

**Association between objectively determined
physical activity levels and body fat percentage in
6-8 year-old children from a black South African
population: BC-IT study**

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Preface



This thesis is submitted in completion for the degree: Doctor of Philosophy in Human Movement Science at the North-West University, Potchefstroom campus. It follows the article format as prescribed by the University.

This research study was completed under the supervision of Prof MA Monyeki and Dr X Janssen. The thesis was written according to guidelines outlined in the “Manual for Higher Degrees Studies” (Approved 1 September 2020).

I, Caroline Molete Sedumedi (student number: 25945408) declare that this thesis is my own work. I further acknowledge the assistance and guidance provided by the promoters and the research team.

Caroline Molete Sedumedi

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Disclaimer

The views and opinions expressed are those of the authors and do not necessarily represent the official views of the South African Medical Research Council (SAMRC), the National Research Foundation (NRF) and International Atomic Energy Agency (IAEA). Any opinion, findings and conclusion or recommendation expressed in this material are those of the authors, and therefore the NRF, SAMRC and IAEA does not accept any liability in this regard.

Dedications



This thesis is dedicated to the children who took part in the study; it would not have been possible without their cooperation. With this work, I hope that the lives of other children will be improved for the better.

Declarations

Prof MA Monyeki (promoter and co-author of articles) and Dr X Janssen (co-promoter and co-author of articles) hereby give permission to the candidate, Ms CM Sedumedi, to include the articles as part of a doctoral thesis. The contribution of each co-author, both supervisory and supportive, was kept within reasonable limits and is explained below:

Ms CM Sedumedi: Developing the proposal, writing the manuscripts, data collection and capturing. Additionally, she performed the analysis, interpretation of the results and compiled the thesis.

Prof MA Monyeki: Principal investigator of the BC–IT Study. Coordinated the study, and provided guidance on statistical analyses and interpretation of results, reviewing the manuscript and comments on the thesis. Additionally, he sourced funding and facilitated CM Sedumedi to undergo technical training in the use of Fourier transform infrared (FTIR) spectroscopy (FTIR 4500t spectrophotometer, Agilent) and accelerometers (ActiGraph Model GT3X-BT, Fort Walton Beach, FL, USA) under the auspices of International Atomic Energy Agency (IAEA) at Physical Activity for Health Group, School of Psychological Sciences and Health University of Strathclyde, Glasgow, Scotland and Unité Mixte de Recherche Nutrition et Alimentation CNESTEN-Université Ibn Tofail, Rabat, Morocco.

Dr X Janssen: Contributed to the thesis and article writing and provided comments on the final thesis.

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

Prof MA Monyeki

Promoter, co-author of articles, and BC–IT Principal Investigator

Dr X Janssen

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Abstract

Background: Physical activity (PA) levels in children are declining, a widespread predicament affecting children from different backgrounds. Decreasing levels of PA coexist with overweight / obesity and stunting in children of sub-Saharan Africa. PA has been shown to decrease adiposity; however, misclassification of PA level and body composition (BC) has led to inconclusive findings. Studies measuring objective PA and direct BC are needed in South African children.

Methods: A total of 93 children aged 6–8 years were sampled from a larger study measuring BC using isotope technique. Birth weight was obtained from Road-to-Health cards. Height and weight, measured according to standard procedures, were used to calculate body mass index (BMI) and BMI z-score. Body fatness was determined using the deuterium dilution method. Accelerometry (ActiGraph: Model GT3X-BT) and a PA questionnaire (PAQ-C) for the older children (aged 8 years only) were used to measure PA levels. Participant characteristics were reported as means and standard deviations (SD), and frequency analysis performed to determine the prevalence of variables. Independent sample t-test and Mann–Whitney U test were performed to report sex differences; level of significance was set at $p < 0.05$. Multiple regression analysis was performed to determine the relationship between birth weight and BC, and between PA and BC. Crude and adjusted models were reported, with adjustments made for age, gender and socio-economic variables. Bland–Altman plots were used to assess the level of agreement between ActiGraph and PAQ-C.

Results: Thirteen percent of the children had low birth weight and almost a third of the children had high adiposity, with girls more affected by high adiposity than boys. Approximately 23% of the children did not meet the recommended PA guidelines. Girls spent significantly more time in sedentary behaviour than boys, who reported higher PA levels than girls ($p < 0.05$). In the adjusted regression model, birth weight was associated with fat mass (FM) ($\beta = 0.21$, $p = 0.02$, 95%CI: 0.001; 0.412) and fat free mass (FFM) ($\beta = 0.24$, $p = 0.013$; 95%CI: 0.032; 0.441) in childhood. Time spent in vigorous PA was significantly associated with lower FM ($\beta = -0.25$, $p = 0.01$) in the age-adjusted model and with lower FM% ($\beta = -0.20$, $p = 0.04$) in the gender-adjusted model. BMI z-score was not associated with any PA indicators ($p > 0.05$). There was a poor level of agreement between PA levels by ActiGraph and PAQ-C. PAQ-C was found to underestimate the PA of the sample population.

Conclusion: Obesity in childhood has an early onset, with birth weight significantly associated with higher FM and FFM. High levels of PA, especially of high intensity, is associated with reduced adiposity. This is only notable when BC is directly assessed, with proxies for BC such as BMI z-score not showing any significant association. Girls show higher adiposity and report lower levels of PA than boys. Interventions to promote healthy birth weight and increase high intensity PA are needed, especially in girls. Use of PAQ-C for the assessment of PA levels in 8-year-old South African children should be approached with caution; other methods such as ActiGraphs are needed.

Key words: Birth weight, body composition, childhood, deuterium dilution method, obesity, objective, overweight, physical activity, stable isotope.

Table of contents

	Page number
Preface	i
Acknowledgements	ii
Disclaimer	iii
Dedication	iv
Declaration	v
Abstract	vi
List of tables	xi
List of figures	xii
List of abbreviations	xiii
Chapter 1: Introduction	
1.1 Introduction	1
1.2 Background	1
1.3 Objectives	6
1.4 Hypotheses	7
1.5 Study framework	7
1.6 Model framework for this thesis	8
1.7 Structure of thesis	9
1.8 Definitions of concepts	9
References	11
Chapter 2: Literature review: Physical activity and body composition in children	
2.1 Introduction	20
2.2 Physical activity	23
2.2.1 Levels of physical activity in children	23
2.2.2 Assessment of physical activity	26
2.2.2.1 Objective methods assessing physical activity	27
• Doubly labelled water	27
• Indirect calorimetry	28
• Heart rate monitors	28
• Pedometers	29
• Accelerometers	29
2.2.2.2 Subjective methods of assessing physical activity	30
• Self-reports	30
• Proxy reports	31
• Direct observation	31
2.2.3 Level of agreement between subjective and objective methods of physical activity	33
Section summary	34
2.3 Body composition	35
2.3.1 Trends in obesity	35
2.3.2 Determinants of childhood obesity	36
2.3.3 Prevention of obesity	38
2.3.4 Assessment of body composition	38
Indirect methods of body composition	40
• Skinfolds	40
	viii

	• Body mass index and body mass index z-scores	41
	• Waist circumference	42
	Direct measures of body composition	43
	• Bioelectrical impedance analysis	43
	• Densitometry	44
	• Deuterium dilution method (Doubly labelled water for body composition measurement)	44
	• Dual-energy X-ray absorptiometry	45
	Section summary	46
2.4	Birth weight and body composition	47
	Section summary	49
2.5	Association between physical activity and body composition	49
	Section summary	52
2.6	Summary and recommendations	52
	References	54
Chapter 3: Association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children: BC–IT study		
	Abstract	72
1	Introduction	73
2	Materials and methods	74
3	Results	76
4	Discussions	79
5	Conclusion	80
	References	82
Chapter 4: Level of agreement between physical activity levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population: BC–IT study		
	Title page	86
	Abstract	87
	Introduction	88
	Methodology	90
	Results	94
	Discussions	97
	Conclusion	100
	References	103
Chapter 5: Association between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC–IT study		
	Title page	110
	Abstract	110
	Introduction	111
	Methodology	112
	Results	116
	Discussions	121
	Conclusion	124
	References	126
Chapter 6: Summaries, conclusions, limitations and recommendations		
6.1	Introduction	134
6.2	Summary	134
6.3	Conclusion	136

6.4	Limitations and recommendations for future studies	141
	References	143
List of appendices		
Appendix A	BC–IT study: Ethics documentation	147
Appendix B	District Education Department Research Approval	148
Appendix C	Recruitment flier, letter to the schools and Department of Education, and informed and assent consent forms	149
Appendix D	BC–IT Study: Anthropometric measurements data form	157
Appendix E	BC–IT Study: ActiGraph compliance verification checklist	159
Appendix F	BC–IT: Stable isotope data form	161
Appendix G	BC–IT Study: BIA data form	162
Appendix H	BC–IT Study: Demographic information, dietary questionnaire and knowledge on food	163
Appendix I	BC–IT: PAQ-C data form	172
Appendix J	Informed consent letter / Lekwalo la go dumela goitsisiwe	201
Appendix K	BC–IT: Written informed consent and assent forms / informed consent letter	218
Appendix L	Instructions for authors: <i>PeerJ</i>	228
Appendix M	Submission letter for publication to PeerJ	239
Appendix N	Instructions for authors: <i>BMC Public Health</i>	241
Appendix O	Guidelines for authors: <i>IJERPH</i>	247
Appendix P	Submission letter for publication: <i>IJERPH</i>	248
Appendix Q	Language editing certificate	271
Appendix R	TURNITIN report	272
Appendix S	Article 3 published in International Journal of Environmental Research and Public Health	273

List of tables

	Page number
Chapter 2: Literature review: Physical activity and body composition in children	
Table 2.1 Advantages and limitations of different methods for assessing physical activity	32
Table 2.2 Models of body composition	39
Table 2.3 Fat mass percentage cut points according to sex	40
Table 2.4 Methods of body composition	40
Table 2.5 BMI cut points	42
Table 2.6 Advantages and limitations of different methods for measuring body composition	46
Table 2.7 Summary of published studies on the relationship between physical activity and body composition in South Africa	52
Chapter 3: Association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children: BC–IT study	
Table 1 Descriptive statistics (minimum, maximum, mean and SD) and percentages (%) for categorical variables of participants	76
Table 2 Birth weight, DDM and BMI z-score percentage score for the total group and by sex	77
Table 3 Participants' body composition according to birth weight groups	77
Table 4 Association between birth weight and body composition measures unadjusted and then adjusted for age, sex and selected SES variables	78
Table 5 Multiple regression analyses of correlates of birth weight (independent variable) and FFM, FM and FM% (dependent variables)	79
Chapter 4: Level of agreement between physical activity levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population: BC–IT study	
Table 1 Anthropometry and body composition for the total sample and by sex	95
Table 2 Characteristics of physical activity measured by ActiGraph and PAQ-C	95
Table 3 Correlation between physical activity by ActiGraph and PAQ-C	96
Table 4 Agreement between ActiGraph MVPA and PAQ-C score for the total sample and sex	96
Chapter 5: Association between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC–IT study	
Table 1 Descriptive statistics of participants	117
Table 2 Prevalence of weight and physical activity categories	118
Table 3 Descriptive characteristics of participants according to the MVPA categories	119
Table 4 Associations between body fatness components and physical activity variables	120

List of figures

	Page number
Chapter 1	
Figure 1 Illustration of the BC–IT study and model framework for data used in the thesis	8
Chapter 2	
Figure 1 An adapted illustration of Ecological model that shows how various factors contributes to childhood obesity	22
Chapter 4	
Figure 1 Bland–Altman plots with differences for PAQ-C total score and MVPA by ActiGraph	97
Chapter 6	
Figure 6.1 Illustration of the study summary	142

List of abbreviations

BC	Body composition
BC-IT	Body composition by stable isotope
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CVDs	Cardiovascular diseases
DAAD	Deutscher Akademischer Austauschdienst
DDM	Deuterium dilution method
DM	Diabetes mellitus
DXA	Dual-energy X-ray absorptiometry
FFM	Fat free mass
FM	Fat mass
FM%	Fat mass percentage
FTIR	Fourier transform infrared
HAKSA	Healthy Active Kids South Africa
HBW	High birth weight
HREC	Health Research Ethics Committee
IAEA	International Atomic Energy Agency
ISAK	International Society for the Advancement of Kinanthropometry
LBW	Low birth weight
LOA	Limits of agreement
LPA	Light physical activity
IOTF	International Obesity Task Force
ml	Millilitre
MPA	Moderate physical activity
MRC	Medical Research Council
MVPA	Moderate-to-vigorous physical activity
NCDs	Non-communicable diseases
NRF	National Research Foundation
NWU	North-West University
PA	Physical activity
PhASRec	Physical Activity, Sport and Recreation
RtHC	Road-to-Health card
SAMRC	South African Medical Research Council
VPA	Vigorous physical activity
WHR	Waist hip ratio

Chapter 1: Introduction

1.1 Introduction

Obesity, defined as excessive accumulation of fat ($\geq 20\%$ boys & $\geq 25\%$ in girls) in the body is a global health problem (Atay & Bereket, 2016:1; Lohman, 1992:150). It is associated with an increasing burden of non-communicable diseases (NCDs) such as cardiovascular diseases (CVD), diabetes mellitus (DM) and metabolic syndrome (Sahoo *et al.*, 2015:187; WHO, 2020:208). Obesity may have an early onset, with the potential to proceed to adulthood if effective strategies are not implemented (Choukem *et al.*, 2020:7). Modifiable risk factors, such as increased physical activity (PA) level, are promising as cost-effective strategies against obesity. Achieving at least 60 minutes of moderate-to-vigorous PA (MVPA) daily in childhood is associated with reduced risk of obesity and general good health (Bull *et al.*, 2020:1456; Choukem *et al.*, 2020:6). However, physical inactivity remains a global problem that affects scores of children from different backgrounds (Aubert *et al.*, 2018:265). Research on the link between physical activity (PA) and body composition (BC) in children has extensively been done. However, the results are conflicting. (Arhab *et al.*, 2019; Ferrari *et al.*, 2015; Collings *et al.*, 2017:777; Reisberg *et al.*, 2020:2261; Vanderloo *et al.*, 2020:9). The contradictions are likely the result of definitions of PA and BC across different studies. Studies employing objective measures of PA show a stronger association with obesity compared to those that rely on subjective measures (Janssen & LeBlanc, 2010:10; Janz, 2006). Studies examining the association between objective measures of PA and BC are needed.

1.2 Background

The global burden of NCDs is on the rise, and associated morbidity and mortality is projected to increase if no intervention is provided (Lin *et al.*, 2020:312). If the world is to achieve at least a 30% reduction in premature deaths from NCDs by 2030, cost-effective strategies are paramount (Roth *et al.*, 2020:3020). Obesity is among the risk factors associated with NCDs such as CVD, DM and metabolic syndrome (Steinberger *et al.*, 2009:638; WHO, 2020:208). Furthermore, obesity exerts a pleomorphic effect on the pathways related to malignant tumour development and progression (Romieu *et al.*, 2017:253). There is increasing evidence suggesting that obesity may have an earlier onset, with genetics and intrauterine factors identified as role players (Choukem *et al.*, 2020:7; Sahoo *et al.*, 2015:187). Birth weight, which is used as a proxy for assessment of intrauterine factors, is associated with obesity in childhood, which, if not corrected, could be

carried into adulthood (Liu *et al.*, 2019:11; Pereira-Freire *et al.*, 2015:448; Weng *et al.*, 2012:1021). It is therefore imperative to assess the impact of birth weight on adiposity indicators in childhood. This can assist in the fight against NCDs as these are the leading causes of deaths globally, they accounted for 74% of all deaths globally in 2019 (WHO 2020b:1). In sub-Saharan Africa (SSA), NCDs are the second most common cause of mortalities, accounting for about 35% of all deaths (Yuyun *et al.*, 2020:2).

With childhood obesity evidently a major problem, it is important to identify risk factors that lead to the development of obesity so that effective eradication strategies can be implemented (Bouchard, 2009:1500; WHO, 2016b:7). In addition to genetic factors and other environmental factors, low levels of PA reported in children as factor underpinning the development of obesity (Aubert *et al.*, 2018:265; Martinez-Gomez *et al.*, 2010:201; Romieu *et al.*, 2017:253). Current World Health Organization (WHO) guidelines are that children and youth (5-17 years) should participate in 60 minutes or more of MVPA per day (Bull *et al.*, 2020:1456). These are activities that get you moving fast moving fast enough to burn more energy than when you are sitting. Such activities include brisk walking, riding a bicycle and playing sports or games. These proposed guideline is a health promotion and disease prevention strategy which needs to be advocated throughout life. Unfortunately, research studies have revealed that PA starts to decline from the age of school entry (6 or 7 years), with levels of PA appearing to decline by 50% by the time the child reaches high school by the age of approximately 14 years (McVeigh & Meiring, 2014:375; WHO, 2016b:21).

Children and youth around the world are not adequately physically active, with some high income countries reporting physical inactivity in approximately 70% of children (Barnes *et al.*, 2018:329; Katzmarzyk *et al.*, 2018:423; Zhang *et al.*, 2020:73). Even in low- to middle income countries, a large number of children are not achieving PA guidelines. Countries in SSA like Ghana and Zimbabwe reports that only about half of the child population achieve the goals set in the guidelines (Manyanga *et al.*, 2018:433; Nyawornota *et al.*, 2018:367). According to the 2018 South Africa Healthy Kids Report Card, only 50% of children and youth are achieving the recommended levels of PA guidelines (Draper *et al.*, 2018:407). These figures should be of concern, this is given the risk factors that are associated with physical inactivity (Draper *et al.*, 2014:103). Such risk factors include increased risk of obesity (Saran *et al.*, 2021:263) and other NCDs. The adoption of urban lifestyles, the introduction of technology-related devices and the shift from active transport to motorised transport, particularly in children from rural areas, are all

responsible for decreasing levels of PA (Choukem *et al.*, 2020:6; Prista *et al.*, 2016:215; Westerterp, 2018:11).

It is important to measure PA levels in children, to assess adherence to PA guidelines and the impact on health markers (Mindell *et al.*, 2014:219). The method of choice for assessing PA depends on the domain of interest, the cost and the knowledge of the research team. The methods of assessing PA are broadly divided into two categories, subjective- and objective PA measurement. Subjective methods include self-reports, interview-administered reports, proxy reports and direct observations. Objective methods of assessing PA involve the measurement of physiological- or biomechanical parameters using equipment (Mindell *et al.*, 2014:219). The method of self-reporting commonly used to assess PA in children is by questionnaire, such as the Physical Activity Questionnaire for Older Children (PAQ-C). However, although validated for use in 8–14-year-olds, the PAQ-C, similar to other questionnaires, may be subject to recall bias (Crocker *et al.*, 1997; Kowalski *et al.*, 2004; Moore *et al.*, 2007:16). For example, children may be able to recall types of PA performed but could fail to recall short bouts of sporadic PA that are common in children (Biddle *et al.*, 2011:6; Crocker *et al.*, 1997). Assessing PA objectively can help overcome participant recall bias. Objective methods of PA include, but are not limited to, the use of accelerometers, heart rate monitors and pedometers (Rowlands & Eston, 2007:274). PA information collected objectively is free from researcher bias and has a low data collection burden for both researcher and participant, but does not provide detailed information about the type of PA performed (Mattocks *et al.*, 2008:110; Oliver *et al.*, 2007:1052). Accelerometers are the most commonly used objective method of PA. Accelerometers are motion sensors that record detailed information on movement count, PA intensity, and date and time of activities (Buchan & McLellan, 2018:782; Oliver *et al.*, 2007:1053). They can collect PA over an extended period and are more affordable and practical than other objective methods such as portable calorimetry (Oliver *et al.*, 2007:1047). Using accelerometer to measure PA eliminates researcher bias, and it also carries lower burden on both researcher and participant. However, accelerometers do not provide detailed information with regard to the type of PA performed and the setting in which this is performed (Oliver *et al.*, 2007:1052; Mattocks *et al.*, 2008:110).

Objective PA assessment is practical and appropriate for use in children and adolescents because, as mentioned above, unlike self-reporting of PA, it is free from recall bias and poses less burden on both researcher and participants (Mattocks *et al.*, 2008:110). However, because of the associated cost, it is often not possible to apply the method in large population studies (Ndahimana

& Kim, 2017:72). Subjective methods such as questionnaires become attractive alternatives (Kowalski *et al.*, 2004; Loprinzi & Cardinal, 2011:16). However, there are discrepancies between the measures of PA determined subjectively and objectively as they often do not give comparable results. These discrepancies are of concern, especially when establishing the relationship between PA and markers of health outcomes (Adamo *et al.*, 2009:23; Benítez-Porres *et al.*, 2016:69; Ben Jemaa *et al.*, 2018). The beneficial effect of PA on markers of health can be missed if PA is not correctly defined.

