to identify your child. Research reports and articles in scientific journals will not include any information that may identify your child.

10. CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent for my child to take part in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have also received, read, and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections for my child to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed, and presented in the reporting of results.
- I understand that my child will not be penalised in any way should my child wish to discontinue with the study and that withdrawal will not affect my child's access to health care.
- My child is participating willingly.
- I have received a signed copy of this informed consent agreement.

______________________________________	______________________	___ / ___ / _____
Name of parent / legal guardian (print)	**Signature**	**Date**

____ ___ / ___ / _____

Signature: Veronica Wessels (researcher) **Date**

____ ___ / ___ / _____

Signature: Ntsepase Matete (researcher) **Date**

Please remind your child to book a times slot for their assessment using the link provided on their consent form.

INFORMATION AND ASSENT FOR PARTICIPANT / STUDENT

We thank you for your time. This study forms part of two research projects being undertaken. Please find the details below.

Study titles:

3. Vitamin D status, weight status and body composition of female adolescents attending a private school in Tshwane (Gauteng, South Africa)
4. The relationship between food patterns, weight status and body composition of female adolescents attending a private school in Tshwane, South Africa

Principal Investigator: Veronica Wessels and Ntsepase Matete

Supervisor: Dr Z White and Dr A Pretorius

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Telephone number/s: 066 092 5922 (Veronica) or 076 525 7384 (Ntsepase)

Email address: upstudy21@gmail.com

All the information will be discussed below. Should you have any questions or require any clarification please don't hesitate to contact the researchers using the above listed contact details.

1. INTRODUCTION

Allow us to introduce the researchers. Veronica Wessels and Ntsepase Matete are master's students, in dietetics and nutrition, at the University of Pretoria where their main focus is research in female adolescents.

The research studies will be explained below. You can choose whether or not you want to participate in this study. The study details have also been communicated with your parent(s) or legal guardian(s) as they are also required to provide consent in the event that you are younger than 18 years old. We would really appreciate your participation in this study; however, it is not compulsory. Should you choose not to participate in the study you will not be disadvantaged in any way. We encourage you to have informed conversations with your family and friends to come to a conclusion.

2. WHAT IS RESEARCH?

Research is what we do to find new knowledge about subjects (and people). In this instance the research will help us further understand the link between nutrition and both health and disease in teenagers.

3. WHAT IS THIS RESEARCH PROJECT ALL ABOUT AND WHAT IS EXPECTED OF ME?

There are two research projects fulfilling 6 purposes, which are:

7. Identifying how much vitamin D is in different teenager's bodies.
8. Identifying how many teenagers are deficient in vitamin D.
9. Identifying how much fat-free mass and fat mass are in teenagers' bodies.
10. Identifying how does your fat mass relate to your vitamin D status.
11. Identifying what the typical food intake of a teenager is.
12. Identifying how a teenager's food intake is related to their fat-free and fat mass.

Please note: All information will be kept confidential (private). Only you and the researcher will know your fat and vitamin D results. Your name and information will not be made available to anyone or published on any platform. We as researchers are bound by the Protection of Personal Information (POPI) act and strictly adhere to this.

4. WHY HAVE I BEEN INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

You are a female teenager (adolescent) aged between 13 and 19 years.

5. WHO IS DOING THE RESEARCH?

A dietitian and nutritional scientist.

6. WHAT WILL HAPPEN TO ME IN THIS STUDY?

We will start by measuring your height using a height meter. You will then move over to have your weight, and body fat (and fat-free mass) measured on a highly specialised scale. We will then do a finger prick to transfer drops of blood onto a piece of paper that we will be sent to the lab in Oregon (USA) for them to test your vitamin D levels. You will then be asked to complete a 10-minute questionnaire on your food patterns.

7. CAN ANYTHING BAD HAPPEN TO ME?

Nothing bad can happen to you because of this research study. You may experience some discomfort with the finger prick, but it will be over in seconds.