There is growing body of literature on the association between PA and obesity in children. (Arhab *et al.*, 2019; Collings *et al.*, 2017:778; Ferrari *et al.*, 2015; Monyeki *et al.*, 2017:119; Reisberg *et al.*, 2020:2261; Vanderloo *et al.*, 2020:9). The results are not the same across different studies due to the different methods used to define PA and BC. It is convenient to use self-reporting methods of measuring PA and to use body mass index (BMI) as a proxy for adiposity, as these are simple and affordable (Loprinzi & Cardinal, 2011:16; Reilly *et al.*, 2018; Steene-Johannessen *et al.*, 2016:240;). These measures have a larger error. Hence, smaller associations become difficult to detect (Ekelund *et al.*, 2004:589; Vanderloo *et al.*, 2020:9). Research carried out in children aged 6–8 years from Finland reported low levels of light PA and MVPA which were significantly associated with higher fat mass (FM) index (Collings *et al.*, 2017:774). In European children aged 6–8 years, objectively measured light PA and vigorous PA were positively associated with fat free mass (FFM) index whilst sedentary behaviour (SB) was negatively related to FFM index (Reisberg *et al.*, 2020:2261), whereas a study in 3-12-year-old children from Toronto, Canada found no association between parent-reported PA and waist-to-hip ratio (WHR) (Vanderloo *et al.*, 2020:9). This trend is also seen in African Countries, although only a few studies could be found (Draper *et al.*, 2014:103; Monyeki *et al.*, 2017:119).

The association between PA levels and BC is also weakened by the method employed to assess adiposity. Even though BMI correlates with FM percentage (FM%) (Monyeki *et al.*, 2005), it cannot distinguish between FM and FFM (Kuriyan, 2018). A study on 9–10-year-old European children examining the association between objectively determined PA and adiposity determined by BMI and skinfolds reported a weak association (Ekelund *et al.*, 2004:589), whereas a study in 6–8-year-old children from Finland reported a strong negative association between PA and adiposity as determined by FM% with dual X-ray absorptiometry (DXA) measurements (Väistö *et al.*, 2014:3). Furthermore, a study in 6–8-year-old children from the United Kingdom reported

that higher levels of PA were associated with low FM determined by deuterium dilution method (DDM) but could not find any significant associations when adiposity was reported as BMI (Rennie *et al.*, 2005:17). It is therefore imperative to accurately determine BC, as it gives whole body descriptive characteristics. These accurate measures can be used as scaling factors to normalise physiological variables such as metabolic rate and physical fitness (Goran, 1998:505). The ideal measurement of body fatness should be accurate, precise, accessible and easily applicable to large population studies; however, a method complying with all these criteria does not currently exist (Freedman & Sherry, 2009:24).

Many studies employ BMI as a measure of adiposity as it is simple and affordable, and can be used in large population studies. However, this method is not without its limitations. BMI assumes that someone with normal BMI has normal FM; furthermore, it assumes that an increase in BMI is linear with an increase in FM. However, this is not always the case (Javed *et al.*, 2014:241). Even though BMI correlates with FM% (Monyeki *et al.*, 2005:879), it cannot distinguish between FM and FFM, as previously mentioned (Wells & Fewtrell, 2006:612). The accuracy of BMI as an indicator of adiposity differs considerably according to the degree of body fatness (Freedman & Sherry, 2009:31). Additionally, different cut points exist for the classification of BMI categories and have been shown to give contradicting results in South African children (Moselakgomo & Van Staden, 2017:3).

In vivo methods of BC such as densitometry, DDM, bioelectrical impedance (BIA), whole body counting, neutron activation, DXA, computer tomography and magnetic resonance imaging are more accurate and have a higher clinical value compared with indices of body composition. Proven more accurate with a higher clinical value are in vivo methods of BC (Kuriyan, 2018:655; Wells & Fewtrell, 2006:615). These methods are applicable in both adults and children; however, they have various constraints (Ellis, 2000:671; Goran, 1998:505; Wells & Fewtrell, 2006:615). BIA measures impedance of the body to a small electrical current, based on the assumption that the body is divided into a set number of single cylinders, which is not the case (Goran, 1998:507; Wells & Fewtrell, 2006:613). Advantages of using BIA are that results are reproducible and that it is relatively affordable, portable and simple to use, with results available immediately (Chula de Castro *et al.*, 2018:145; McCarthy *et al.*, 2006:601). However, the disadvantage is weak accuracy when compared to more sophisticated methods such as DDM (McCarthy *et al.*, 2006:601), and BIA has been reported to underestimate FM in children (Chula de Castro *et al.*, 2018:145). The use of stable DDM in children has been shown to be a safe and reliable tool (Bila *et al.*, 2013:66;

Kuriyan, 2018:652). A dose of labelled water is given and, after equilibration, enrichment of the body water pool is measured in saliva, urine or blood. Analysis is made by isotope ratio mass spectrometry (Kuriyan, 2018:652; Wells & Fewtrell, 2006:614), from which overweight/obesity can be reliably determined (Bila *et al.*, 2013:66). Although the procedure is lengthy and expensive, it is simple to carry out and minimal subject cooperation is required, and for these reasons it can easily be used in children and infants (Wells & Fewtrell, 2006:614).

It is against this background that the following research questions are posed: firstly, what is the association between birth weight and BC determined by stable isotope in 6–8-year-old children from a black South African population? Secondly, what is the level of agreement between PA levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population? Lastly, what is the association between objective PA levels and BC determined by stable isotope in 6–8-year-old children from a black South African population? Answering these questions will be of great value, as there is a paucity of data in this regard, particularly from South African children. Findings from the study could guide policies addressing childhood obesity and physical inactivity in South Africa. The study will also add new knowledge of the association between birth weight and BC determined by stable isotope; the relationship between objectively determined PA levels and BC; and the level of agreement between PA measured by accelerometry and PAQ-C in children. The study may serve as a baseline for future studies using the “gold standard” technique of stable isotope and other objective measures in South Africa. The financial constraints and other logistical issues in conducting this type of research limit the number of participants, hence the use of a targeted sample. Furthermore, compared to previous research using less objective methods, findings from this study will be closer to the truth, as more reliable methods will be used.

1.3 Objectives

The objectives of this study were:

- To determine the association between birth weight and BC determined by stable isotope in 6–8-year-old children from a black South African population.
- To compare the level of agreement between PA levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population.
- To determine the association between objective PA levels and BC (FM, FFM and FM%) determined by stable isotope in 6–8-year-old children from a black South African population.

1.4 Hypothesis

This study is based on the following hypotheses:

- Birth weight will be positively associated with adiposity as determined by stable isotope in 6–8-year-old children from a black South African population.
- Poor level of agreement will exist between PA levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population.
- Low PA levels will be significantly negatively associated with adiposity as determined by stable isotope in 6–8-year-old children from a black South African population.

1.5 Study framework

This study is of a cross-sectional nature and forms part of a larger study titled ‘Body composition by isotope techniques and objectively assessing PA in 6–8-year-old children: Body Composition by Isotope Technique (BC–IT) study (2017/2018-IAEA, SAF6020 National Study)’. The larger study examines the relationship between objective (accelerometer) and subjective (PAQ-C) measures of PA and direct (DDM, BIA) and indirect (anthropometric variables) measures of BC indices among 6–8-year-old South African children, and the relationships thereof with other health-related determinant factors (Figure 1) (blood pressure, lifestyle habits).

1.6 Model framework for this thesis

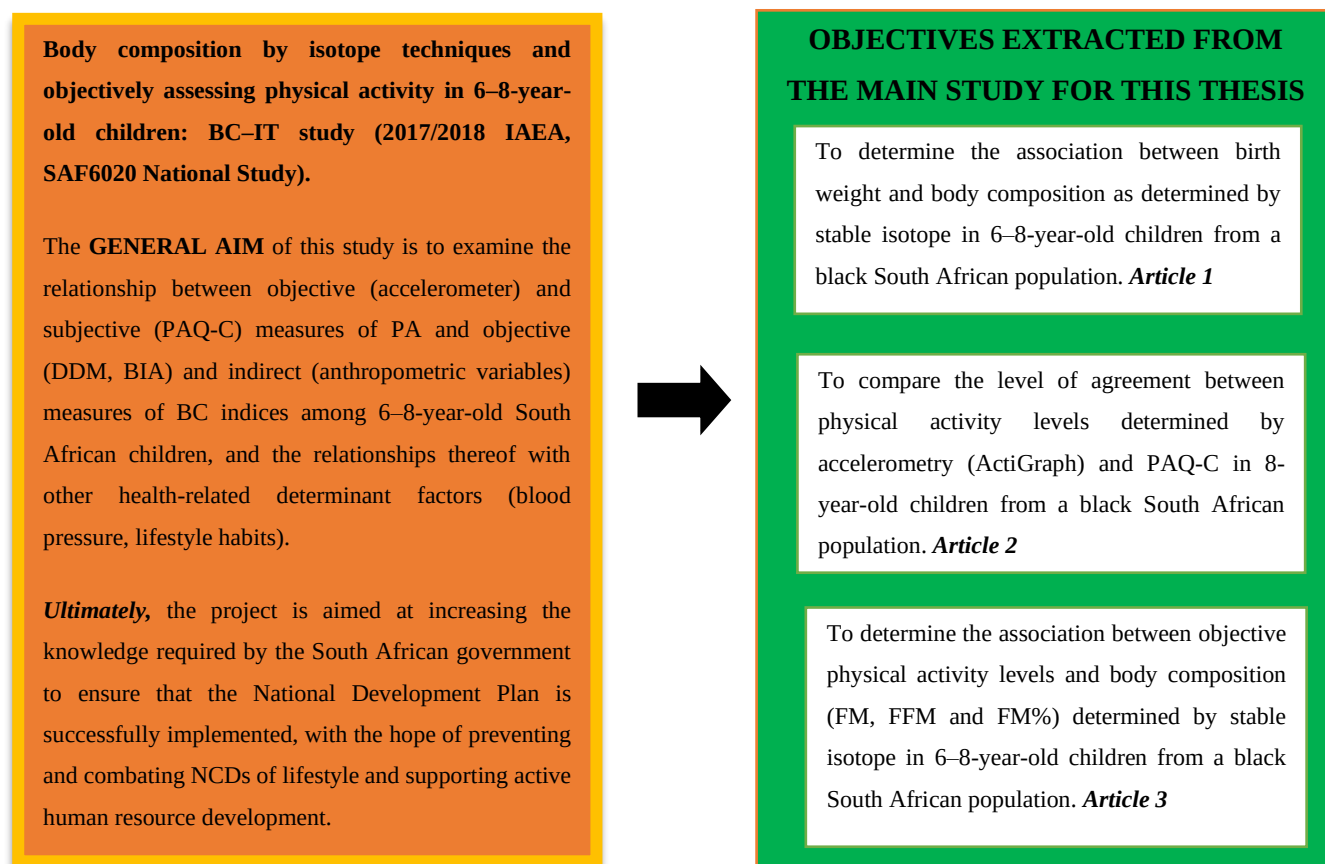


Figure 1: Illustration of the BC–IT study and model framework for data used in the thesis (Data analysed for each objective in accordance with completeness of the data from the main study). BC = Body composition; BIA = bioelectrical impedance; DDM = deuterium dilution method; FFM = fat free mass; FM = fat mass; FM% = fat mass percentage; PA = physical activity; PAQ-C = Physical Activity Questionnaire for Older Children.

1.7 Structure of thesis

The thesis is presented in six chapters. Chapters 1, 2 and 6 were prepared according to the North-West University (NWU) Harvard referencing guideline. The remainder of the chapters (chapters 3, 4 and 5) followed the referencing guide of the journal to which submissions were made. **Chapter 1** serves as an introductory chapter in which the background, problem statement, objectives and hypothesis are outlined. **Chapter 2**, titled *Physical activity and body fatness in children*, provides an overview on various concepts such as childhood PA levels and their impact on BC. The chapter also touches on the different methods of assessing PA and BC. The information reviewed served as the basis for the following three articles, which were prepared according to the guidelines of the journals they were submitted to for publication.

Chapter 3, a research article, titled *Association between birth weight and body composition as determined by DDM in 6- to 8-year-old South African children: BC–IT study*, was adapted and submitted to *Peer-reviewed Journal (PeerJ)*. **Chapter 4**, also a research article, titled *The level of agreement between physical activity levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population*, is formatted to the guidelines of *BMC Public Health*. **Chapter 5**, also a research article, titled *Association between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC–IT study*. The article is prepared according to the *International Journal of Environmental Research and Public Health (IJERPH)* guidelines. **Chapter 6** provides general discussions, conclusions, limitations and recommendations for future research.

With reference to Chapters 3, 4 and 5, the guidelines for authors for the journals the articles are submitted to are attached as appendices. Informed consent, data sheets, ethics approval letter and other important documents are also included in the appendices. Appendices follow at the end of the thesis.

1.8 Definition of concepts

Low birth weight: Birth weight of the baby taken after birth of less than 2.5 kg (WHO, 2016a:1)

High birth weight: Birth weight of the baby taken after birth of greater or equal to 4.5 kg (Evensen *et al.*, 2017:5)

Body composition: The proportion of FM and FFM in the body (Goran, 1998:505).

Moderate-to-vigorous physical activity: The sum of time spent in moderate and vigorous PA (PA of greater or equal to 2296 counts per minute), these are activities that make you breath harder or your legs feel tired. Examples of such activities include sports, games and dancing (Evensen *et al.*, 2008:1561)

Obesity: Excess amount of fat in the body, that is, FM% of >20% in boys and >25 & in girls (Atay & Bereket, 2016:1; Lohman, 1992:150)

Physical activity: Body movement produced by skeletal muscles that result in substantial energy expenditure above resting energy expenditure (Caspersen *et al.*, 1985:126; Welk *et al.*, 2000:65)

Sedentary behaviour: Engaging in activities that involve energy expenditure of less than 99 counts per minute, this is when you are sitting down or laying down but not sleeping (Evenson *et al.*, 2008:1561)

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Chapter 2: Literature review: Physical activity and body composition in children

2.1 Introduction

Cardiovascular diseases (CVD) accounted for 6.2 million deaths globally in people between the ages of 30 and 70 years, in 2019 (Roth *et al.*, 2020:3020). Overweight and obesity, defined as excessive body fatness (fat mass (FM) percentage of >20% in boys and >25% in girls) are among the risk factors that cause non-communicable diseases (NCDs) of lifestyle (Lohman, 1992:150; WHO, 2020:208). Furthermore, in wake of the recent coronavirus global pandemic, which has claimed millions of lives, overweight and obesity perpetuated complications and deaths from the disease (Wang *et al.*, 2020:9). The prevalence of overweight in school-aged children is 10.6% in sub-Saharan Africa (SSA), with obesity reported at 2.5% (Choukem *et al.*, 2020:6). Although these figures are lower than reported in high income countries, the numbers are still worrying, given the increased risk of diseases such as diabetes mellitus (DM), hypertension and some cancers that is associated with obesity later in life (Choukem *et al.*, 2020:6; Thorpe & Ferraro, 2004:127). Further to these predicaments, SSA is faced with an increase in the coexistence of malnutrition and overweight / obesity, which runs parallel with reduced growth rate (Choukem *et al.*, 2020:3; Melaku *et al.*, 2018:838; Monyeki *et al.*, 2014:117). To achieve at least 30% reduction in premature death linked to NCDs by 2030 globally, cost-effective strategies are paramount (Roth *et al.*, 2020:3020). Modification of risk factors such as overweight and obesity using diet and physical activity (PA) has emerged as possible strategies (Weihrauch-Blüher *et al.*, 2018:268).

Childhood overweight and -obesity may have an earlier onset because of maternal and intrauterine factors (Choukem *et al.*, 2020:7). Birth weight is used as a proxy for the assessment of intrauterine growth (Wilcox, 2001:1242). Both low birth weight (LBW) and high birth weight (HBW) are associated with childhood obesity (Liu *et al.*, 2019:11; Noel *et al.*, 2020:197). Furthermore, low levels of PA and high levels of sedentary behaviour (SB) have been pinpointed as causes of overweight and obesity in childhood (Choukem *et al.*, 2020:6). In research, findings on the impact of PA on obesity have been contradictory, with some studies

reporting a positive relationship and others failing to show a significant relationship (Ben Jemaa *et al.*, 2018:236; Monyeki *et al.*, 2017:119; Vanderloo *et al.*, 2020:12). An adapted Ecological Theory developed by Davison and Birch (2001) demonstrated the complexity of obesity through a multifaceted system (Figure 1). The illustration revealed that child behavioural patterns such as dietary intake, physical activity, and sedentary behaviour (such as TV viewing) can place a child at risk of overweight. It is evident how child characteristics including age, gender, and susceptibility to weight gain that interact with child risk factors. The same model also demonstrated that the development of child risk factors is shaped by parenting styles and family characteristics (parents' dietary intake and activity patterns, nutritional knowledge, child feeding practices, and peer and sibling interactions) (Davies & Birch, 2001:19). Additionally, the school environment (structured periods for activity and the dietary quality of school lunches, and community, demographic), and larger environmental factors (parent work-related demands (i.e. work hours and leisure time)), ethnic background and the availability and accessibility of recreational facilities, influence child weight status as a result of their influence on parenting practices and children's daily eating and activity behaviours (Davies & Birch, 2001:19).

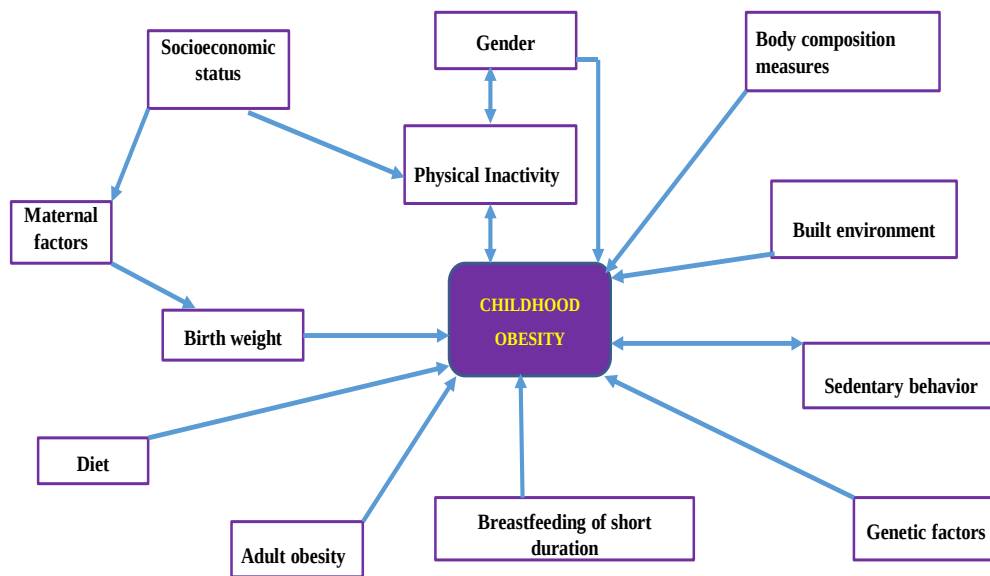


Figure 1: An adapted illustration of Ecological conceptual model that shows how various factors contributes to childhood obesity (Davison & Birch, 2001)

Although it is acknowledged that other factor may result in different finding across studies. This contradiction may also be because of the different methods that are available to measure PA and body composition (BC) (Biddle *et al.*, 2011:6; Janssen & LeBlanc, 2010:10). Studies using more sophisticated methods such as objective PA and direct BC report stronger association, whereas those that use least sophisticated methods such as self-reported PA and indirect PA reporting weak or no association (Ben Jemaa *et al.*, 2018:236; Vanderloo *et al.*, 2020:12). The use of objective measures of determining PA and direct measures of BC is proving to be beneficial (Ben Jemaa *et al.*, 2018:236; Vanderloo *et al.*, 2020:12). To help fight overweight and obesity in SSA, robust clinical methods should be established to assess physical inactivity, overweight and obesity (Ben Jemaa *et al.*, 2018:236; Choukem *et al.*, 2020:10). Other non-methodological factors that might bring contradictions in different studies are also acknowledged.

This literature review serves as a framework and enables the establishment of the available ‘gaps’ in research described in this thesis. An electronic and manual literature search was conducted to identify literature on PA and BC in children. Various concepts such as birth weight, childhood BC, PA and SB, and different methodologies for measuring PA and BC are discussed. Furthermore, the level of agreement between different methods of measuring PA are explored. Recommendations for improvements are made.

The literature review is presented according to the following non-exhaustive sub-topics that are derived from the research objectives, and which encapsulate the essence of the study: PA, BC, birth weight and BC, association between PA and BC, summary and recommendations. The review ends with the reference list.

2.2 Physical activity

PA, defined as any bodily movement produced by skeletal muscles that results in energy expenditure substantially above resting energy expenditure (Caspersen *et al.*, 1985:126; Welk *et al.*, 2000:65). Activity-induced energy expenditure varies from day to day, and is a function of body movement and body weight (Westerterp, 2018:9). Human subjects start off by being mainly sedentary, with PA beginning to increase as children start to move independently, reaching its peak in reproductive age and eventually reducing with age (Westerterp, 2018:11). In childhood, activities are more anaerobic than in adulthood (Strong *et al.*, 2005:736). Children play games that assist them in learning both basic and more specialised motor skills. As children progress into puberty (Ages $\approx$ 9-10), they focus on a greater variety of individual- and group activities, as well as on several organised sports (Jones *et al.*, 2009: Strong *et al.*, 2005:736; Welk *et al.*, 2000:65). In adulthood ($\geq$ 18 years), work, commuting and leisure-time PA may become the main PA contributors (Caspersen *et al.*, 1985:127). In essence, the domains of PA that contribute significantly to the overall level of daily or weekly PA vary according to age group.