8. CAN ANYTHING GOOD HAPPEN TO ME?

You will be provided with your results which can empower you to live a healthier lifestyle. You will receive your weight and height immediately. Because the specialised equipment is designed for adults, we must use a specialised equation to calculate your fat mass and fat-free mass. Therefore, you will receive your fat mass, fat-free mass, and vitamin D levels once the lab has sent the vitamin D results. This may take time as it is being sent from a lab in the US. This specialised vitamin D test cost around R1000.00 and the adolescent body composition costs between R300.00-R600.00. Because this assessment forms part of a study it will be free of charge.

You are also invited to join a virtual webinar hosted by dietitians on "Healthy Eating during Exams". The link will be provided on the day of your assessment.

9. ETHICS APPROVAL

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Medical Campus, Tswelopele Building, Level 4-59, Telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee.

10. WILL ANYONE KNOW I AM IN THE STUDY?

Only the researchers and your parents (if you are younger than 18 years old) will know that you are participating in the study unless you personally inform anyone else.

11. WHAT IF I DO NOT WANT TO DO THIS?

You do not have to participate in the study, even if your parent or legal guardian(s) have signed consent that you can participate.

You can also withdraw from the study at any time without any consequences.

12. CONSENT TO PARTICIPATE IN THIS STUDY

Please tick the applicable blocks below:

a) Do you understand this research study and are you willing to participate in it?

Yes	No

b) Do you understand that you will have your weight, height, fat mass, fat-free mass, and vitamin D levels measured (finger prick)?

Yes	No

c) Do you have any questions for the researcher? If yes, please send your questions via email, SMS, WhatsApp, or phone using the details above.

Yes	No

d) Do you understand that you can pull out of the study at any time without any consequences?

Yes	No

Please note: This form can be completed and submitted through the various means:

- Electronically prior to the assessment
- Completed at home and submitted to the researcher on the day of your assessment
- Completed at the sight of the assessment

______________________________	____________________	___ / ___ / _____
Name of participant / student (print)	**Signature**	**Date**

If you have completed the consent, please proceed to book your timeslot below:

→ Link

Appendix C

<u>School A</u>

12 May 2021

To whom it may concern

Ms Ntsepase Matete is hereby given permission to conduct her research into Vitamin D status, weight status and body composition in female adolescents, at [redacted]nder the following conditions:

- The school will email a letter from her out to the parents of girls in the school to guage who is interested. The responses will go straight to Miss Matete.
- She will then contact the parents and arrange a date and time for testing at the school. This will be done over three agreed upon afternoons starting at 2:15pm.
- All communication will take place directly between Miss Matete and the families concerned
- The sanitisation and social distancing etc will be managed by her.

Yours Sincerely,

Keith Viljoen
College Principal

School B

8 March 2022

To whom it may concern

Ms Ntsepase Matete and Ms Veronica Wessels (as Principal Investigators) are hereby given permission to conduct research for their projects, as listed below, at [redacted] under the conditions which follow.

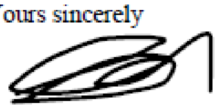
Study Titles:

1. The relationship between food patterns, weight status and body composition of female adolescents attending a private school in Tshwane, South Africa.
2. Vitamin D status, weight status and body composition of female adolescents attending a private school in Tshwane (Gauteng, South Africa).

Conditions of acceptance.

- The investigators will present the project to the learners in an assembly.
- The school will then send a letter communicating about the research project, and the consent and assent forms, to the parents via the school communicator. The responses will go directly to the researchers.
- The investigators will carry out the data collection at [redacted]n the afternoons of 29, 30 and 31 March 2022.
- All communication will take place directly between the investigators and the participants.

Yours sincerely



Luciel Morgan

Deputy Principal – Student Character and Wellness

Appendix D

SEE WHAT YOU ARE MADE OF

Participate in a research study

Protein
Minerals
Body fat mass
Total body water

We are looking for females aged 13 - 19 years of age to participate in a study looking at body composition, weight status, vitamin D and food patterns.