2.2.1 Levels of physical activity in children

Insufficient PA levels in children, are a growing global concern, and 7.2% and 7.6% of all-cause and CVD mortalities, respectively, are because of low levels of PA (Katzmarzyk *et al.*, 2021:6). High income countries are faced with the highest relative burden whereas middle income countries have the highest number of affected people (Katzmarzyk *et al.*, 2021:6). Back in 2016, the Global Matrix 2.0, which summarises global PA-related indicators from different

countries, revealed that the majority of children reported low levels of PA and active play and, furthermore, that more time was spent in SB (Tremblay *et al.*, 2016:353). A follow-up, Global Matrix 3.0, revealed that not much had changed over the two-year period, and children are still performing poorly according to PA indicators (Aubert *et al.*, 2018:265). Children from countries with poor infrastructure, who participate in active play and walk or ride a bicycle to school, report high levels of PA and low levels of SB (Tremblay *et al.*, 2016:359). The opposite is true for children from countries with good infrastructure, who mostly participate in organised sport and have good schools with good infrastructure (Aubert *et al.*, 2018:265; Tremblay *et al.*, 2016:359). The difference in the adherence to the PA guidelines between children from countries with poor infrastructures and those with good infrastructure represented is between 14% and 26% respectively (Aubert *et al.*, 2018:265) (Aubert *et al.*, 2018:265). This paradox suggests that playing and moving around in public spaces freely, rather than the good infrastructure, increases the levels of PA in children (Tremblay *et al.*, 2016:359).

To achieve health benefits, children and youth must achieve at least 60 minutes or more of moderate-to-vigorous PA (MVPA) per day (Bull *et al.*, 2020:1456). MVPA is PA of ≥ 2296 counts per minute that can be measured by devices such as accelerometers (Evensen *et al.*, 2008:1561). Only approximately 24% of children and adolescents in the United States of America achieve the recommended PA guidelines and 77% are sedentary (Katzmarzyk *et al.*, 2018:423). In Canada, 35% of children and adolescents are adequately active (Barnes *et al.*, 2018:329). Less than 20% of Chinese children and adolescents meet the required daily PA levels (Liu *et al.*, 2018:4). A review article summarising PA findings in China revealed that, on average, children and adolescents aged between 7 and 18 years spend 41.11 minutes per day in MVPA (Zhang *et al.*, 2020:73). These figures are worrying, as low PA levels are associated with adverse health effects such as an increased burden of NCDs (Katzmarzyk *et al.*, 2021:6). Although the situation in African countries is not yet as serious as in North America and China, the challenges are similar, with scores of children and adolescents not meeting the PA guidelines. Approximately 48% of Ghanaian and 59% of Zimbabwean children and adolescents achieve the recommended daily MVPA guidelines (Manyanga *et al.*, 2018:433; Nyawornota *et al.*, 2018:367).

Even in South Africa, physical inactivity remains a concern., where only about 50% of children are achieving the required average of 60 minutes of MVPA per day (Draper *et al.*, 2018:407). The prevalence of preschoolers in Mpumalanga, South Africa meeting recommended levels of

MVPA was determined using ActiGraph. It was revealed that 96.9% met MVPA guidelines (Tomaz *et al.*, 2020:153). Of preschoolers from Cape Town, South Africa, 98.2% met the recommended guidelines for MVPA (Draper *et al.*, 2017:10). A study on South African children aged 8 to 14 years that used the Physical Activity Questionnaire for Older Children (PAQ-C) revealed that 31% achieved recommended MVPA levels (Van Biljon *et al.*, 2018:126). Wushe and colleagues (2014:4) revealed that approximately a quarter of older children from Potchefstroom achieved the recommended PA levels, with measurements objectively derived using the ActiHeart. From this information, it can be deduced that PA decreases with an increase in age. This should be of concern to all South Africans, given the risk of obesity and other NCDs that is associated with physical inactivity, and thus the time has come to engage parents and communities in advocacy and social mobilisation (Choukem *et al.*, 2020:6; Draper *et al.*, 2014:103).

In recent years, PA levels in children have declined, because of a reduction in outdoor play and active transport (Westerterp, 2018:11). In SSA, physical inactivity is a result of urbanisation, which results in reduced space for playgrounds (Choukem *et al.*, 2020:6; Prista *et al.*, 2016:215). Criminal activities in some neighbourhoods make them unsafe for outdoor activities, with children choosing academic excellence over PA (Choukem *et al.*, 2020:6; Prista *et al.*, 2016:215). Research studies have revealed that PA starts to decline from the age of school entry, with levels of PA appearing to decline by 50% by the time a child reaches high school (McVeigh & Meiring, 2014:375; Riddoch *et al.*, 2004:90; WHO, 2016:21). These levels decline with an increase in school grade and age (Brodersen *et al.*, 2007:141).

Several factors are associated with PA levels. Sex has a bearing on PA levels, with boys more physically active than girls (Darling *et al.*, 2019:36; Zhang *et al.*, 2020:73). Van Biljon and colleagues (2018:126) revealed that boys were more active than girls in a population of 8–14-year-old South African children. Even in preschoolers, boys perform more PA than girls, highlighting the early onset of sex differences in the risk of developing obesity (Tomaz *et al.*, 2020:154). These sex differences may be explained by the different roles that are played by children. Boys are usually required to do things that need strenuous PA, therefore increasing daily MVPA; this is uncommon in girls (Choukem *et al.*, 2020:6). Socio-economic status (SES) also plays a major role in the levels of PA in children. In low- to middle income countries, high SES is associated with low levels of PA coupled with increases in SB. Additionally, ethnicity has a bearing on the prevalence of physical inactivity. A study on a multi-ethnic group of South

African (Western Cape) children revealed that physical inactivity levels were significantly higher in white (35.9%) than in coloured (28.7%) and black learners (22.2%) (Negash *et al.*, 2017:3).

In the attempt to increase PA levels, a multi-component approach that includes childcare and the school setting is needed. Family-based care is an important factor, as parents can assist in ensuring that children are adequately active. Support from parents and peers is recognised as a correlate of PA in children and adolescents (Aubert *et al.*, 2018:267). In the school setting, providing more physical education (PE) classes, training PE teachers and improving the quality of the lessons may be beneficial (Messing *et al.*, 2019:9). Children spend most of their time in school but the school setting is currently not generating enough PA for children to achieve the PA guidelines. Strategies should be put in place to help increase the amount of time children spend in MVPA in school settings during school hours (Grao-Cruces *et al.*, 2020:14). For example, introduction of a high intensity PA programme at school can be highly beneficial as it can improve the BC of school-going children (López-Sánchez *et al.*, 2017:243). The quality and / or quantity of PA opportunities offered by schools are associated with the economic and development status of a given country. Cultural values attributed to sport and / or PA can also be potential barriers or facilitators for this indicator (Aubert *et al.*, 2018:267).

Although high PA is associated with favourable BC indicators, in disadvantaged areas in South Africa, highly active children are susceptible to communicable diseases such as soil-transmitted helminth infection, and care should be taken to prevent such diseases when promoting PA in these areas (Gerber *et al.*, 2018:110). However, the impact of physical inactivity is clearly outlined; therefore, for affected children to be identified and interventions implemented, assessment of PA must be done.

2.2.2 Assessment of physical activity

PA assessment in children is undertaken to assess adherence to PA guidelines or to identify target populations in need of intervention. Moreover, PA levels and behaviours are assessed to study their impact on health markers (Mindell *et al.*, 2014:2). PA can be assessed in three ways, either subjectively or objectively, or by combining these two methods. Each method is presented with its own advantages and pitfalls, this will be discussed below and summarised in table 2.1 (Corder *et al.*, 2008:978; Mindell *et al.*, 2014:2). The choice of method depends on factors such as cost, the area of PA interest and the practicality of the method.

2.2.2.1 Objective methods of assessing physical activity

Objective methods of assessing PA involve measurements of physiological- or biomechanical parameters using equipment or observation (Mindell *et al.*, 2014:2). This information is then used to estimate PA outcomes such as daily total energy expenditure (TEE) (Corder *et al.*, 2008:978). A wide variety of objective methods exist, and the most commonly used ones being, doubly labelled water, indirect calorimetry, pedometer, heart rate monitoring and accelerometry (Rowlands & Eston, 2007:274). They are discussed below.

Doubly labelled water

Doubly labelled water is used to measure TEE over a period (up to 14 days) and this method has been validated against whole-room calorimetry in adults and periodic respiratory gas exchange in infants (Sirard & Pate, 2001:442). Studies show that it is accurate within 10%, and it is regarded as the gold standard because of its precision (Loprinzi & Cardinal, 2011: 21; Mindell *et al.*, 2014:4; Westerterp, 2018:9). It involves oral administration of radio-labelled isotope ($^2\text{H}_2^{18}\text{O}$, deuterium-labelled water and oxygen-18-labelled water) (Loprinzi & Cardinal, 2011:21). Deuterium-labelled water is lost from the body in the form of water while oxygen-18-labelled water is lost as carbon dioxide and water (Loprinzi & Cardinal, 2011: 21; Ndahimana & Kim, 2017:72). The difference between the elimination rates of these two stable isotopes is directly proportional to carbon dioxide production or energy expended (Loprinzi & Cardinal, 2011: 21; Ndahimana & Kim, 2017:72).

Use of doubly labelled water has several advantages in the evaluation of energy expenditure because it can easily be used in normal daily life and is has low reactivity (Sirard & Pate, 2001:442; Westerterp, 2018:9). Furthermore, its accuracy is of high standard (Sirard & Pate, 2001:442; Westerterp, 2018:9). It can also be used to assess PA levels over a longer period. There are, however, disadvantages, including difficulty in obtaining isotopes and cost thereof, making its use in large studies impractical. Accurate dietary records need to be collected during the measurement period for calculation of energy expenditure (Ndahimana & Kim, 2017:72). Another disadvantage is that measurements must be taken over at least three days and from that only TEE can be obtained (Sirard & Pate, 2001:442). Doubly labelled water is unable to determine the duration, intensity and frequency of PA performed. In addition, the method cannot differentiate the types of PA (Loprinzi & Cardinal, 2011:21) of energy expenditure.

Indirect calorimetry

Indirect calorimetry is an accurate and non-invasive method aimed at measuring energy expenditure from oxygen consumption and carbon dioxide production (Ndahimana & Kim, 2017:73). This method is extensively used during rest or exercise and is seen as an accurate and valid measure of short-term energy expenditure (Ndahimana & Kim, 2017:73). Measuring free-living PA is difficult due to a lack of required portable gas analysis equipment, but it is used to validate heart rate monitors or accelerometers, which can be used to measure free-living PA (Sirard & Pate, 2001:442; Ndahimana & Kim, 2017:73).

Heart rate monitors

The use of heart rate monitors is based on the linear relationship between heart rate and oxygen consumption during PA. Oxygen demand is increased in PA to meet the increased demand from exercising muscles (Ndahimana & Kim, 2017:74). The method relies on the individual laboratory calibration of the relationship between heart rate and oxygen uptake, as measured during standardised activities in the laboratory. It is important to note that there are other factors that can affect this relationship. Such confounding factors include fitness level and the muscle groups recruited in PA. The relationship between heart rate and oxygen consumption becomes weak at low PA intensity, so it cannot be used reliably to measure SB and light PA (Loprinzi & Cardinal, 2011:16). Moreover, heart rate can be affected by several factors apart from body movement, such as stress, certain medications and caffeine, etc. (Sirard & Pate, 2001:443). The flex heart rate, which has been validated against doubly labelled water and whole-room calorimetry, can be employed to mimic / limit those effects. To obtain the flex heart rate, an individual's heart rate is measured in conjunction with maximum oxygen consumption / VO_2max , so that distinction can be made between resting heart rate and active energy expenditure (Sirard & Pate, 2001:444).

Use of heart rate monitors in children can prove problematic, as most of their time is spent in SB and light PA (Craig *et al.*, 2013:83; Diouf *et al.*, 2016:5; Prista *et al.*, 2009:396). Moreover, owing to the delay in heart rate response after movement, the short sporadic bouts of PA that children normally partake in can be missed (Loprinzi & Cardinal, 2011:16). Use in large studies is difficult as the flex heart rate must be determined for everyone, which can be time consuming. Nonetheless, the use of heart rate monitors for assessing PA in children is non-invasive (Loprinzi & Cardinal, 2011:16).

Pedometers

Pedometers are small electronic devices that use a spring mechanism and can be used to estimate the number of steps taken over a period (Mindell *et al.*, 2014:4; Ndahimana & Kim, 2017:75). However, they cannot assess the intensity or pattern of PA (Oliver *et al.*, 2007:1052; Sirard & Pate, 2001:445). They are affordable and can be used repeatedly. PA in children comprises mostly ambulatory movements, meaning pedometers can effectively estimate overall PA levels (Loprinzi & Cardinal, 2011:20). Correlations between this instrument and the amount of oxygen consumed during treadmill range between $r=0.62$ to $r=0.93$, indicating suitability for its use in the population-based assessment of PA in children (Corder *et al.*, 2008:978; Sirard & Pate, 2001:445).

Accelerometers

Accelerometers use a piezoelectric lever to detect motion acceleration, following which a signal is generated that is in proportion to the magnitude of the acceleration (Ndahimana & Kim, 2017:73; Oliver *et al.*, 2007:1053). From this the intensity of the motion is generated and reported as counts. They have been validated against the use of doubly labelled water and indirect calorimetry and can be used to measure free-living PA (Ndahimana & Kim, 2017:73; Oliver *et al.*, 2007:1053). Accelerometers are either uniaxial, biaxial or triaxial, denoting the number of planes in which acceleration is measured (the vertical / up-down (Y), horizontal / right-left (X) and horizontal / front-back axis (Z)) (Loprinzi & Cardinal, 2011:18; Ndahimana & Kim, 2017:73). Widely available cut points use the uniaxial axis; however, recent literature suggests that use of the triaxial axis may be beneficial as movement is captured in all directions. Velocity magnitude counts, determined from raw data, are a commonly used processing method to calculate PA intensities (Buchan & McLellan, 2018:7). Accelerometers can accurately classify PA, such as walking, running, cycling and rope skipping, up to 100%; furthermore, they can be used to report SB (Sirard & Pate, 2001:444).

The advantage of using accelerometers is that PA information collected is free from researcher bias, and the burden on both the researcher and participant is low. Additionally, accelerometers can collect PA over an extended period and are more affordable than other objective methods (Oliver *et al.*, 2007:1047). Although use of accelerometers provide objective measure of PA, it does have a number of limitations such as the inability to pick up body movement that does not include the area of attachment (Sirard & Pate, 2001:447). The use of accelerometers is also met with many decisions. Placement of the device must be decided (most commonly wrist or

waist), and decisions about measurement frequency (epoch length), duration of data collection and which cut points to use must be made (Loprinzi & Cardinal, 2011:18). Numerous cut points exist, making it difficult for researchers to choose. This takes away uniformity, making comparison across studies difficult (Ndahimana & Kim, 2017:73). Only until recently that a consensus was reached after discussions amongst researchers that may possibly allow some uniformity across different studies (Migueles *et al.*, 2021:7). ActiGraphs accelerometers are one commonly used accelerometer. The first models produced were uniaxial; more recent models are triaxial (Buchan & McLellan, 2018:7) and have been validated for use in children (Bassett & John, 2013; Draper *et al.*, 2018; Ben Jemaa *et al.*, 2018; Tomaz *et al.*, 2020).

2.2.2.2 Subjective methods of assessing physical activity

Subjective methods of PA assessment are used to evaluate PA behaviour in children. Techniques in this category include self-reports, interview-administered reports, proxy reports and direct observations (Mindell *et al.*, 2014:2). The accuracy of information collected by subjective instruments is dependent on the ability of the participant to accurately recall all relevant details. It may also be influenced by the opinion and perception of the participant, proxy reporter or investigator (Corder *et al.*, 2008:978). Nonetheless, subjective methods are important for the assessment of activity setting and mode of activity behaviours and their determinants, as these may be more difficult to assess objectively (Corder *et al.*, 2008:978).

Self-reports

Self-reports are generally used in population studies. This method mainly relies on the ability of the individual to recall PA behaviours in different times and places (Loprinzi & Cardinal, 2011:16; Mindell *et al.*, 2014:2). The advantage of using self-reports is that they are easy to administer and are cost effective. Additionally, they present with low participant burden (Ndahimana & Kim, 2017:75). The limitations on the use of this method are also acknowledged. Children may not be able to accurately recall their PA because of limited cognitive ability, and so the method has low accuracy and reliability (Ndahimana & Kim, 2017:75). Furthermore, room exists for difficulty in item interpretation. Reliability coefficients of self-reports range from 0.56 to 0.93, while validity coefficients range from 0.03 to 0.88 (Loprinzi & Cardinal, 2011:16). Self-reports generally have lower validity and reliability in children compared to adolescents, and it is suggested that studies that include children aged 10 years or younger should include objective measures of PA or, where not possible, rely on proxy reports (Mindell *et al.*, 2014:2; Ndahimana & Kim, 2017:75).

Examples of self-reports include self-administered recalls in the form of questionnaires, diaries and interview-administered recalls (Loprinzi & Cardinal, 2011:16; Ndahimana & Kim, 2017:75). Self-administered recalls in the form of questionnaires are the most used. The commonly used questionnaires include the International Physical Activity Questionnaire (PAQ) and the 7-day Physical Activity Recall, to name a few (Ndahimana & Kim, 2017:75). The PAQ-C has been regarded as an appropriate and valid tool for use in school-going children aged 8–14 years (Crocker *et al.*, 1997; Kowalski *et al.*, 2004:3). The PAQ-C is a 10-item, seven-day PA recall questionnaire designed for use in a field-based setting. It is used to assess the PA behaviour of the participants at different times and places (i.e. during school, after school, recess, weekends, etc.) (Kowalski *et al.*, 2004:2). Scoring is based on a five-point Likert-type scale, with an overall PA score derived from the mean of each scored item. The mean of all items is used to indicate the level of PA. A high score indicates higher volumes of PA and a low score indicates low PA (Kowalski *et al.*, 2004:5).

Proxy reports

Owing to low cognitive ability, younger children may not be able to effectively report their PA behaviours. Proxy reports can be used instead (Loprinzi & Cardinal, 2011:16; Ndahimana & Kim, 2017:75), when parents or teachers are asked to recall or report PA levels on the children's behalf. Although these are not significantly associated with direct observation, proxy reports are significantly positively associated with accelerometer ($r=0.41-0.66$) and heart rate monitor data. Proxy reports are promising in providing accurate information on the PA behaviours of children; however, improvement of this method is needed (Loprinzi & Cardinal, 2011:16; Welk *et al.*, 2000:69).

Direct observation

Direct observation is when a trained observer observes and classifies a child's free-living PA over a period in a natural setting such as a school or at home. Behaviours are recoded into computer-based programs or on paper (Welk *et al.*, 2000:68). The advantage of direct observation is that it is objective, and provides the information on the context type and intensity of PA behaviour (Welk *et al.*, 2000:68). The pitfalls of using direct observation are the lengthy, intense training that the observer must go through and the data coding for the programs used to measure the PA behaviour of children. Considerable time and effort are needed for data collection (Loprinzi & Cardinal, 2011:16). Direct observation of PA in children and adults is the most appropriate method, more especially if PA to be measured is of short duration.

Table 2.1: Advantages and limitations of different methods of assessing physical activity

Method	Advantages	Limitations	Reference
Accelerometers	Affordable compared to other objective measures Collects PA information over a longer period Measures PA intensity Measures SB	Cannot detect some movements Many methodological decisions to make which influence the outcomes	Loprinzi & Cardinal (2011) Oliver <i>et al.</i> (2007) Ndahimana & Kim (2017)
Pedometers	Cost effective Can be used repeatedly	Cannot assess PA intensity or pattern Can only measure PA from walking	Oliver <i>et al.</i> (2007:1052) Sirard & Pate (2001:445) Ndahimana & Kim (2017)
Heart rate monitors	Non-invasive Relative low cost Can measure PA in controlled setting and in free living	Heart rate can be affected by factors such as stress and medication Measuring light PA and SB is difficult Heart rate subject to interference from electrical and magnetic devices	Sirard & Pate (2001:442) Loprinzi & Cardinal (2011)
Indirect calorimetry	Accurate and valid for short-term energy expenditure Used to validate other PA methods	Measuring free-living PA is difficult especially in children due to weight and size of the equipment	Sirard & Pate (2001:442) Loprinzi & Cardinal (2011)
Doubly labelled water for energy expenditure	Easy to use in daily life Non-invasive High accuracy Can assess PA levels over a longer period Used to validate other PA methods	Costly Time consuming Difficulty obtaining isotopes Impractical in large studies High participant burden Does not provide specific details of PA	Sirard & Pate (2001:442) Loprinzi & Cardinal (2011) Westerterp, (2018:9) Ndahimana & Kim (2017)
Self-reports	Easy to administer Cost effective Low participant burden	Recall bias Low validity and reliability Difficulty in item interpretation	Sirard & Pate (2001:442) Loprinzi & Cardinal (2011) Ndahimana & Kim (2017)
Direct observation	Objective Provides the type and intensity Can be used in different settings	Intense training required for observer Intense data coding skills training Researcher burden	Welk <i>et al.</i> (2000:68) Loprinzi & Cardinal (2011)

Where it is not possible, such as when PA measurement for longer periods is required or costs are prohibitive, accelerometers are a promising alternative (Sirard & Pate, 2001:452).