Expectations

- Body composition and weight status analysis using a bioelectrical impedence analysis scale. (1,2)
- Questionnaire to asses food patterns. (1)
- Finger prick test to asses Vitamin D levels. (2)

Benefits

- Know if your food patterns/eating habits are healthy or unhealthy, which is important to avoid food related diseases .
- Know what your body consists of (fat vs fat-free mass), which help you make choices to improve your health.
- Know your weight status (BMI)
- Know your vitamin D levels

Location

St Mary's DSG, Pretoria

For more information on how you can take part:
Email: upstudy21@gmail.com
Call/WhatsApp: 0765257384 or 0660925922

SCAN ME

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1. This study is conducted by Ntsepase Matete, Masters student, University of Pretoria, supervised by Dr A Pretorius. Ethical approval received from the Faculty of Natural and Agricultural Research Ethics Comittee (clearance number: NAS154/2021)
2. This study is conducted by Veronica Wessels, Master student, University of Pretoria, supervised by Dr Z White. Ethical approval received from the Faculty of Health Science Ethics Comittee (clerance number: 262/2021)

Appendix E

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

PRE-TEST CHECKLIST

We thank you for your participation in this study. We request that you complete this questionnaire to ensure accurate results when assessing your body composition. Please note this questionnaire is anonymous. Your honesty would be greatly appreciated.

Question	Agree	Disagree
1. I have not consumed alcohol within the past 24 hours.		
2. I have not eaten within the past hour.		
3. I have not taken part in heavy / intense exercises within the past 12 hours.		
4. I am well hydrated		
5. I have emptied my bladder		
Participant code:		

Appendix F

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Natural and Agricultural Sciences
Ethics Committee

E-mail: ethics.nas@up.ac.za

23 March 2022

ETHICS SUBMISSION: LETTER OF APPROVAL - AMENDMENT

Dr A Pretorius
Department of Consumer and Food Sciences
Faculty of Natural and Agricultural Science
University of Pretoria

Reference number: NAS154/2021 Line 3
Project title: The Relationship between food patterns, weight status and body composition of female adolescents attending a private school in Tshwane, South Africa

Dear Dr A Pretorius,

We are pleased to inform you that the **Amendment** conforms to the requirements of the Faculty of Natural and Agricultural Sciences Research Ethics Committee.

Please note the following about your ethics approval:

- Please use your reference number (NAS154/2021) 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.
- Please note that ethical approval is granted for the duration of the research (e.g. Honours studies: 1 year, Masters studies: two years, and PhD studies: three years) and should be extended when the approval period lapses.
- The digital archiving of data is a requirement of the University of Pretoria. The data should be accessible in the event of an enquiry or further analysis of the data.

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.
- **Applications using GM permits:** If the GM permit expires before the end of the study, please make an amendment to the application with the new GM permit before the old one expires.
- **Applications using Animals:** NAS ethics recommendation does not imply that Animal Ethics Committee (AEC) approval is granted. The application has been pre-screened and recommended for review by the AEC. Research may not proceed until AEC approval is granted.

Post approval submissions including application for ethics extension and amendments to the approved application should be submitted online via the ethics work centre.

We wish you the best with your research.

Yours sincerely,

Appendix G

Dissertation

ORIGINALITY REPORT

14%	12%	7%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	hdl.handle.net Internet Source	1%
2	vital.seals.ac.za:8080 Internet Source	1%
3	hirosaki.repo.nii.ac.jp Internet Source	1%
4	open.uct.ac.za Internet Source	1%
5	researchspace.ukzn.ac.za Internet Source	1%
6	repository.up.ac.za Internet Source	1%
7	"Handbook of Anthropometry", Springer Science and Business Media LLC, 2012 Publication	<1%
8	encore.lib.gla.ac.uk Internet Source	<1%
9	bmcpediatr.biomedcentral.com Internet Source	<1%