2.2.3 Level of agreement between subjective and objective methods of measuring physical activity

Prevention is better than cure, and focusing on prevention can mitigate future healthcare costs and improve quality of life (LBD, 2020:756). The benefits of PA are well documented, and it is therefore important to accurately measure PA levels to effectively identify groups of children in need of urgent attention (Haskell *et al.*, 2009:282). As mentioned in the previous section, methods of assessing PA can be divided into two main groups: subjective and objective. The choice of method is dependent on several factors such as cost and the domain of PA that needs to be assessed. Discrepancies in the measures of PA determined subjectively and objectively exist; these are of particular concern when establishing the relationship between PA and health markers (Adamo *et al.*, 2009:23; Benítez-Porres *et al.*, 2016:69). Discrepancies that arise in the levels of PA due to the selected method can result in the beneficial effect of PA being missed and interventions delayed (Ben Jemaa *et al.*, 2018:236; Vanderloo *et al.*, 2020:9).

Objective PA assessment is practical and appropriate for use in children and adolescents; it is free from recall bias and poses less burden on both researcher and participants (Bassett & John, 2013:141; Mattocks *et al.*, 2008:110). However, because of the associated costs, practicality and level of knowledge needed by the researcher, it is often not possible to apply to large population studies (Ndahimana & Kim, 2017:72). It is therefore necessary to validate subjective methods in different settings as PA behaviours in children varies in different locations. Several attempts have been made and they are not all in agreement (Ben Jemaa *et al.*, 2018:236; Monyeki *et al.*, 2018:9; Muthuri *et al.*, 2015:244).

A study performed with 6–10- and 11–17-year-old children from Germany using the Seven-day Recall PAQ and an accelerometer revealed that the correlation between self-reported PA and objective PA is weak (SB: $r=0.28$, 95% confidence interval [CI] 0.15–0.41, light PA: $r=0.14$, 95%CI 0.01–0.28 and MVPA: $r=0.20$, 95%CI 0.06–0.34) (Sprengeler *et al.*, 2017:8). In 8–11-year-old Tunisian children, PA determined by PAQ-C did not significantly correlate with objectively determined PA by accelerometer (ActiGraph) ($r=0.119$, $p=0.466$) (Ben Jemaa *et al.*, 2018:237). Furthermore, PA assessed by PAQ-C failed to differentiate between normal weight and overweight/obese children. PA by ActiGraph demonstrated that children who spend more time in vigorous physical activity (VPA) were likely to have healthy weight compared to those who spend less time in VPA (Ben Jemaa *et al.*, 2018:238). Inconsistencies in PA levels determined by PAQ-C and ActiGraph were also reported in 8–11-year-old children from

Senegal. In Kenyan children aged 9–11 years old, no association was found between self-report and objective measures of PA. The significant associations were only found in weekday and weekend-day measures of PA among the underweight and healthy weight children. This indicates that the strength of the association may vary according to weight status of the children (Muthuri *et al.*, 2015:243). In a regional study (Potchefstroom, South Africa), Monyeki and colleagues (2018:6) reported no significant level of agreement between self-report PA and objective PA in older children (15 years).

On the other hand, Mosha *et al.* (2020:5) reported moderate positive correlation ($r=0.36$, $p=0.009$) between self-reported PA and accelerometer-derived PA in 9–10-year-old children from Tanzania. Mciza and colleagues (2007:122) also reported a positive correlation between moderate and vigorous energy expenditure determined by PAQ and activitygram in 9–12-year-old girls. Furthermore, a positive significant correlation ($r=0.53$, $p=0.004$) was found between objectively measured PA (Actical) and self-report PA (interview-administered) in primary school children in South Africa (McVeigh & Norris, 2012:47). All this information taken together highlights the need for validation of subjective methods in different settings before they can be used. It is also important to note that different methodologies for both subjective and objective PA were applied, which could be the reason why no uniformity was found across different studies.

Section summary

Large numbers of children are not meeting the recommended PA guidelines (Draper *et al.*, 2018:407; Katzmarzyk *et al.*, 2018:423). Low levels of PA have detrimental health effects, as has been mentioned previously, it is associated with increased risk of obesity and other NCDs (Katzmarzyk *et al.*, 2021:6). It is therefore important to accurately assess PA levels in children to confidently identify target populations in need of urgent interventions (Mindell *et al.*, 2014:2). Both subjective- and objective methods have been described and validated for use in children. However, no specific method can be identified as the best option for all studies (Welk *et al.*, 2000: 69). Selecting the appropriate method depends on the specific research question being addressed, as well as the practicality (Biddle *et al.*, 2011:6). To accurately assess children's PA behaviours, an instrument must be sensitive enough to detect or record sporadic and intermittent activities. Despite the limitations on the use of objective methods of assessing PA in children and the associated costs, they offer more promise than subjective methods (Mindell *et al.*, 2014:6).

2.3 Body composition

BC is of interest to health professionals and is a way of assessing the nutritional status and functional capacity of an individual (Kuriyan, 2018:648). The human body is comprised of the atomic model (oxygen, hydrogen and carbon), the cellular model (cell mass, extracellular fluid), the tissue model (skeletal, bone, adipose tissue) and the molecular model (water, lipid, protein (Goran, 1998:505). The molecular model is thought to be the most useful in obesity research, in which BC is broken down into FM and fat free mass (FFM) (Goran, 1998:505). Pathology and morbidity associated with obesity are driven by excessive body fatness (Fortuño *et al.*, 2003:57). Obesity is simply defined as an excess amount of fat in the body, and it is linked with several health risk factors, including type two DM and CVD (Atay & Bereket, 2016:1). Different methods of assessing obesity are available and will be discussed below. In childhood, boys with FM of $\geq 20\%$ and girls with FM $\geq 25\%$ are classified as obese Atay & Bereket, 2016:1). Childhood is an important stage in the lifespan of humans in developing a healthy BC for later life (Westerterp, 2018:9).

2.3.1 Trends in obesity

Daily energy expenditure or TEE is segmented into three components, namely, resting energy expenditure, diet-induced energy expenditure and activity energy expenditure (Ndahimana & Kim, 2017:69). The largest of the three components is resting energy expenditure and largely depends on body size and BC (Ndahimana & Kim, 2017:69; Westerterp, 2018:9). Diet-induced energy expenditure comprises about 10% daily energy expenditure when intake matches expenditure, and is dependent on the quantity and quality of the food consumed (Westerterp, 2018:9). PA denotes activity-induced energy expenditure and varies from day to day; it is a function of body movement and body weight (Ndahimana & Kim, 2017:70). In most cases, imbalances between diet-induced energy expenditure and activity energy expenditure results in unfavourable BC. Reduction in PA results in decreased energy expenditure. Muscle is the key fat oxidiser, which means that if there is a reduction in muscle activity the result will be reduced fat oxidation, promoting excess fat accumulation in the body (Maffeis, 2000:41). BC is closely related to metabolism and, as such, is an important marker of physiological function (Tewari *et al.*, 2018:4). Assessment of BC throughout life can allow monitoring of a person's health and disease risk and is therefore useful for clinical- and national interventions (Tewari *et al.*, 2018:4). The greatest change in BC in terms of age occurs in adolescence (Westerterp, 2018:9). At this stage there are sex-specific patterns in fat distribution, and FM increases in

girls and decreases in boys (Westerterp, 2018:9). FFM increases sharply after the years of puberty in men and only slightly in women (Westerterp, 2018:10).

In 2006, worldwide trends indicated the obesity rates in children were rapidly growing with the highest rates reported in high income countries (Choukem *et al.*, 2020:6; Wang & Lobstein, 2006:23). However, more recent reports show that while developed countries are still experiencing the highest burden of childhood obesity (Dai *et al.*, 2020:12), low- and middle income countries are also experiencing the burden. As food security in these countries has improved in the past decade, they may experience a nutritional transition, where undernutrition is replaced by overweight, or an occurrence of both conditions (Biswas *et al.*, 2019:7; LBD, 2020:756). The prevalence of overweight and obesity in low- to middle income countries in children under five years has increased from 5.2% to 6% (LBD, 2020:751). The prevalence in SSA is reported as 6.8% in preschool children while the prevalence of overweight in school-aged children is 10.6%, with obesity reported at 2.5% (Choukem *et al.*, 2020:6).

According to both the 2014 and 2016 Healthy Active Kids South Africa Report Cards, over 50% of children and youth are reported to be overweight (combined overweight and obesity) (Draper *et al.*, 2014:100; Uys *et al.*, 2016:267). In recent years, the national prevalence of overweight and obesity was found to be inconclusive because of paucity of data (Draper *et al.*, 2018). Pienaar and Kruger (2014:111) reported the prevalence of overweight and obesity in grade one pupils to be 7.5% and 3.6%, respectively. Using the deuterium dilution method, Moeng-Mahlangu and colleagues (2020:7) reported a prevalence of 20.8% and 28.7% for overweight and obesity, respectively. When adiposity is measured using robust clinical methods, a higher prevalence of overweight and obesity is reported, possibly capturing affected children who may not be identified using body mass index (BMI) alone. Additionally, BMI, which is largely used as an indicator of risk related to obesity, does not differentiate between FM and FFM (Tewari *et al.*, 2018:4). Robust clinical methods are needed to identify overweight and obesity in children (Choukem *et al.*, 2020:10).

2.3.2 Determinants of childhood obesity

Obesity is multifactorial, and may be related to one or more of the following factors: biological, psychological, economic and environmental (LBD, 2020:756). With obesity in childhood clearly a major problem, it is important to understand what causes it, to be able to effectively eradicate it. In SSA, the sex distribution in the prevalence of overweight and obesity is tilted

towards girls (Darling *et al.*, 2019:36). On average, 15.4% of girls and 7.6% of boys are overweight or obese (Choukem *et al.*, 2020:6; Darling *et al.*, 2019:36). Findings from the Soweto Birth to Twenty cohort, revealed that in boys, the prevalence of overweight was highest through the ages of 4–8 years and declined in the periods leading to puberty (Lundeen *et al.*, 2015:76). Paradoxically, in girls the prevalence of overweight increased steadily after the ages of 4–8 years, reaching 19% by ages 16–18. Likewise, the prevalence of obesity increased from ages 4–8 years and reached a prevalence of 8% at ages 16–18 years (Lundeen *et al.*, 2015:76). In grade one, pupils aged 6–7 years from Potchefstroom, North-West Province, the prevalence of overweight was higher in girls (9.3%) compared to boys (6.4%), although the difference was not statistically significant. The years following the onset of puberty fuel the development of obesity in girls (Lundeen *et al.*, 2015:79; Uys *et al.*, 2016:267). The sex differences may be explained physiologically or by the different roles that are played by children. Boys are usually required to do things that need strenuous PA, therefore increasing their MVPA (Choukem *et al.*, 2020:6).

SES also has a strong bearing on childhood overweight and obesity. A quarter of Australian children are obese because of social, environmental, economic, cultural and lifestyle factors. Children of low SES are more susceptible to the development of obesity as they may not be able to afford healthy diets, or payments for sporting activities that can increase PA levels (Mchugh, 2016:97). In developing countries, the reverse is true: high SES is related to high risk of overweight and obesity. Children of high SES are more sedentary and have more access to foods high in sugar and saturated fats; furthermore, they maybe residing in urban areas that are likely to have less space for playing outdoors (Choukem *et al.*, 2020:6). A study in children from Cape Town revealed that the overweight prevalence was 8.82% and that mostly children from urban areas, which is mostly equated to high SES, were affected (Draper *et al.*, 2017:5). A study in 9–10-year-old children from Soweto revealed that high SES was associated with increased fatness in childhood (Griffiths *et al.*, 2008:866).

Ethnicity also determines the prevalence of overweight and obesity. In a study reporting on overweight and obesity among grade one pupils aged 6–7 years from North West Province, South Africa, white children (13.3%) were significantly more overweight than black children (6.0%) (Pienaar & Kruger, 2014:111). In a 7–18-year-old group of children from Western Cape, South Africa, the prevalence of overweight was significantly higher in white (20.7%) children compared with black (18.8%) and coloured (12.8%) children. Obesity was the highest

in coloured children (7.5%) when compared with other racial groups (black: 7.1%; white: 6.9%) (Negash *et al.*, 2017:3). To combat the rise in childhood obesity worldwide, intervention strategies should focus on the identified target populations most at risk of overweight and obesity.

2.3.3 Prevention of obesity

The causes of overweight and obesity are well identified, and measures should be put in place to prevent or control overweight prevention is preferable to cure; it can avoid future health-related costs and improve quality of life (LBD, 2020:756). Several tools have been identified as possible prevention strategies. Obesity can be prevented through behaviour-oriented and environment-oriented interventions. Behaviour-oriented interventions aim to improve and increase PA levels at an individual level, whereas environment-oriented intervention involves policy-making and environmental (residential area) changes that will promote healthy living (Weihrauch-Blüher & Wiegand, 2018:255). Randomised controlled trials have shown that family-based nutrition intervention in children over five years can be successful in improving dietary behaviour and subsequently decrease adiposity (Perdew *et al.*, 722:2021). PA intervention studies, including exercise and educational programmes have also been identified as effective tools for preventing obesity in children. In SSA, there are no clinical trials to ascertain the best prevention strategies against obesity in children (Choukem *et al.*, 2020:8). However small-scale studies have shown promise. A 10-week PA and nutrition education intervention programme in older children from Kwa-Zulu Natal, South Africa significantly reduced BMI in obese and overweight children (Grace *et al.*, 2021:8). This suggests a move towards interventions of longer duration and high intensity is necessary. Furthermore, improvement in diet and maternal factors is needed. Before all of this can be achieved, assessment of overweight and obesity must be made, to identify the affected populations clearly and confidently. Assessment of BC is discussed in the next section.

2.3.4 Assessment of body composition

Accurately determining BC is imperative as it gives whole body descriptive characteristics, accurate measures that can be used as scaling factors to normalise physiological variables such as metabolic rate and physical fitness (Goran, 1998:505). Numerous tests are employed to determine BC in children (Ellis, 2000:671; Goran, 1998:505; Wells & Fewtrell, 2006:615). These methods can be divided according to their number of compartments (Table 2.2). They

range from the simplest, a one-compartment model, to the most complex, the multi-compartment model (Kuriyan, 2018:649).

Table 2.2: Models of body composition

Model	Information given
One-compartment	Body weight
Two-compartment	FFM and FM
Three-compartment	FM, solids and TBW
Four-compartment	FM, mineral, protein and TBW
Multi-compartment	FM, water, nitrogen, calcium, potassium, sodium and chloride

Reference: (Kuriyan, 2018:650). FFM = Fat free mass; FM = fat mass; TBW = total body water.

Proven more accurate than indices of BC (indirect) and with a higher clinical value are in vivo methods of measuring BC (Table 2.3) such as densitometry, isotope dilution, bioelectrical impedance and conductance and dual-energy X-ray absorptiometry (Kuriyan 2018:655; Wells & Fewtrell, 2006:615). However, these methods are not without constraints, such as the cost and extensive knowledge required of the research team (Kuriyan, 2018:655).

Of importance in obesity research is that in the molecular model, BC is broken down into FM and FFM (Goran, 1998:505). Different cut points for FM and FFM exist for boys and girls (Table 2.3). Measuring the two compartments of body weight is extremely challenging, as no direct method exists (apart from in vivo neutron activation analysis, which has very limited availability). Science relies mainly on indirect measures, which are not without flaws. These methods require several assumptions, where age and state of maturation must be considered since they influence hydration, FFM and density of FFM, etc. (Goran, 1998:505).

Table 2.3: Fat mass percentage cut points according to sex

Fat category	FM% Boys	FM% Girls
Under fat	<12	<12
Normal fat	12-19	25-24
Over fat	>20	>25
Excessive fat	>25	>30

Reference: Lohman, 1992:150; FM% = Fat mass percentage.

Table 2.4: Methods of body composition

Methods of body composition	Examples
Indirect	➤ Body mass index and body mass index z-scores ➤ Waist circumference ➤ Hip circumference ➤ Waist-hip ratio ➤ Skinfolds
Direct	➤ Bioelectrical impedance ➤ Hydrodensitometry ➤ Air displacement plethysmography ➤ Doubly labelled water for body composition ➤ Dual-energy X-ray absorptiometry ➤ Computed tomography ➤ Magnetic resonance imaging ➤ Whole body potassium counter

Common methods (Table 2.4) are discussed next.

Indirect methods of body composition

- *Skinfolds*

There are four fat deposits that have been historically defined historically – subcutaneous adipose tissue, intermuscular adipose tissue, intramuscular adipose tissue and visceral adipose tissue (Lohman *et al.*, 2013:576). Of these four fat storage places, the anthropometric method of examining skinfolds (Table 2.4) can only assess subcutaneous adipose tissue (Lohman *et al.*, 2013:576). The method is based on a variety index, which is based on ratios of subcutaneous skinfold sites used to characterise body fat patterns and distribution (Lohman *et al.*, 2013:576). Measuring skinfold thickness is a non-invasive indirect method of fat estimation by applying body density equations (Freedman & Sherry, 2009:30). Measurement sites include the biceps, triceps, subscapular and suprailiac muscles, the measurements of which are used in age- and gender-specific equations to calculate body fatness (Kuriyan, 2018:650). The problem

with using skinfolds is that it is subject to large measurement errors, making interpretation difficult if the examiner has not been well trained (Freedman & Sherry, 2009:30; Monyeki *et al.*, 2007:555; Wells & Fewtrell, 2006:612). The use of equations in predicting percentage body fat may not be valid in populations other than those from which they were derived, because the accuracy in individuals is invariably poor (limits of agreement, $\pm 9\%$ fat). As such, it is suggested that the use of the raw form of skinfolds is a more reliable indicator of regional fatness than attempts to predict total FM (Well & Fewtrell, 2006:613). Skinfold measurement, however, provides a more accurate estimate of body fatness than BMI (Freedman & Sherry, 2009:30).

- *Body mass index and body mass index z-scores*

Many studies employ BMI (weight in kg divided by height squared) as a measure of adiposity, as this is a simple and affordable method that can be used in large population studies (Ellis, 2001:1590). However, this method is not without its limitations. Obesity denotes excess body fat and BMI relies on body weight regardless of BC. The shortcomings of BMI are that it is based on the assumption that those with normal BMI have normal body fat and that an increase in BMI is accompanied by an increase in body fat, which is not always the case (Javed *et al.*, 2014:241). Although BMI correlates with FM% (Monyeki *et al.*, 2005:879), it cannot distinguish between FM and FFM (Wells & Fewtrell, 2006:612). The accuracy of BMI as an indicator of adiposity varies considerably according to the degree of body fatness (Freedman & Sherry, 2009:31). In most cases, it misclassifies individuals with greater than average FFM for height (Lohman *et al.*, 2013:579).

In children, BMI has high specificity for determining obesity but performs moderately when it comes to sensitivity (Javed *et al.*, 2014:237). BMI fails to classify over a quarter of children as being obese when they have excess adiposity. This will misinform clinicians, public health and policy makers, delaying or missing the time for intervention and increasing health risk as a result (Javed *et al.*, 2014:237). Based on the findings of the study performed by Javed and colleagues (2014:241) on children, it is apparent that a child with BMI classified as obese is almost always obese, but in those with normal BMI, other tools are necessary to confidently rule out obesity. Tewari and colleagues (2018:5) alluded that although BMI may not be the best tool for determining BC, it may be a useful tool if used longitudinally for comparison. BMI performed well in detecting body fatness in African children; however, it shows moderate sensitivity (Adom *et al.*, 2020:9; Wilkes *et al.*, 2019:7). The use of BMI z-scores as an index

for adiposity in children before they reach puberty is limited. Care should be taken when it is used alone; additional measurements such as skinfolds can be beneficial in identifying children with excess adiposity (Wilkes *et al.*, 2019:7).

Table 2.5: BMI cut points

Method	Cut points/formula			Reference
CDC (2–20 years)	Underweight: <5th percentile Overweight: >85th < 95th percentile Obesity: ≥95th percentile			CDC (2000)
IOTF (kg/m ²)	6 years old	Overweight	B: 7.55; G:17.34	Cole <i>et al.</i> (2000)
		Obesity	B: 19.65; G:19.78	
	7 years old	Overweight	B:17.92; G:17.75	
		Obesity	B: 20.63; 20.51	
	8 years old	Overweight	B: 18.44; G:18.35	
		Obesity	B: 21.60; G:21.57	
WHO (5–19 years)	Overweight: BMI > +1SD Obesity: BMI > +2SD			De Onis <i>et al.</i> (2007)

B = Boys; BMI = body mass index; CDC = Centers for Disease Control and Prevention; G = girls; IOTF = International Obesity Task Force; SD = standard deviation; WHO = World Health Organization.

Different cut points for BMI exist (tabulated in Table 2.5) and do not results in the same prevalence estimates. A study in 9–13-year-old South African children revealed that the prevalence of overweight (9.94%) and obesity (5.46%) based on the Centers for Disease Control and Prevention’s (CDC) classification is higher compared with the International Obesity Task Force’s (IOTF) classification (2.6% overweight and 0.7% obesity). Conversely, the IOTF shows significantly higher underweight prevalence compared to the CDC’s classification. Use of BMI cut points should be approached with caution as it can result in the actual prevalence of overweight and obesity being over or underestimated (Moselakgomo & Van Staden, 2017:3).

- *Waist circumference*

Measuring waist circumference (WC), as a surrogate for abdominal adipose tissue, is a non-invasive tool that can be implemented with ease as a measure of anthropometry (Table 2.6). It is regarded as an appropriate tool for assessing central obesity in children and adults (Fredriksen *et al.*, 2018:18). WC is measured midpoint between the lower rib margin and the iliac crest or at the level of the umbilicus with a tape (Fredriksen *et al.*, 2018:18 WHO, 2008:5).

Cut points for WC were developed largely based on studies conducted in European countries (WHO, 2008:8). However, WC is significantly different across different ethnicities, making it difficult to confidently apply the cut points for all children (Fernández *et al.*, 2004; 442-443; Nawarycz *et al.*, 2013:794). Additionally, FM distribution is different in males and females. The use of WC is far less common than the use of BMI in studies; however, in recent times the use of WC has become common as it has been found to be associated with increased mortality rates in adults, independent of BMI (Koster *et al.*, 2008:1474). Literature has shown that high WC is associated with adverse health outcomes such as high blood pressure, dyslipidaemia, DM and metabolic syndrome in both adults and children (Lohman *et al.*, 2013:579).

Direct measures of body composition

- *Bioelectrical impedance analysis*

Bioelectrical impedance analysis (BIA) is portable, easy to perform, non-invasive and relatively affordable, and has low participant burden with immediately available results (Table 2.6) (Kuriyan, 2018:651; McCarthy *et al.*, 2006:601). The principle of BIA is dependent on the fact that FFM, which consists of water and electrolytes, is a good conductor of electricity whereas FM, which does not contain any water, is a poor conductor (Kuriyan, 2018:651). A small amount of electrical current is sent to the body and the electrical resistance by the body is measured. Electrical resistance is a function of body shape and the volume of conductive tissue in the body. Total body water is then predicted from height squared multiplied by electrical resistance (Goran, 1998:507; Wells & Fewtrell, 2006:613).

A limiting factor for the use of BIA is that lean mass must be computed from total body weight, and the hydration factor of lean mass must be known. The hydration factor is thought to be constant in adults but varies in children, which has led to the publication of age- and sex-specific hydration constants (Goran, 1998:507; Lemos & Gallagher, 2017:312). Furthermore, BIA measures of current assume that the body is divided into a set number of single cylinders, which is not the case (Goran, 1998:507; Wells & Fewtrell, 2006:613). Other factors such as limb length, hydration level, electrolytes in the body, nutrition status and the placing of electrolytes can affect the readings (Kuriyan, 2018:651). BIA exhibits good reproducibility for fat mass percentage (FM%) because of ease of handling and less influence on the evaluator. Evidence on the validity of the BIA when estimating FM and FFM is limited and inconclusive. Estimates of absolute values of FM and FFM with BIA correlates with reference methods have been made; however, they have underestimated FM in both girls and boys (Chula de Castro *et*

al., 2018:145). Inconsistencies exist regarding the findings from different studies, with some studies reporting good accuracy and others reporting poor results. Further to that, there are a few equations available for estimation of BC from BIA (Tewari *et al.*, 2018: 5).

- *Densiometry*

Densiometry, which is a two-compartment model, estimates BC from measurements of total body density (Table 2.6). If total body density and densities of fat and lean mass are known, an equation can be generated for converting total body density to percentage of fat (Goran, 1998:505; Kuriyan, 2018:651). In adults, specific densities of fat and lean mass are known; these are, however, influenced by factors such as age, gender and ethnicity. To determine total body density, a person has to climb into a large tank with water, empty the lungs and sit still under water for a few seconds; therefore, use of this technique in children is difficult (Goran, 1998:505; Lohman *et al.*, 2013:575). However, in recent years, a new laboratory method has been developed that does not require submersion in water. This is suitable for use in children as they may not be able to hold their breath under water (Lohman *et al.*, 2013:575). In devices such as the BodPod, air instead of water is used for measuring body density. However, the use of densiometry in children is still limited since density of fat and lean mass depends on the stage of maturity, gender and ethnicity (Goran, 1998:506).

- *Deterium dilution method (Doubly labelled water for body composition measurement)*

Doubly labelled water is another method used for the measurement of BC. It is achieved using trace elements such as stable isotope. It is considered safe and reliable in children (Bila *et al.*, 2013:66; Kuriyan, 2018:652) (Table 2.6). It performs very well compared to four-compartment models, with FM% determined by the method showing a variance of less than 1% (Bila *et al.*, 2013:66; Kuriyan, 2018:652). Deuterium (^2H) / D_2O , tritium (^3H) and ^{18}O have all been used as isotopes / trace elements to measure total body water. D_2O is normally the trace element of choice because of the radiation hazard associated with the use of ^3H , and the relative expense of using ^{18}O .

The DDM for BC measurement is based on the dilution principle. If the amount and concentration of a stable isotope is known, the total body water can be estimated. First, fluids such as urine, saliva or blood are collected and serve as background, then a dose of labelled water is given. The trace element is then allowed to reach equilibrium with all the water spaces in the body (two-three hours in children and three-four hours in adults) (Kuriyan, 2018:652).

Enrichment of the body water space is measured in saliva, urine or blood. Analysis is made by isotope ratio mass spectrometry or infrared spectrophotometry (Kuriyan, 2018:652; Wells & Fewtrell, 2006:614). FFM is estimated from total body water using age- and gender-specific hydration factors (Kuriyan, 2018:652). The procedure is simple to carry out and very minimal subject involvement is required; for these reasons it can easily be used in children and infants (Wells & Fewtrell, 2006:614). However, the method is costly, it takes time to reach the required equilibrium and variations in the type of fluid measured exists (Kuriyan, 2018:652).

FFM is calculated using age- and sex-specific Lohman hydration factors in children from total body water (Wang *et al.*, 1999:837). FM and FM% are calculated as follows (Moore *et al.*, 1963):

$$\begin{aligned}\text{FM (kg)} &= \text{body weight (kg)} - \text{FFM (kg)} \\ \text{FM\%} &= \text{FM (kg)} / \text{body weight (kg)} \times 100.\end{aligned}$$

- *Dual-energy X-ray absorptiometry*

Dual-energy X-ray absorptiometry (DXA), validated against magnetic resonance imaging (MRI), provides FM, FFM and bone density using two X-ray energies, (Kuriyan, 2018:652; Lemos & Gallagher, 2017:314). The reduction of the intensity of an X-ray beam as it moves through the tissue is dependent on the density and chemical composition of FM, FFM and bone (Kuriyan, 2018:652). DXA is a gold standard for bone properties but can be used for regional FM and FFM or total BC (Kuriyan, 2018:652).

The following points serves as limitations for use. The method assumes that fat over the bone is similar to the fat over bone-free tissue (Table 2.6). In fact, this is not the case, therefore it is not good for estimating FM%. Furthermore, it assumes a constant hydration of FFM, but FFM differs with age, gender and disease state (Kuriyan, 2018:652). A low dose of radiation is required; therefore, certified radiology personnel are required to administer the test. In addition, although it is safe to use in children, parents do not always accept the test being administered in their children out of fear of radiation. The test is not safe for use in pregnant women (Lemos & Gallagher, 2017:314). The method has been found to overestimate visceral adipose tissue in obese individuals (Lemos & Gallagher, 2017:314). Although the use of DXA is met with a number of limitations, it does provide reliable BC results in children and adults alike (Lemos & Gallagher, 2017:314).

Table 2.6: Advantages and limitations of methods of measuring body composition

Methods	Advantages	Limitations	Reference
BMI	Simple Affordable Can be used in large studies Low participant burden	Cannot differentiate FM and FFM Does not correlate with FM / FFM in other population	Javed <i>et al.</i> , 2014 Wells & Fewtrell, 2006 Lohman <i>et al.</i> , 2013
WC	Non-invasive Simple Affordable Low participant burden	Only reports regional fat Cut points not applicable to all ethnic groups	Lohman <i>et al.</i> , 2013:579
Skinfolds	Non-invasive Affordable Low participant burden	Subject to large measurement errors Equations only valid for intended population Training required for personnel	Freedman & Sherry, 2009:30 Well & Fewtrell, 2006:613
Bioelectrical impedance analysis	Portable and easy to use Non-invasive Results available immediately Low participant burden Affordable	Measures of current based on wrong assumptions	McCarthy <i>et al.</i> , 2006:601 Kuriyan, 2018:651
DDM (Doubly labelled water)	High accuracy Safe for all ages	Costly Time consuming Variations in the type of fluid measured High participant burden	Bila <i>et al.</i> , 2013 Wells & Fewtrell, 2006:614 Kuriyan, 2018
Dual-energy X-ray absorptiometry	Can provide regional and total FM and FFM mass	Not safe for use in pregnancy Parents reluctant due to radiation use, although small Costly	Lemos & Gallagher, 2017 Kuriyan, 2018

DDM= Deterium dilution method; FFM = Fat free mass; FM = fat mass

Section summary

Overweight and obesity in childhood are a global challenge that need addressing as they are related to adverse health complications that track into adulthood. Obesity is associated with increased risk of DM and various cancers (Lega *et al.*, 2020:34). Large randomised controlled studies in overweight children have shown that current prevention strategies for behaviour change are insufficient in reducing weight loss in the long term, in most parts of the world. Sustainable interventions of longer duration are needed. Environmental changes that will allow sustainable PA participation are also needed (Weihrauch-Blüher & Wiegand, 2018:255). To win the fight against overweight and obesity, particularly in developing countries such as South Africa, robust clinical methods for the assessment of BC are required (Choukem *et al.*,

10:2020). A range of BC assessment techniques are available for use from birth to adulthood. However, their use is met with many challenges, making their use in large studies impractical. Efforts should be focused on new techniques, or tailoring available techniques, for simple, inexpensive, safe, and accurate assessments in all age groups (Lemos & Gallagher, 2017:314).

2.4 Birth weight and body composition

Disturbances that occur in the uterus or in infancy may cause long-standing metabolic- and physiological adaptations that result in obesity later in life. Such factors include maternal overnutrition, DM and excessive weight gain (Kumordzie *et al.*, 2019:316; Rito *et al.*, 2019:240). Breastfeeding in infancy, especially if continued for longer than six months, offer protection against overweight / obesity in childhood (Pruszkowska-Przybylska *et al.*, 2019:418; Rito *et al.*, 2019:240). Birth weight has been largely used as an indicator of intrauterine growth (Wilcox, 2001:1242). Foetal undernutrition results in LBW, increasing risk of obesity later in life when associated with rapid postnatal catch-up growth (Campbell, 2016:206) and higher risk of chronic diseases such as CVD, DM and poor liver function (Liu *et al.*, 2018:196; Zanetti *et al.*, 2018:7). Furthermore, children that are born with HBW are likely to carry on being overweight in childhood (Liu *et al.*, 2019:11; Pereira-Freire *et al.*, 2015:448).

The mechanisms that drive the differential development of FM and FFM in the uterus are unclear; however, it has been suggested that maternal nutrition and hormones play a role (Liu *et al.*, 2019:10). At the time of birth, the fat cell numbers are complete and postnatal FM is mainly through the increase in the size of adipocytes (Liu *et al.*, 2019:10). This highlights the impact that maternal factors have on the association between birth weight and BC. Obesity has genetic components, and a child's risk for obesity begins with biological genes inherited from his or her parents (Bouchard, 2009:7). Several genes have been identified as role players. Environmental factors also play a role in the development of obesity. It is difficult to separate genetic factors from environmental factors because children not only inherit genes that can possibly cause obesity from their parents and but also the lifestyle. It has, however, been shown that genetic factors show stronger association with obesity (Mohamed *et al.*, 2021:25). Over- and underfeeding during pregnancy is associated with obesity later in life, possibly because of hyperglycaemia or hyperinsulinaemia exposure to the foetus (Maffeis, 2000:37). Over- and undernutrition in the uterus influences appetite regulation and adipocyte numbers (Dietz, 1994:956). Critical points in childhood development are associated with obesity later in life.

FM% is approximately 14% at birth and increases dramatically to about 25% at 6 months. It decreases progressively, reaching its lowest at age six years and then increases again until maturity (Maffeis, 2000:38). This period, referred to as adiposity rebound, may have an impact on fatness later in life (Dietz, 1994:957).

Children born to mothers who had high pre-pregnancy weight are more likely to have high weight at birth and be overweight in childhood than children born to mothers who had normal pre-pregnancy weight (Larqué *et al.*, 2019:478). Such children are at greater risk of being obese in childhood (Crowther *et al.*, 1998:1166; Frontini *et al.*, 2004:5; Rogers *et al.*, 2006:746; Weng *et al.*, 2012:1021). Weight status of the parent is strongly related to the weight status of the child up to the age of approximately five years. It can also predict the risk of adulthood obesity (Bouchard, 2009:7).

Most studies that assess the association between birth weight and overweight / obesity in childhood use BMI as a measure of BC. Such studies report that HBW is associated with high BMI; however, high BMI could either be high FM or FFM (Monyeki *et al.*, 2005; Fonseca *et al.*, 2015:582; Weng *et al.*, 2012:1020). This observed association may also be due to increases in both FM and FFM (Rogers *et al.*, 2006:746). HBW was associated with childhood obesity in European children (Rito *et al.*, 2019:240). In 6–13-year-old Chinese children, HBW was also associated with high BMI in childhood (Cai *et al.*, 2018:1147), and such associations are also reported in African countries (Katzmarzyk *et al.*, 2019:9; Noel *et al.*, 2020:197).

Fewer studies investigating the associations between birth weight and BC report BC as FM and FFM. Findings are contradictory among different studies, ranging from no relationship to relationship with either FM or FFM or both (Bernhardsen *et al.*, 2019:1641; Pruszkowska-Przybylska *et al.*, 2019:418). Bernhardsen and colleagues (2019:1641) did not find any relationship between birth weight and BC (FM and FFM) in childhood. Contradictory to the previous study, in children from Portugal, birth weight was positively associated with FFM at ages 4 and 7 years (Fonseca *et al.*, 2015). In 7–10-year-olds from Brazil, a significant positive correlation was also reported between birth weight and FFM (Moura-Dos-Santos *et al.*, 2014:474). Pereira-Freire and colleagues (2015:447) reported significant positive associations between birth weight and FM and FFM in their prospective cohort study on 5-8-year-olds from Brazil. Birth weight was found to be associated with both FM and FFM at age 9–10 years in

England (Rogers *et al.*, 2006:744). The observed contrary findings may be explained in part by the different methods used in determining BC and different cut points to classify BC.

HBW is not the only risk factor for childhood obesity. LBW is also associated with childhood obesity and adverse health outcomes (Frontini *et al.*, 2004:5; Liu *et al.*, 2019). LBW may increase the risk of DM if it results in low FFM (Liu *et al.*, 2019). Further to the factors mentioned previously, other factors attenuate the association between birth weight and BC, including diet, PA and SES (Larqué *et al.*, 2019:478; Noel *et al.*, 2020:197). When studying the relationship between birth weight and BC in childhood, all these factors should be considered, as they have been proven to affect the association.

Section summary

Birth weight, a marker of intrauterine growth, is reported to have an impact on childhood BC. Both HBW and LBW are associated with increased risk of overweight and obesity later in life. Effective management of maternal factors (such as diet during pregnancy, pre-pregnancy weight and pregnancy weight gain) can be implemented to ensure normal birth weight.

2.5 Association between physical activity and body composition

During growth and maturation, PA is a potential determinant of BC (Westerterp, 2018:11). It is recommended that children and adolescents aged 5–17 years participate in at least 60 minutes of MVPA daily (Bull *et al.*, 2020:1456). Sports, games, and dancing are examples of such activities. Achieving this guideline is associated with reduced odds of overweight / obesity and general good health (Choukem *et al.*, 2020:6). Physical inactivity, however, remains a global predicament (Aubert *et al.*, 2018:265). The decline in PA levels is in parallel with the increasing levels of childhood overweight and obesity (Masocha *et al.*, 2019:13; Moeng-Mahlangu *et al.*, 2020:7F). There is a growing body of literature that recognises the importance of PA levels on BC (Collings *et al.*, 2017:774; Janssen *et al.*, 2019:746; Wiersma *et al.*, 2019). It is acknowledged that in some studies, especially in high income countries, objective methods are used. However, conclusions from low- and middle income countries are mostly drawn from studies that employ the use of subjective PA and BC (Biddle *et al.*, 2011:6; Janssen & LeBlanc, 2010:10). Subjective methods misclassify PA in children, whereas BMI cannot distinguish between FM and FFM (Wiersma *et al.*, 2019:11; Vanderloo *et al.*, 2020:12).

Contradicting findings are reported in studies from different settings that employ different methodologies for measuring either PA levels or BC (Table 2.7). A study in 6–8-year-old children from Finland established a strong negative association between PA and adiposity, determined by FM% by DXA (Väistö *et al.*, 2014:3). Additionally, research done in children aged 6–8 years from Finland reported significant relationships between low light PA, MVPA and high FM index (Collings *et al.*, 2017:774). Higher levels of MVPA determined by accelerometry were associated with lower levels of fat mass index (FMI) and BMI in 7–15-year-old children from the United Kingdom (Janssen *et al.*, 2019:746). In European children aged 6–8 years, objectively measured light PA and VPA were positively associated with FFM index whilst SB was negatively related to FFM index (Reisberg *et al.*, 2020:2255). A study on 9–10-year-old European children looking at the association between objectively determined PA and adiposity as determined by BMI and skinfolds reported a weak association (Ekelund *et al.*, 2004:589). Furthermore, a study in 3-12-year-old children from Canada Toronto found a weak association between parent-reported PA and WHR (Vanderloo *et al.*, 2020:9). In light of the information provided, it is apparent that studies employing objective measures of PA show stronger association with obesity compared to those that rely on subjective measures (Janssen & LeBlanc, 2010:10; Janz, 2006:191).

The evidence from low- to middle income countries is limited. A study on 8–11-year-old children from Tunisia revealed that PA measured using ActiGraph was associated with FM (Ben Jemaa *et al.*, 2018:236). In 10–15-year-old South Africa children (Table 2.7), participation in high MVPA was associated with reduced adiposity (skinfold thickness) (Müller *et al.*, 2020:6). Furthermore, in a regional study, objective PA was not associated with FM by skinfolds; however, it did show significant relationship with BMI in adolescents (Monyeki *et al.*, 2017:119). Draper *et al.* (2018:617) reported that spending more time in MVPA was positively associated with BMI in South African children aged 3-6 years. Tomaz *et al.* (2019:528) reported that objective PA was not associated with BMI. This highlights the complexity of the relationship between PA and adiposity in children in different settings. Several other factors are known to have an effect of obesity and these must also be acknowledged. As mentioned above, genetic material and familial factors have been identified. Furthermore, nutritional transition / accessibility, and affordability of energy-dense food has also led to increased intake and excess energy intake. The increased energy intake is often not coupled with increased energy expenditure, and this has led to increased occurrence of obesity (Weihrauch-Blüher & Wiegand, 2018:257).

Children spend a considerable amount of time in light PA and SB (Draper *et al.*, 2017:10; Muthuri *et al.*, 2014:12). Although no global threshold for time spent in SB exists, it has been recommended that no more than two hours should be spent in SB (Chaput *et al.*, 2020:4). There is evidence that more time spent in SB is associated with adverse health risk factors (Bull *et al.*, 2020:1455). Associations between markers of adiposity and SB is not clearly defined. These associations are reported to be affected by the coexistence of SB with other factors such as MVPA and diet and therefore cannot be assessed independently of PA (Biddel *et al.*, 2017:17; Chaput *et al.*, 2018:455). Findings from a multinational study including children aged 9–11 years showed that grouping by SB levels did not lead to a better predictive ability for differentiating between obese and non-obese children than with MVPA alone (Chaput *et al.*, 2018:455). Furthermore, research done by Ayala and colleagues (2020:5) reported that MVPA levels did not influence the relationship between SB and adiposity in children. As such, it can be concluded that spending more time in SB can have detrimental health effects even if recommended MVPA levels are achieved (García-Hermoso *et al.*, 2017:1094). Interventions are needed to reduce SB and replace it with MVPA.

Information on whether light PA has a beneficial effect on BC is sparse and more research is needed (Craig *et al.*, 2013:83; García-Hermoso *et al.*, 2017:1092). A study that aimed to examine the association between light PA and body fatness in children found that light PA was negatively associated with body fatness at 11 years of age but not at age five. At eight years old, only girls showed a negative association (Janz, 2011:191). Additionally, Talarico and Janssen (2018) reported that light PA was positively associated with adiposity in 10–13-year-olds. This is suggestive of the potential difference in the association being brought by age, which might be explained in part by the change of PA patterns and fat during childhood (Janz, 2011).

Table 2.7: Summary of published studies on the relationship between physical activity and body composition in South Africa

Authors	Setting	Methodology	Findings
Draper <i>et al.</i> (2018)	3–6-year-olds, multi-ethnic, Western Cape	PA: Accelerometer BC: BMI	↑PA ↔ ↑ BMI
Tomaz <i>et al.</i> (2019)	3–5-year-olds, multi-ethnic, Gauteng	PA: Accelerometer BC: BMI	PA ≠ BMI
Monyeki <i>et al.</i> (2017)	Multi-ethnic, North West	PA: ActiHeart BC: Skinfolds, BMI	PA ≠ skinfolds ↑PA ↔ ↓ BMI
Müller <i>et al.</i> (2020)	10–15-years olds	PA: Accelerometer BC: Skinfolds	↑PA ↔ ↓ skinfolds
Moselakgomo <i>et al.</i> (2015)	9–13-year-olds, Limpopo, Mpumalanga	PA: IPAQ BC: FM%	↑PA ↔ ↓ FM% PA ≠ BMI

BC = Body composition; BMI = body mass index; FM%: Fat mass percentage; PA: physical activity; IPAQ: International Physical Activity Questionnaire; ↑ = increase; ↓ = decrease; ≠ = no association; ↔ = significant association.

Section summary

Current knowledge about the association between objective PA and BC is largely from high income countries, with data from low- to middle income countries scanty. Conflicting findings are reported because of different methodologies applied across studies. Nonetheless, the beneficial effect of PA on childhood BC is acknowledged. Although MVPA, as opposed to SB, is necessary to benefit child BC, higher doses of PA in terms of duration and intensity provide greater health benefits (Collings *et al.*, 2017:778; Wiersma *et al.*, 2019). Effectively implementing interventions to increase levels of PA and encourage lower the levels of SB can reduce the global burden of overweight and obesity and hence prevent the occurrence of morbidity and mortality due to NCDs.

2.6 Summary and recommendations

Considering the reviewed literature, it is evident that overweight or obesity in childhood is a global pandemic. The rising levels of overweight and obesity run parallel with high levels of physical inactivity and SB. Further to physical inactivity and SB, childhood overweight and obesity also sets in early in life. As a result of maternal factors including genetics, children

with HBW and LBW are more likely to become overweight or obese compared to children normal birth weight. This predicament, if not managed, is carried to adulthood where it perpetuates morbidity and mortality rates. For target populations in need of urgent intervention to be effectively and confidently identified, objective measures of PA and direct measures of BC are paramount. A variety of methodologies exist for the assessment of PA and BC. Some perform better than others but owing to their cost and impracticality are difficult to employ in large studies.

The following recommendations are made: Effective management of maternal factors such as pre-pregnancy and pregnancy weight can assist in reducing the prevalence of obesity in childhood. Studies in low- to middle income countries to assess the association between PA and BC in children using robust clinical methods are needed. It is apparent that in large-scale surveillance studies, DDM cannot be used; instead, strong BC measurements with appropriate sensitivity and specificity are required. Validations of instruments such BIA should be done for use in this population. With regard to PA measurements, accelerometry is one of the viable option because the technology is reliable and the prices are reasonable. With emerging research findings, uniformity in the protocol set up and calculations of PA levels is promising across different studies.

To address unresolved issues and the gaps highlighted in the literature chapter, this thesis makes use of cross-sectional data from a larger study which assessed BC using the isotope technique, to address the objectives outlined in the thesis. The reviewed literature served as a grounding for the three research articles, which can be read independently in the thesis.

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Chapter 3: Article 1

Association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children: BC–IT study

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Abstract

Background: Sub-Saharan Africa is faced with the double burden of undernutrition and overweight or obesity. Evidence exists that low- and high birth weight associate with obesity later in life; however, this has not been extensively studied in African countries. The present study investigates the association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children.

Methods: Studied were 91 children (40 boys, 51 girls) aged 6-8 years living in the Tlokwe local municipality area, North West Province, South Africa. Birth weight was recorded from the Road-to-Health cards, which are designed to track a child's growth and health status during the first five years of life. Weight and height were measured using standard procedures. The deuterium dilution method determined body fatness. Fatness was classified using McCarthy centiles set at 2nd, 85th and 95th (underfat, overfat and obese) in conjunction with high fatness cut-off points (25% in boys and 30% in girls). Normal fatness in the study was set at above 9th to below 85th centile. Partial correlation and multiple regression analysis were calculated to show the relationship between birth weight and body composition. Birth weight was set

as the independent variable, whereas body composition measures were used as independent variables.

Results: Birth weight correlated with all the body composition measures, and significantly correlated with body weight ($r=0.23$, $p<0.05$), height ($r=0.33$, $p=0.01$) and fat free mass (FFM; $r=0.26$, $p<0.05$). When multiple regression analysis was employed, birth weight significantly and positively with FFM ($\beta=0.24$, $p=0.013$; 95%CI: 0.032; 0.441) and FM ($\beta=0.21$, $p=0.02$, 95%CI: 0.001; 0.412) in girls and boys combined. Thirteen percent of the children had a low birth weight. In the current study, a prevalence of 21% and 17% for overweight and obesity respectively, is reported. Girls were more affected by overweight and obesity in childhood compared to boys.

Conclusion: Birth weight significantly associates with FFM and FM at age 6- to 8 years. Also, a high percentage of overweight and obesity was evident in the sample. Strategies that promote healthy uterine growth for optimal birth weight, coupled with sex-specific interventions in childhood are needed to help against the global obesity pandemic.

Keywords: Birth weight, body composition, obesity, stable isotope, South African children

1. Introduction

Childhood obesity is increasing at an alarming rate globally, with approximately 50 million girls and 75 million boys affected [1]. Childhood obesity is associated with an increased risk of obesity in adulthood and early life onset of non-communicable diseases [2,3]. A child's risk for obesity begins with genetic factors inherited from his or her parents [4]. Obesity is further enhanced by environmental factors such as low physical activity, poor diet, socio-economic status (SES) and breastfeeding practices [4-6]. Sub-Saharan Africa is faced with coexistence of undernutrition and overweight or obesity [7]. Although paucity exists in data, maternal malnutrition also has an influence on the development of obesity in the child later in life [4].

Disturbances that occur in the uterus or in infancy may cause longstanding metabolic and physiological adaptations that result in obesity later in life. Such factors include maternal over nutrition, diabetes mellitus and excessive weight gain [8,9]. As an indicator of intrauterine growth, birth weight has been largely used [10]. High birth weight (HBW) is associated with obesity in childhood [4,11]. Foetal undernutrition results in low birth weight (LBW), increasing the risk of obesity later in life when associated with rapid postnatal catch-up growth [5], and a higher risk of chronic diseases such as cardiovascular disease, diabetes mellitus and poor liver function [12,13-15]. Most studies that have assessed the association between birth weight and overweight or obesity in childhood used the body mass index (BMI) as a proxy for body composition [9,11,16]. Such studies have reported that HBW is associated with high BMI; however, high BMI could either be a result of high fat mass (FM) or of high fat free mass (FFM) [7,9]. BMI with appropriate cut-points performed reasonably well in detecting those with high body fatness in African children; however, it shows only moderate sensitivity [17,18].

The need to report body composition by FM and FFM, especially in children, is paramount. Inconsistent findings have been reported on the impact of birth weight on both FM and FFM [4,19]. Bernhardsen and colleagues [20] reported no relation between birth weight and body composition (FM and FFM) in Norwegian children aged 9–12 years, whereas Pruszkowska-Przybylska and colleagues [21] reported a relationship between HBW and high BMI, and low FFM percentage (FFM%) in 6- to 13-year-old Polish children. Birth weight was found to be positively associated with FM and FFM in 5- to 8-year-old Brazilian children [22].

It is, therefore, not known whether associations between birth weight and body composition will hold for South African children, who are faced with the paradoxes of nutritional transition linked to underweight and obesity. The present study aimed to determine the association between birth weight and body composition as determined by the deuterium dilution method (DDM) in 6- to 8-year-old South African children. We hypothesized that birth weight would be associated with the FM and FFM components of body composition in childhood. This information will be useful in designing strategies for improving maternal health status to prevent obesity in childhood.

2. Materials and methods

2.1. Study Design and Participants

A cross-sectional descriptive study design was used in the study. Data were collected as previously described in a larger study on body composition using a stable isotope technique (BC–IT study) [23, 24]. Specifically, a subsample of 91 participants with complete birth weight (primary outcome) data from the Road-to-Health cards (RtHC) was included. More details about BC–IT study are published elsewhere [23,25]. The RtHC is designed to keep track of babies' healthcare needs and is free for all babies born in South Africa at public or private healthcare facilities. The RtHC is a useful databank and patient-held child medical record, as it summarises a child's health status in the first five years of life [26]; and it depends on the knowledge, dedication and co-operation of mothers or caregivers and healthcare personnel [27]. The details about the sample size in this subsample of 91 participants are published elsewhere [24]. This sample size was, however, largely dependent on the availability of a completed RtHC birth record for each child and should not be viewed as a representation of children in the age groups.

Permission for the study was received from the school principals and district office of the Department of Basic Education in the Dr Kenneth Kaunda District Municipality district of North West Province. Subsequently, the Health Research Ethics Committee in the Faculty of Health Sciences (HREC) of North-West University approved the study (ethics no: NWU-00025-17-A1). Participant recruitment was done through advertisement in primary schools in the district with permission from the Department of Education. A sample that best represented both high and low SES was selected from the schools within Potchefstroom in the North West province of South Africa. The class lists for Grade R to Grade 3 were requested from the five participating schools and every third child on the class lists was nominated to participate in the study. Subsequently, only children with parental informed consent and verbal assent (6-year-olds)/written consent (7–8-year-olds) were included in the study. Furthermore, in this sub-sample, only children who provided the completed RtHC were included. Data collection started in 2017 (September) up until 2019 (May).

2.2. Measuring instruments

2.2.1. Socio-demographic questionnaire

Information for socioeconomic status (SES) information, seeking socio-demographic personal and household level (i.e. education of the parents, employment, type of dwelling, household amenities and marital status) from the parents or guardians of participating children were collected as previously described [24].

2.2.2. Birth weight

For each participating child, birth weight was taken from the RtHC and recorded in kilograms (kg). For analysis, birth weight was then divided into LBW (<2.5 kg), normal birth weight

(NBW; ≥ 2.5 kg to < 4.5 kg) and high HBW (≥ 4.5 kg) in line with the World Health Organization (WHO) definitions [28-30].

2.2.3. Anthropometric measurements

Body height (cm), weight (kg) and waist circumference (cm) were determined by following the International Society for the Advancement of Kinanthropometry (ISAK) procedures [31]. Measurements were conducted by Level I anthropometrists, and boys and girls were measured in separate rooms to ensure privacy [24]. The BC-IT study measurements procedures as described elsewhere [23,24] was that; body height was measured by a Seca 213 stadiometer (Birmingham, United Kingdom) with a child barefoot and standing upright with their head in the Frankfort plane position to the nearest 0.1 cm. Also, body weight to the nearest 0.1 kg was measured using a Seca 813 digital scale (Birmingham, UK) with a child barefoot and in light clothing. A Lufkin metal tape (Cooper Industries, USA) was used to measure waist circumference to the nearest 0.1 cm at the midpoint between the lower rib margin and the iliac crest).

BMI z-scores were calculated using WHO reference data, and subsequently as previously described in the BC-IT study [23] participants were categorised as follows; underweight: < -2 standard deviations (SD) from the median; normal weight: -2 SD to $+1$ SD; overweight: more than $+1$ to $+2$ SD; and obesity: more than $+2$ SD [32].

2.2.4. Body composition by deuterium dilution method

The determination of FM% by DDM was guided by the protocol provided by International Atomic Energy Agency (IAEA) [33]. The implementation of the current study follows a multicentre study which involves twelve African countries [34]. After an overnight fast, children provided a saliva sample, referred to as the pre-dose saliva sample. Each child was given a dose of accurately prepared deuterium oxide-labelled water according to their body weight and age. The doses were administered under a close supervision with drinking straws to avoid potential spillage. To ensure complete intake of dose, dose bottles were rinsed with water (50 ml per rinse) twice and the rinsing water consumed. The time for dose administration was recorded and at two and three hours post dosage, saliva samples were collected. The saliva samples were stored at -20°C in the lab until analysis was performed. Fourier transform infrared (FTIR) spectroscopy (FTIR 4500t spectrophotometer, Agilent) was used to analyse the saliva samples. To determine FFM, age- and sex-specific Lohman hydration factors for children were used, FM and FM% were calculated [30, 32-34]. The children were then classified as underfat/underweight, overfat/overweight, and obese at the 2nd, 85th and 95th centiles respectively [36,38,39]. Normal fatness in the study was set at above 9th to below 85th centile. The concept and methodology are explained in detail elsewhere [23, 33, 35, 37].

2.3. Statistical Analysis

Data was analysed with the help of the Statistical Package for the Social Sciences (SPSS) software version 26 (IBM Corp., Armonk, NY, USA). Normality was assessed using normal QQ plots for visual inspection and the statistical one-sample Kolmogorov-Smirnov normal distribution examination. The logarithmic transformations were made for data that were not normally distributed (BMI z-score, FM). To describe participants' characteristics, descriptive statistics in terms of averages and standard deviations were calculated for continuous data. Independent Welch's unequal variances t-tests were performed to determine the differences

between the birth weight categories. For all categorical variables, per-centages were calculated, and Pearson's Chi-square (χ^2) was calculated to determine the differences between categories. Multiple regression analysis ('crude', and adjusted for age, sex and SES factor for family income) and partial correlation were determined to show the relationship between birth weight (independent variable) and childhood body composition (dependent variables). In performing regression models and summarizing data in a correlation matrix showing correlation coefficients between variables, analyses were adjusted for age, sex and selected socio-economic factors. The probability level of significance was set at $p \leq 0.05$.

3. Results

A total of 91 children (40 boys and 51 girls) with birth weight data were included. **Table 1** presents the descriptive statistics of the participants in terms of means, minimum, maximum and SDs. Thirteen percent (13%) of the total participants were born with LBW.

Table 1. Descriptive statistics (minimum, maximum, mean and SD) and percentages (%) for categorical variables of participants

Variables	N	Minimum	Maximum	Mean	SD
Age (Year)	91	6.0	8.8	7.7	0.7
BW (g)	91	1000	4320	3053.9	538.2
Weight (kg)	91	15.1	48.7	25.0	5.9
Length (cm)	91	103.5	138.4	122.2	7.0
FFM (kg)	91	10.7	25.9	17.7	3.2
FM (kg)	91	2.7	22.8	7.3	3.5
FM (%)	91	12.0	46.8	28.1	7.2
TBW_D ₂ O	91	8.3	19.9	13.7	2.4
BMI for age Z-score	91	-2.4	3.6	0.3	1.2

BMI: Body mass index; cm: centimetres; FFM: fat free mass; FM: fat mass; FM(%)= fat mass percentage; kg: kilograms, DDM: deuterium dilution method, n=number.

The prevalence of overweight and obesity was 21% and 17% respectively when using the DDM based on body fatness (**Table 2**) respectively, whereas the prevalence of overweight and obesity was 13% and 5% respectively by BMI z-score. Girls showed a higher prevalence of overweight and obesity compared with the boys, when the DDM was used.

Table 2. Birth weight, DDM and BMI z-score percentage score for the total group and by sex.

Total group (n=91) Boys (n=40) Girls (n=51)				
Birth weight categories	n(%)	n(%)	n(%)	χ^2 test for sex difference
LBW	12(13)	5(12)	7(14)	
NBW	78(87)	35(88)	44(86)	
DDM fat percentage categories				
Underweight	4(4)	2(5)	2(3.9)	0.016
Normal weight	53(58)	30(75)	23(45.1)	
Overweight	19(21)	6(15)	13(25.5)	
Obese	15(17)	2(5)	13(25.5)	
BMI z-score categories				
Grades 1 and 2 thinness	7(8)	3(7)	4(8)	0.58
Normal	67(74)	33(83)	34(67)	
Overweight	12(13)	4(10)	8(15)	
Obese	5(5)	-	5(10)	

BMI: Body mass index; DDM: deuterium dilution method; HBW: high birth weight; LBW: low birth weight; NBW: normal birth weight; χ^2 test = Pearson Chi-square t test.

Table 3 presents descriptive statistics according to birth weight groups. Children with NBW were significantly taller than the LBW group (1232.1±6.1 cm vs. 117.4±10.7 cm; p=0.010). Although not significant, children with LBW showed a trend of being smaller than children with NBW, with a strong trend of lower FM in the LBW group compared with the NBW group (p=0.0657).

Table 3. Participants' body composition according to birth weight groups.

	LBW categories	NBW group	p-value
	Mean±SD	Mean±SD	
Age (years)	7.45±0.9	7.71±0.7	0.38
Birth weight (kg)	2.10±0.40	3.20±0.38	<0.0001*
Weight (kg)	22.27±6.5	25.48±5.8	0.1
Height (cm)	117.42±10.6	122.97±6.1	0.10
FFM (kg)	16.47±4.3	17.95±3.0	0.27
FM (kg)	5.81±2.8	7.53±3.6	0.08
FM (%)	25.59±6.22	28.51±7.27	0.16

*p-value of birth weight group differences; independent samples t-test; LBW: n=12; NBW: n=79.

BW: Birth weight; cm: centimetres; FFM: fat free mass; FM: fat mass; FM(%): fat mass percentage; kg: kilograms; LBW: low birth weight; NBW: normal birth weight; SD=standard deviation. "FM(kg)" the statistical test was performed for the data with the logarithmic transformation

Table 4 presents the associations for birth weight and body composition measures, as well as partial correlation, controlled for age, sex and selected SES variables. Before adjustments were made for confounding factors, birth weight showed a positive correlation with weight ($r=0.23$, $p=0.03$), height ($r=0.33$, $p<0.001$), FFM ($r=0.27$, $p=0.01$) and FM ($r=0.23$, $p=0.03$). After adjustment of age and sex, only height showed a significant correlation with birth weight. This correlation was no longer significant after adjustment for parent education level and household income.

Table 4. Association between birth weight and body composition measures unadjusted and then adjusted for age, sex and selected SES variables*.

		BW unadjusted	BW adjusted for age and sex	BW adjusted for age, sex and SES
Weight	r	0.23	0.20	0.21
	p	0.03*	0.06	0.20
Height	r	0.33**	0.31	0.22
	p	<0.001*	0.003	0.16
FFM (kg)	r	0.27	0.21	0.27
	p	0.01*	0.51	0.10
FM (%)	r	0.11	0.16	0.09
	p	0.30	0.12	0.57
FM (kg)	r	0.23	0.16	0.19
	p	0.03*	0.14	0.24

BW: Birth weight; FFM: fat free mass; FM: fat mass; FM(%): fat mass percentage; kg: kilograms; p-value: independent samples *t*-test; SES: education of the parents, household income, * $p<0.05$; ** $p=0.01$.

Table 5 shows a multiple regression analysis model, crude and adjusted. In the crude model, birth weight positively associated with FFM ($\beta=0.24$, $p=0.013$; 95%CI: 0.032; 0.441) and FM ($\beta=0.21$, $p=0.02$, 95%CI: 0.001; 0.412) in girls and boys combined. When the group was separated according to sex, birth weight was positively associated with FFM ($\beta=0.32$, $p=0.02$, 95%CI: 0.050; 0.574) and showed a trend of positive association with FM ($\beta=0.27$, $p=0.054$) in girls. After adjustments were made for age, sex and household income in the total group, only FM remained positively associated with birth weight ($\beta=0.23$, $p=0.04$, 95%CI: 0.031; 0.375); however, sex ($p=0.007$) showed a positive association with FM in the same model. In the adjusted regression model for girls and boys separately, birth weight explains a very low percentage of variance in the body composition variables.

Table 5. Multiple regression analyses of correlates of birth weight (independent variable) and FFM, FM and FM% (dependent variables).

Dependent variable		Unstandardised β	Adjusted r square	p value	95% CI
Crude models					
Total group	FFM (kg)	0.24	0.057	0.01	0.032; 0.441
	FM (kg)	0.21	0.044	0.02	0.001; 0.412
	FM (%)	0.18	0.033	0.30	-0.027; 0.338
Boys	FFM (kg)	0.13	0.430	0.43	-0.198; 0.454
	FM (kg)	0.24	0.057	0.08	-0.081; 0.557
	FM (%)	0.25	0.063	0.12	-0.067; 0.568
Girls	FFM (kg)	0.32	0.085	0.02	0.050; 0.574
	FM (kg)	0.18	0.202	0.06	-0.101; 0.464
	FM (%)	0.13	0.016	0.38	-0.159; 0.411
Adjusted models*					
Total group	FFM (kg)	0.18	0.390	0.07	-0.013; 0.381
	FM (kg)	0.17	0.110	0.04	0.031; 0.375
	FM (%)	0.17	0.075	0.17	-0.069; 0.405
Boys	FFM (kg)	0.24	0.320	0.16	-0.102; 0.576
	FM (kg)	0.27	0.160	0.15	-0.108; 0.653
	FM (%)	0.22	0.094	0.26	-0.171; 0.607
Girls	FFM (kg)	0.12	0.510	0.36	-0.124; 0.381
	FM (kg)	0.12	0.100	0.37	-0.158; 0.408
	FM (%)	0.15	0.050	0.37	-0.182; 0.477

*Adjusted for age, sex, household income.

FFM: Fat free mass; FM: fat mass; FM %: fat mass percentage; kg: kilograms, 95% CI= 95% Confidence Interval.

4. Discussion

The aim of the study was to determine the association between birth weight and body composition in 6- to 8-year-old South African children. In summary, the results from a sample of children from Potchefstroom in the North West province of South Africa showed that birth weight significantly and positively associated with body composition measures of FFM and FM. LBW was reported in 13% of the children, and children with LBW were significantly smaller in terms of height compared with children with NBW. High prevalence of overweight and obesity was reported in children, with girls more affected than boys. The positive association between birth weight and body composition in childhood has been shown in several studies [12,21,40]. In the current study, an inconclusive positive association between birth weight and FM is reported. It is noteworthy to mention that sex was the strongest predictor of FM in this age group. The observed significant association between birth weight and FM in our study is somewhat different from other studies. To cite examples, Bernhardsen and colleagues [20] did not demonstrate any relationship between birth weight and body composition (FM and FFM) in 9- to 12-year-old children. No significant relationship was reported between birth weight and FM in European children and adolescents, although a positive relationship with FFM index was reported, but in boys only [41]. A longitudinal study in 7-10-year-old Brazilian children also reported no significant associations [42]. The mechanism that drives the differential development of FM and FFM in the uterus is unclear; however, it has been suggested that maternal nutrition and hormones are key contributors [12]. This highlights the impact of maternal factors on the association between birth weight and body composition. Care should be taken to ensure optimum maternal nutrition and a healthy intrauterine environment in order to prevent obesity and related health risk factors in early childhood.

The prevalence of overweight and obesity in children is rising at an alarming rate in Sub-Saharan Africa [43]. Similarly, the present study reports a high percentage of overweight and obesity in children, especially in girls; however, we failed to show conclusively its significant association with birth weight at the age of 6-8 years. Birth weight may show a weaker association with body composition in the present study as a result of the small number of children with LBW and no children with HBW. The observed contradictory findings may also be explained in part by the different methods used in determining body composition and the different cut-points applied to classify body composition compared to other studies. The age of the children when outcomes are assessed may also play a role. Further to methodological differences, there are several confounding factors that can have an effect on childhood body composition. Diet, physical activity, sleep, familial factors such as SES, genetics and maternal factors, to name a few, have been linked to childhood obesity [44,45]. In the present study, sex and SES showed stronger associations with childhood body composition than birth weight. Unlike in developed countries where high SES and childhood obesity show an inverse relationship, SES in Sub-Saharan African is one of the driving forces behind the development of obesity [43,46]. More attention should be given to children with high SES, in particular girls, as they appear to be more affected by childhood obesity. Intrauterine growth indicated by birth weight is one of the factors that drives the global epidemic of obesity [43]. The noted prevalence of LBW (13%) is a concern to future growth and development of the children in the study for several reasons. Physiological reasons underpinning low birth weight might be an indication of lower levels of androgens, thus generating positive relationships of birth weight with muscle mass [12,47-49]. LBW may increase the risk of diabetes mellitus if it results in low FFM [12]. The current study, however, does not report any significant low FFM in the LBW group. Furthermore, there was no significant difference in FFM and FM between the LBW and NBW groups; the difference was only noted in height, with children with LBW being significantly shorter. The strength and novelty (i.e. South African context) of the study is that it reports body composition in terms of FM and FFM determined by the DDM in contrast to many previous studies which have used the crude outcome variable of BMI-for-age. This allows us to look at the association between birth weight and body composition using objective measures in South African children. Findings from this study can be used to guide larger studies on which method to use to measure adiposity. However, there are limitations, for example, lost data from children without an RtHC affected the sample size. Also, to note is that this study was based on cross-sectional study design, and therefore no causal relationship can be suggested. From available literature, the use of birth weight as a proxy for prenatal growth has some limitations of body composition programming [41], due the fact that body composition may vary even when birth weight is the same and within the normal range [50]. To cite, an example, in a study by Yajnik and co-workers [51], it was revealed that Indian babies have more adipose body composition despite being “small and thin” relative to UK infants. The results are not representative of the population of the North West province, nor the entire South Africa. Additionally, a lack of information on parental body size, breastfeeding practices and mother’s smoking habits during pregnancy limited the adjustment of the observed associations in the study. Also, the unavailability of dietary practice is a limitation for the study and hopefully future studies should consider inclusion of dietary practice.

5. Conclusion

In line with our hypothesis, birth weight significantly associated with FFM and FM at age 6 to 8 years. However, sex appeared to be the strongest predictor in the relationship between birth weight and FM in this population. The prevalence of overweight and obesity was high and more pronounced in girls compared with the boys. As such, sex-specific intervention and strategies that will help promote healthy body composition and normal birth weight are needed to help the fight against the obesity pandemic.

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Authors' contributions: CMS conceptualised the design, drafted the manuscript, and interpreted the data. MAM (as principal investigator in the BC–IT study) contributed to the conceptualisation, design, funding acquisition of the BC–IT study, supervision, project administration, analysis, and interpretation of data, and critical reviewing of the manuscript. JJR advised on the study design, review and commented on the manuscript. JX commented on the manuscript and HSK contributed to the design of the study and provided comments on the manuscript. RK and CUL advised on study design and reviewed the manuscript. All authors read and approved the final manuscript.

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Chapter 4: Article 2

Level of agreement between physical activity levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population: BC–IT study

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Abstract

Background: Misclassification of physical activity (PA) levels in children due the use of invalid methods may heighten related adverse health risks. Objective methods for assessing PA are preferable but are not always feasible due to costs and related logistics, and questionnaires may be more suitable for national surveillance purposes. However, their validity and reliability vary in different populations. The study therefore aimed to determine the level of agreement between PA levels measured by accelerometry (ActiGraph Model GT3X-BT) and the Physical Activity Questionnaire for Older Children (PAQ-C) in 8-year-old children from a black South African population.

Methods: Thirty-seven children (8.37 ± 0.73 years) from a larger study were participants. PA was determined using the objective and subjective methods of accelerometer (ActiGraph) and PAQ-C, respectively. Bland–Altman plots were used to assess the level of agreement between ActiGraph and PAQ-C.

Results: No significant gender difference in PA score determined by PAQ-C was found. When ActiGraph was used, boys reported significantly ($p < 0.05$) higher moderate PA, vigorous PA and moderate-to-vigorous PA than girls. The results show a significant ($p < 0.001$) mean bias of -0.50, and equivalent (r^2) of -0.01%, with limits of agreement ranges from -0.23 to -0.68, SEE of 0.14, equivalent (r^2) to -0.1% for total sample. Furthermore Bland–Altman plots showed poor level of agreement between PA levels by ActiGraph and PAQ-C ($p > 0.05$). The results further reveal that PAQ-C underestimated the PA of the sample population.

Conclusion: Poor level of agreement existed between the two methods used to assess PA. PAQ-C underestimated PA levels in a sample of South Africa black children. PAQ-C, when used as a lone method for assessment of PA levels, should be approached with caution and where possible, the use of both objective measures and self-report is recommended.

Keywords: Physical activity, objective, subjective, obesity, deuterium dilution method, South African children.

Introduction

High levels of physical activity (PA) show favourable health outcomes such as improved motor- and cognitive development and better psychosocial and cardiometabolic health in children (1). Furthermore, high levels of PA are associated with reduced risk of overweight and obesity (2,3). The global PA recommendation for health states that children should participate in an average of 60 minutes of moderate-to-vigorous PA (MVPA) per day (4). Although the benefits of high levels of PA have been well documented and global guidelines exist, recent times have seen a reduction in PA levels among children (5,6). Only about a third of children and adolescents in high income countries achieve the recommended MVPA guidelines (7,8). Although not as marked, African countries too face a similar challenge, with scores of children and adolescents not meeting the PA guidelines. About half of children and adolescents in Zimbabwe and Ghana achieve the daily recommended 60 minutes of MVPA (9,10). South African children are no exception to the challenge of reduced PA levels, and according to the Healthy Active Kids South Africa (HASKA) report, approximately 50% of children and youth achieve the guidelines (11). However, in the last few years, studies reporting on children's PA levels report varying prevalence levels, possibly due to the use of different measurement methods (12-14).

Accurate measurement of PA level is necessary to help identify areas that need intervention (15). Discrepancies that arise in the level of measured PA due to the chosen method can result in the beneficial effect of PA being missed (16,17) and this can delay interventions in areas that need attention. A wide variety of tools are currently available to measure PA in children (18). The choice of the tool depends on factors such as cost and the knowledge of the research team (19). Tools available for the measurement of PA include self-report, such as questionnaires, and objective methods, such as pedometer, heart rate monitoring and

accelerometer (18,20,21). Recommendation for use depends on the aspect of PA the researcher wants to measure, as well as the target population (18).

Objective PA assessment is practical and appropriate for children and adolescents (22,23). Since 2001, there has been an increase in the use of accelerometers in children (21,24). They are designed to directly capture acceleration as the body moves during activity and provide the intensity and pattern of activity (21,24). Furthermore, their use is regarded as a valid tool for assessment of PA in children (25,26). Although an ideal method, employing them is difficult in large population studies due to cost. The use of accelerometers also requires decision-making such as placement of the device and cut points to be used, taking away uniformity and making comparison across studies difficult (27-29).

Self-reporting tools such as questionnaires are widely used in population studies (20). They can easily be used in large population studies because they are simple to administer and are cost effective (20,30). They also provide information on the type and context of PA (20). The challenge with the use of self-reporting lies in the difficulty in recalling and reporting sporadic activity patterns of short duration that contribute to overall PA (23). As such, there is evidence that use of self-report can misclassify PA levels in children (31-33).

Although the use of objective measures of PA in South African studies is steadily on the rise, they have mostly been used in small-scale studies (12,13,34,35,36). The Physical Activity Questionnaire for Older Children (PAQ-C) has been regarded as an appropriate tool for use in school-going children aged 8–14 years (30). Accelerometer-derived PA data can be useful in validating self-reporting tools (20). The level of agreement between objective- and subjective PA varies across studies in low- to middle income countries, with some studies reporting no

agreement (16,35,37) and others reporting weak to moderate agreement between methods (32,38,39). This highlights the impact of applying different tools and the settings in which the studies are performed, and validation of self-reporting is needed accommodate different settings. Information is scarce on the validity of self-reporting in primary school children in South Africa and the validity of the PAQ-C has not been fully explored in this group, particularly not in North West Province. It was unclear if children from our setting can accurately report PA using the PAQ-C. For this reason, the level of agreement between PA measured by ActiGraph and PAQ-C in 8-year-old children was determined. Findings from this study provide guidance to larger studies on the use of appropriate tools for assessing PA in children.

Methodology

Participants

Study design and participants

The current study, which was part of a larger study, was cross-sectional in nature (40). It was performed in children who attended primary schools within the Tlokwe Local Municipality, North West Province. The larger study examined the relationship between PA (accelerometer / PAQ-C) and measures of body composition among 6–8-year-old South African children, and their relationships with other health-related determinants (blood pressure, lifestyle habits). For the present study, only 8-year-old children (N=37) who completed the PAQ-C and had valid PA data from ActiGraph were included. Six and seven year-old children from the larger study were excluded as the PAQ-C is used from the age of eight years.

The Health Research Ethics Committee (HREC) of the Faculty of Health Sciences of North-West University (ethics no: NWU-00025-17-A1) approved the study. Whilst, permission to

performed the study was granted by the Department of Education and school principals. Upon receiving the class lists for grade R to grade three learners from the five participating schools, every third child was nominated to participate in the study. However, only children whose parents gave informed consent were included. Furthermore, children were asked to give written consent before measurements could be done.

Measuring instruments

Socio-demographic questionnaire

Socio-demographic information, including data on personal information and family (i.e. education of the parents, employment, type of dwelling, household amenities and marital status) was collected using a socio-demographic questionnaire.

Anthropometric measurements

Anthropometric measurements were taken in separate rooms for boys and girls to ensure privacy. Anthropometric measurements were taken by a level I anthropometrist following procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (41). The Harpenden portable stadiometer (Holtain Limited, UK) was used to measure height to the nearest 0.1 cm with the child barefoot and standing upright with their head in the Frankfort plane. Weight was measured to the nearest 0.1 kg with an electronic scale (Beurer Ps07 Electronic Scale, Ulm, Germany), with participants wearing minimal clothing and barefoot. Two measurements were taken of each variable and the average reported and used for analyses. Weight and height were used to calculate BMI ($\text{weight} / \text{height}^2$) and BMI z-score

Body composition by stable isotope dilution

The determination of fat mass (FM) and fat free mass (FFM) by deuterium dilution method (DDM) was guided by the protocol provided by the International Atomic Energy Agency

(IAEA). The implementation in this study forms part of a multi-centre study that involves eight other African countries (42). After an overnight fast, children provided a saliva sample, referred to as the pre-dose saliva sample. Each child was given a dose of accurately prepared deuterium oxide-labelled water according to their body weight and age. The doses were administered under close supervision with drinking straws to avoid spillage. To ensure complete intake of dose, dose bottles were rinsed with water (50 ml per rinse) twice and the rinsing water consumed. The time for dose administration was recorded and at two- and three -hours post dosage, saliva samples were collected. The saliva samples were stored at -20°C in the lab until analysis was performed. Fourier transform infrared (FTIR) spectroscopy (FTIR 4500t spectrophotometer, Agilent) was used to analyse the saliva samples. To determine FFM, age- and sex-specific Lohman hydration factors for children were used, and FM and fat mass percentage (FM%) were calculated (40, 43-44). The children were then classified as underfat, overfat and obese at the 2nd, 85th and 95th centiles, respectively (45-47). The concept and approach are described in detail elsewhere. (40, 43-44).

Physical activity using ActiGraph accelerometer

Objective PA assessment was performed using accelerometers (ActiGraph Model GT3X-BT, Fort Walton Beach, FL, USA), a method that has been validated for use in children (26). The ActiGraphs were fitted around the waist just over the right mid-axillary line, as outlined in the manufacturer's instructions. Valid wear time was set for a minimum of four days which included at least one weekend day, and the required wear time per day was at least ten hours. Consecutive zero counts for 20 minutes or more were considered as non-wear time (48). Participants were advised to remove the accelerometers only during water-based activities such as bathing or swimming and when going to bed. Each child was provided with a user manual for proper use and daily log sheet to indicate the time the ActiGraph was worn and removed.

Following the final day of data collection (after seven days), accelerometers were returned to the school. ActiLife software (Version 6.13.3) was used to extract and analyse data. Only valid data were included in the analysis. PA data are expressed as average daily minutes spent at different intensities (49):

Sedentary behaviour: <99 counts per minute

Light PA: ≥ 100 to <2296 counts per minute

Moderate PA: ≥ 2296 to <4012 counts per minute

Vigorous PA: ≥ 4012 counts per minute.

MVPA was calculated as the sum of moderate PA and vigorous PA (50).

Physical activity measured using the PAQ-C

The PAQ-C is a widely used tool for self-reporting PA in children 8–14 years of age (51,52). It is administered once and asks children to recall their participation in PA behaviour at different times and places (i.e. during school, after school, recess, weekends, etc.) over the last seven days to compute an activity score. The PAQ-C is designed for use with primary- and middle-school children in a field-based setting.

The PAQ-C has ten items, of which the tenth is not included in the calculation, but is used to determine if the child had unusual activity in the last seven days. Scoring is based on a five-point Likert-type scale, with an overall PA score derived from the average of each scored item. The average of all items is used to indicate the level of PA. A score of one indicates low PA, whereas a score of five indicates high PA (30). Kowalski and coworkers (30) reported that PAQ-C had acceptable measurement properties, internal consistency, and reliability for using the average of either two or three PAQ-C scores gathered during fall, winter, and spring.

Statistical analyses

For statistical analysis, SPSS 27.0 (IBM, Chicago, IL, USA) software package was used. Data were tested for normality using the Kolmogorov–Smirnov test and tests for skewness and kurtosis. Normally distributed data were analysed with parametric tests, with non-parametric analyses performed on the data not normally distributed. Mean, standard deviations (SD) and frequencies for percentages were reported to provide participant characteristics. Chi-square was used to determine the difference between the frequencies for FM% and school quintile categories between boys and girls, and a Mann-Witney U test was used for the non-parametric variables at nominal level. Since data were not normally distributed, Spearman correlation coefficient (r) was used to determine the level of agreement between ActiGraph accelerometer and PAQ-C methods of assessing PA. Before Bland–Altman plots were drawn, data were log transformed and used to assess the agreement between the total PA using ActiGraph accelerometer data and PA level assessed by the PAQ-C (total score). The limits of agreement (LOA) (ActiGraph accelerometer–PAQ-C) were computed as the mean difference (mean difference $\pm$ [$1.96 \times$ standard deviation]). Regression analysis was used to determine the best prediction proportion of variance explained (R^2). The interpretation of level of agreement was based on Landis and Koch (53) for strength of agreement: $\kappa < 0.20$: poor agreement; $\kappa = 0.21–0.40$: fair agreement; $\kappa = 0.41–0.60$: moderate agreement; $\kappa = 0.61–0.80$: good agreement; and $\kappa = 0.81–1.00$: perfect/very good agreement. The level of significance was set at $p \leq 0.05$.

Results

Anthropometric and body composition variables for the total sample and divided by sex are presented in **Table 1**. The prevalence of overweight in the total group was 29%. Girls showed significantly higher adiposity compared to boys ($p < 0.05$).

Table 1: Anthropometry and body composition for the total sample and by sex

	Total sample (n=37) Mean±SD	Boys (n=16) Mean±SD	Girls (n=21) Mean±SD	p-value of sex and groups differences
Age (years)	8.37±0.73	8.56±0.47	8.23±0.84	0.16
Height (cm)	124.56±5.86	125.64±5.00	123.73±6.43	0.33
Weight (kg)	25.74±5.27	24.31±3.32	26.83±6.24	0.31
BMI z-score	0.07±1.28	-0.49±1.07	0.51±1.26	0.01
FFM (kg)	18.45±2.68	18.77±1.84	18.20±3.20	0.52
FM%	27.25±8.11	22.21±5.85	30.09±6.96	<0.001
Normal (n, %)	17 (46)	9 (56)	8 (38)	<0.001
Underweight (n, %)	7 (19)	6 (38)	1 (5)	
Overweight (n, %)	13 (35)	1 (6)	12 (57)	
Representing the poorest quintile SES (n, %)	22 (60)	11 (68)	15 (52)	0.01
Representing the least poor quintile SES (n, %)	15 (40)	5 (32)	11 (48)	

BMI = Body mass index; cm = centimetre; FFM = fat free mass; FM% = fat mass %; kg = kilogram; SD = standard deviation; SES = socio-economic status

Table 2: Physical activity levels measured by ActiGraph and PAQ-C in children

	N	Mean±SD	Ranges (min–max)	Percentiles		
				25th	50th (median)	75th
PAQ-C score	37	1.34±0.09	1.11–1.49	1.26	1.61	1.41
Sedentary time (min/day)	37	349.62±48.80	247.56–427.67	315.82	362.37	389.57
Light intensity (min/day)	37	354.62±43.03	255.81–434.85	328.73	348.37	390.18
Moderate intensity (min/day)	37	51.44±13.27	23.71–82.92	42.79	49.87	604.88
Vigorous intensity (min/day)	37	166.38±55.26	30.25–229.00	72.62	105.50	154.87
MVPA (min/day)	37	72.46±20.21	32.75–111.75	56.14	73.58	87.37
Average wear time per day	37	776.91±49.20	706.58–883.90	730.33	773.17	814.42
Calendar Days (no./7 days)	37	5.57±0.87	4–7	5.00	6.00	6.00

MVPA = Moderate-to-vigorous physical activity, PA = physical activity; PAQ-C = Physical Activity Questionnaire for Older Children; SD = standard deviation; ST = sedentary time.
Values are means ± SD.

Table 2 presents the PA characteristics, means and SD, ranges, and percentiles. The average MVPA was 72.46±20.21 minutes per day with an average wear time of 776.91±49.20 minutes per day. Boys (mean: 1.92±0.07) compared to the girls (mean: 1.78±0.14), measured by ActiGraph and PAQ-C (mean: 1.37±0.07 boys; and mean: 1.31±0.10), participated significantly more in physical activity (p<0.005).

Spearman correlation coefficient between PAQ-C score and total PA by ActiGraph for the total sample was reported as r=0.32, p=0.06 (Table 3). The relationship was not significant.

Table 3: Correlation between physical activity by ActiGraph and PAQ-C

		Total PA	Average MVPA
PAQ-C Score	r	0.32	0.35
	p	0.06	0.04

MVPA = Moderate-to-vigorous physical activity; PA = physical activity; PAQ-C = Physical Activity Questionnaire for Older Children.

Table 4: Agreement between ActiGraph MVPA and PAQ-C score for the total sample and sex

		PAQ-C score	MVPA z- values ActiGraph	Mean bias ±SD	95% CI ^a	SEE	LOA ^b
		Mean±SD	Mean±SD				
Estimate for total sample (n=37)		1.34±0.10	1.84±0.14	-0.50±.14	-0.48; 0.23	0.14	-0.23; -0.68

^a95% confidence interval for the average mean difference (Accelerometer – PAQ-Cc). ^bLimits of agreement calculated as: mean difference ± (1.96 *x standard deviation of mean difference).

CI = Confidence interval; LOA = limits of agreement; MVPA = moderate-to-vigorous physical activity; PAQ-C = Physical Activity Questionnaire for Older Children; SD = standard deviation; SEE = standard error of estimates

The results showed a significant ($p < 0.001$) mean bias of -0.50, and equivalent (R^2) of -0.01%, with LOA ranges from -0.23 to -0.68, SEE of 0.14 and equivalent (R^2) to -0.1% for total sample (**Table 4**). The agreement interval was narrow. The dots were widely spread with some lying outside the -1.96 SD. Overall, the results showed that PAQ-C underestimated PA levels in this sample population.

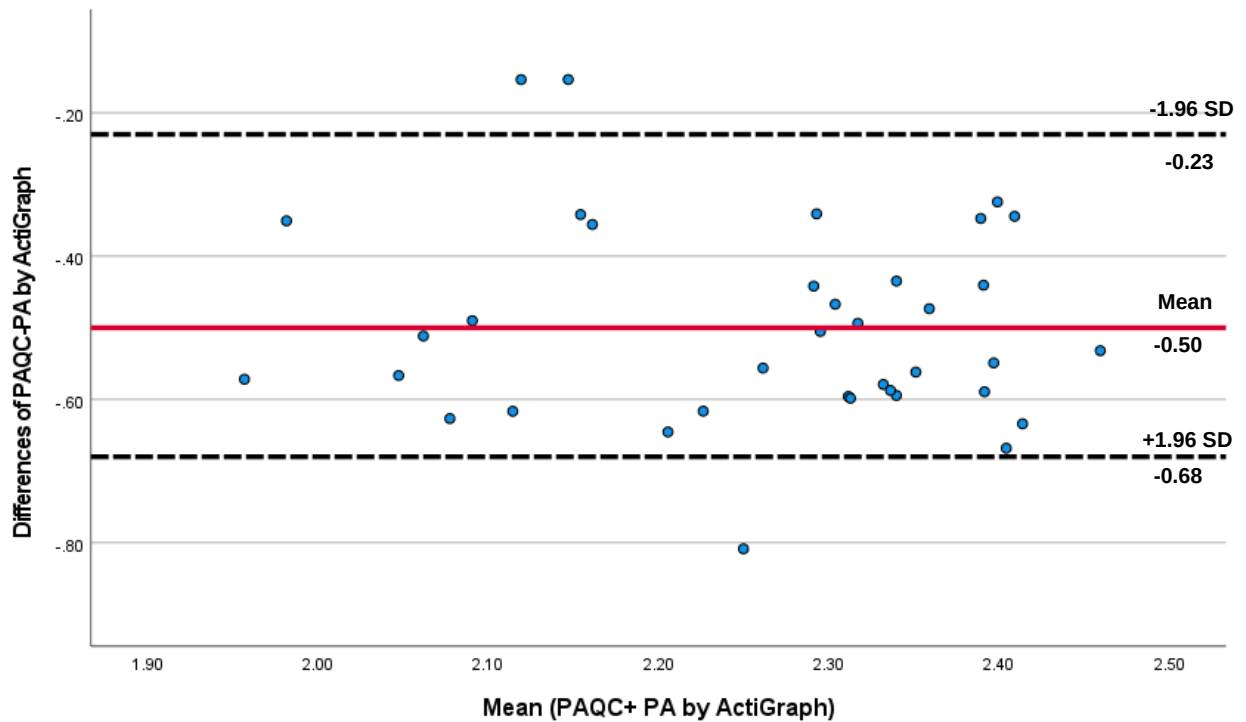


Figure 1: Bland–Altman plots with differences for PAQ-C total score and MVPA measured by ActiGraph.

Discussion

This paper explores the level of agreement between PA determined by accelerometry and PAQ-C in children. Using the PAQ-C, no significant gender difference was found in the level of PA. When ActiGraph was used, boys were found to be more physically active compared to girls. A poor level of agreement was found between PAQ-C score and MVPA measured using ActiGraph in this sample of South African children. When data were analysed for girls and boys separately, both sexes showed a poor level of agreement. PA level was underestimated by the PAQ-C.

The most plausible explanation for the poor level of agreement found in this study is probably the inability of the children to recall all body movement when completing the PAQ-C, whereas the accelerometers automatically captured PA data (21,24). Furthermore, self-reports only

follow a series of questions included in the questionnaire, other activities that might contribute to overall PA may not have been included. PA levels measured by PAQ-C were underestimated, and no sex differences were found when PA was measured using the PAQ-C whereas sex differences could be seen when ActiGraph was used. These findings agreed with what has been reported in several studies (31-33).

The present study reports the poor level of agreement between PA determined by PAQ-C and ActiGraph. Similarly, although in older children, Monyeki and colleagues (35) reported insignificant correlation ($r=0.11$, $p=0.29$) between PA measured using ActiHeart and PA measured using the International Physical Activity Questionnaire – Short Form (IPAQ-S) in 15-year-old South African children. No significant correlation was reported between PA measured with the PAQ-C and accelerometer in 8-11-year-old children from Tunisia (16). In Kenyan children aged 9–11 years, no association was found between self-report and objective measures of PA. Significant associations were only found in weekday and weekend-day measures of PA among the under- / healthy weight children. This indicates that the strength of the association may vary according to weight status of the children (37).

Not all studies are incongruent with the outcomes of the present study. For example, a study in 9–10-year-old children from Tanzania reported moderate positive correlation ($r=0.36$, $p=0.009$) between self-reported PA and accelerometer-derived PA (32). A positive and significant relationship ($r=0.53$, $p=0.004$) was found between objective PA measured using Actical and a self-report PA questionnaire (PAQ) (in the form of an interview) in primary school children in South Africa (39). Mciza (38) and colleagues also reported positive associations between moderate and vigorous energy expenditure determined by a PAQ and activitygram in 9–12-year-old girls. Discrepancies among studies may be due to the application

of different tools and cut points. It is also important to note that the settings are different in these studies, which highlights the need for population-specific validations as PA patterns and behaviours differ between settings.

A poor level of agreement exists between self-reported and objectively measured PA. As such, the method of choice for the assessment of PA has the potential to influence the results with associated factors. When the PAQ-C is used as a PA assessment tool in studies that explore the relationship between PA and health outcomes, the positive effect of PA on health outcomes is often not revealed. The beneficial effect of PA can be missed and interventions delayed (16,17). This highlights the need to validate questionnaires before use in different settings. Although self-reported PA provides insight on the type of PA and the context in which PA was performed, alone it is insufficient in accurately capturing total daily PA. Therefore, objective measures and self-report will complement each other when used together, and give a clearer picture on the type and intensity of activities that increase PA (33).

Based on the findings from the current study, the following recommendations are made. Since the PAQ-C has been shown to underestimate PA levels in this group of children, the use of PAQ-C as a sole PA measure should be used with caution. Objective methods of measuring PA in eight-year-old children are needed. The strength of the study includes the use of accelerometers (ActiGraph), a preferred method of PA assessment. Several participants were excluded due to invalid ActiGraph data. Furthermore, the study only included eight-year-olds from a black population, and future validation studies should include a wide range of age groups and ethnicities.

Conclusion

Poor level of agreement exists between two methods used to assess PA. The PAQ-C underestimated PA levels in a sample of South African black children. The PAQ-C, when used as a standalone method for assessment of PA levels, should be approached with caution and, where possible, the use of objective measures of PA is recommended.

List of abbreviations

HAKSA: Healthy Active Kids South Africa

HREC: Health Research Ethics Committee in the Faculty of Health Sciences

IPAQ-S: International Physical Activity Questionnaire – Short Form

Kg: Kilogram

LOA: Limit of agreement

MVPA: Moderate-to-vigorous physical activity

NWU: North-West University

PA: Physical activity

PAQ: Physical activity questionnaire

PAQ-C: Physical Activity Questionnaire for Older Children

SD: Standard deviation

SES: Socio-economic status

SPSS: Statistical Package for the Social Sciences

WHO: World Health Organization

Declarations

Ethics approval and consent to participate: Ethical approval was granted by HREC of North-West University (ethics no: NWU-00025-17-A1).

Consent for publication: Parents of participating children provided consent for children to participate and for data obtained to be used for publications.

Availability of data and materials: The datasets used in the analysis in this study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Author contributions: CMS conceptualised the design, drafted the manuscript, and interpreted the data. MAM (as principal investigator in the BC–IT study) contributed to the conceptualisation, design, funding acquisition of the BC–IT study, supervision, project administration, analysis and interpretation of data, and critical reviewing of the manuscript.

JJR advised on the study design and reviewed and commented on the manuscript. XJ read and gave comments on the manuscript. All authors read and approved the final manuscript.

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Chapter 5: Article 3

Associations between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC–IT study

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ABSTRACT (200)

Physical inactivity in children is a global pandemic in parallel with increasing obesity prevalence. However, studies assessing the association between physical activity (PA) and body composition (BC) report conflicting findings, possibly because of the different methodologies across studies, with objective methods promising reliable results. This study determines the association between objectively determined PA levels and BC in 6–8-year-old children from a black South African population. Ninety-three children aged 6–8 years, who formed part of a larger study on BC using the deuterium dilution method (DDM), were included. Height and weight were measured according to the standard procedures, and body mass index z-score calculated. Fatness was determined by DDM. Accelerometer (ActiGraph: Model GT3X-BT) was used to measure PA levels. Regression models were performed to determine the relationship between PA and BC. Approximately 23% of the children did not meet the recommended PA guidelines and 27% were overfat. After adjustments were made, more time spent in vigorous PA was significantly associated with lower fat mass ($\beta=-0.25$, $p=0.01$) and fat mass % ($\beta=-0.20$, $p=0.04$). Participation in high PA, more especially of high intensity, was associated with reduced adiposity in children. Behavioural changes such as increasing high intensity PA is strongly recommended.

Keywords: Fat mass, fat free mass, deuterium dilution method, objective, physical activity.

Introduction

The decline in physical activity (PA) levels in children has been linked to a high prevalence of obesity and overweight.¹⁻³ In recent regional studies in South African children and adolescents, high prevalence of obesity and physical inactivity were reported.^{4,5} In sub-Saharan Africa, overweight and obesity increases in childhood and is more prevalent in girls compared to boys.^{6,7} If overweight and obesity are not identified early in life and preventative measures put in place, physical inactivity and excess adiposity in childhood can have long-lasting negative health effects.⁸⁻¹⁰ Furthermore, childhood obesity is associated with an increased risk of morbidity and mortality later in life – it accounts for as much as 20% of cardiovascular deaths in midlife.¹¹

To achieve health benefits, it is recommended that children and adolescents aged 5–17 years participate in an average of 60 minutes or more of moderate-to-vigorous physical activity (MVPA) per day.¹² Although the benefits of PA have been well identified, physical inactivity remains a major public health problem.^{13,14} The Healthy Active Kids South Africa (HAKSA) 2018 report indicated that 50% of children are not meeting the recommended at least 60 minutes of MVPA per day.¹⁵ It appears that adoption of urban lifestyles, introduction of technology-related devices and the shift from active transport, particularly in children from rural areas, are all responsible for decreasing levels of PA.^{2,16}

In population-based studies, it is convenient to use self-reporting methods of PA and body mass index (BMI) as a proxy for adiposity, as these are simple and affordable methods.¹⁷⁻¹⁹ However, studies with self-reported PA and the use of BMI often report inconclusive findings. Even though BMI correlates with fat mass percentage (FM%),²⁰ it cannot distinguish between fat mass (FM) and fat free mass (FFM).²¹ Excessive fat accumulation is associated with obesity-

related pathology and morbidity.²² Additionally, although the use self-reported or parental-reported PA is easy and cost effective, this method is subject to participants' recall bias and, as such, often fails to report the true levels of PA.^{23,24} Objective assessment of PA and adiposity is warranted for valid results.

Studies assessing the association between PA and body composition (BC) have been extensively performed. But findings thereof are contradictory.²⁴⁻²⁸ What is currently known about the association between objective PA and BC is largely from high income countries, and data on low- to middle income countries is scanty. While few studies have been done in South African children, the focus has not been on the years of school entry.²⁹⁻³³ PA levels decrease by up to 50% in the years of school entry; furthermore, overweight and obesity are higher in mid-childhood.³⁴⁻³⁶ More studies to understand the association between sedentary behaviour (SB), PA and adiposity in South African school children are urgently needed.²⁹ We attempt to close this gap. It was therefore fitting to investigate the association between objective PA levels and BC determined by stable isotope methods in 6-8-year-old South African children. It is hypothesised that higher levels of PA are associated with lower body fatness in South African children.

Methodology

Study design and participants

The current study follows a cross-sectional design and is descriptive in nature.⁵ It forms part of a larger study on BC using isotope technique (BC-IT). The larger study examines the relationship between objective (stable isotope) and indirect (anthropometric variables) measures of BC indices and objective (accelerometer), and subjective (Physical Activity Questionnaire for Older Children [PAQ-C]) measures of PA among 6-8-year-old South African

children, and the relationships thereof with other health-related determinant factors (blood pressure, lifestyle habits). For the present study, all children with ActiGraph and deuterium dilution method (DDM) data (93 children: 51 girls and 42 boys) attending different primary schools within the Tlokwe Local Municipality of the North West Province were included.

The study was approved by the Health Research Ethics Committee (HREC) in the Faculty of Health Sciences of North-West University (ethics no: NWU-00025-17-A1). After advertisement to primary schools with permission from the Department of Education, approval was received from school principals. The class lists for grade R to grade three were requested from the five participating schools. From the lists, every third child was nominated to participate in the study. Subsequently, only children whose parents gave informed consent were included in the study. Children were asked to give verbal assent in the case of 6-year-olds and written consent in 7–8-year-olds before measurements could commence. Data collection started in 2017 (September) and continued to 2019 (May)

Measuring instruments

Socio-demographic questionnaire

Socio-demographic information was collected by use of a socio-demographic questionnaire; the information was used to put schools into different quintiles according to socio-economic status. The Quintiles 1 to 3 refer to schools in the most economically disadvantaged (poorest) geographical areas (non-fee-paying schools that receive more funding per learner from the government), and for statistical analysis were coded as number 1. Quintiles 4 and 5 refer to fee-paying schools that require less governmental support, because parents can afford to pay fees,^{37,38} and for statistical analysis were coded as number 2.

Anthropometric measurements

Anthropometric measures of height (cm) and weight (kg) were determined by following the International Society for the Advancement of Kinanthropometry (ISAK) procedures.³⁹ Measurements were taken by level I anthropometrists. To ensure privacy, anthropometric measurements were taken in separate rooms for boys and girls. A Harpenden portable stadiometer (Holtain Limited, UK) was used to measure height to the nearest 0.1 cm with the child barefoot and standing upright with the head in the Frankfort plane. Weight was measured to the nearest 0.1 kg with an electronic scale (Beurer Ps07 Electronic Scale, Ulm, Germany), with participants wearing minimal clothing and no shoes.

Two measurements were taken of each variable indicated and the average of the two measurements was used for the analyses. Weight and height were used to calculate BMI ($\text{weight}/\text{height}^2$); BMI z-score was calculated relative to WHO reference data.⁴⁰

Body composition by deuterium dilution method

BC was determined by use of DDM. Sample collection and analysis followed the protocol provided by the International Atomic Energy Agency (IAEA). The concept and methodology are explained in detail elsewhere.^{4,41,42} Age- and sex-specific Lohman hydration factors for children were used to calculate FFM, FM and FM%.^{4,41,42} The children were classified as underfat, overfat, and obese at the <2nd, >85 to 95th and >95th centiles of FM% respectively.⁴³⁻

45

Physical activity using ActiGraph accelerometer

PA and SB were assessed using the ActiGraph accelerometer (Model GT3X-BT, Fort Walton Beach, FL, USA), which has been validated for use in children.⁴⁶ Trained research assistants

fitted ActiGraphs on elastic belts worn at the waist (just over the right mid-axillary line), according to the manufacturer's instructions. Participants were instructed to wear the ActiGraph for a minimum of 10 hours/day for seven consecutive days.⁴⁷ They were advised to remove the accelerometers only during water-based activities such as bathing or swimming and when going to bed. Each child, with the help of the parents/guardian, was required to complete a daily log sheet indicating the time the ActiGraph was worn and removed. An instruction manual on the proper usage of accelerometers was given to each participant for additional guidance.

Following the final day of data collection, accelerometers were returned to the school. ActiLife software (Version 6.13.3) was used to extract and analyse data. The first day of data collection was excluded, Epoch length was set at 15 seconds. PA data is expressed as average daily minutes spent in light PA (LPA) ≥ 100 counts per minute, moderate PA (MPA) ≥ 2296 counts per minute and vigorous PA (VPA) ≥ 4012 counts per minute. Average daily minutes spent in SB will also be reported (< 99 counts per minute).⁴⁸ Time in MVPA was calculated as the sum of MPA and VPA.³² Participants who provided a minimum of four days of valid data, including one weekend day, were included in the analysis. Valid days were those days in which the accelerometer was worn for at least 600 minutes (ten hours) per day. Consecutive zero counts for 20 minutes or more was considered as non-wear time.⁴⁹

Statistical analysis

Statistical Package for the Social Sciences (SPSS, Version 27; IBM Corp., Armonk, NY, USA) was used to analyse data. To describe participant characteristics, means and standard deviations (SD) were computed for the whole group and for girls and boys separately. Data that were not normally distributed were log transformed. To describe gender differences, independent

sample t-test was performed for normally distributed data and Mann–Whitney U tests when not normally distributed. To achieve the aim of determining the relationship between PA and BC, multiple linear regression models were used to determine the associations between PA (SB, LPA, MPA, VPA and MVPA) and BC variables (BMI, FM, FFM, FM%). The outputs are reported as standardised β coefficients, p-value and standardised r-square (r^2). The crude model and adjusted models were reported, and models were adjusted for age, sex, and school quintile: Model 1 = sex; Model 2 = age; Model 3 = school quintile.

Results

Table 1 shows descriptive statistics of participants, reported as means and SD. Girls were significantly ($p < 0.05$) more sedentary and had higher levels of fat mass compared with boys, when using objective measures. No significant ($p > 0.05$) gender differences were reported when BMI z-scores were used. Boys spent significantly ($p < 0.05$) more time in MPA and VPA than girls. There was no significant ($p > 0.05$) gender difference in time spent in LPA.

Table 1: Descriptive statistics of participants

Variable	Whole group (N=93)	Girls (n=51)	Boys (n=42)	
	Mean±SD	Mean±SD	Mean±SD	p- value
Age (yr)	7.74±1.25	7.72±1.29	7.75±1.20	0.89
Height (cm)	121.56±8.66	121.42± 9.04	121.73±8.28	0.86
Weight (kg)	23.93±5.87	24.35±6.45	23.41±5.10	0.45
BMI z-scores	-0.05±1.06	-0.08±1.09	-0.20±1.00	0.20
SB (min)	342±52	356±49	325±49	0.003
LPA (min)	363±45	355±44	372±43	0.06
MPA (min)	57±16	49±13	66±15	<0.001
VPA (min)	23±11	19±9	27±11	<0.001
MVPA (min)	80±25	67±20	93±23	<0.001
FM (kg)	6±3	7±3	5±2	0.04
FFM (kg)	17±3	17±4	18±3	0.19
FM%	26±7	28±7	22±5	<0.001

SD = standard deviation; BMI = body mass index; SB = sedentary behaviour; LPA= light physical activity; MPA = moderate physical activity; VPA = vigorous physical activity; MVPA = moderate-to-vigorous physical activity; FM = fat mass; FFM = fat free mass; yr = year; cm = centimetre; kg = kilogram; min = minutes; % = percent.

Table 2 reports the prevalence of weight and PA categories, based on DDM, and shows that 27% of the children were classed as having a high FM%. There was a noted significant gender difference in the prevalence of high fatness; more girls (41.2%) had high FM% compared with boys (9.5%; $p<0.001$). When BMI z-scores were used to assess BC, no gender differences were noted. A total of 77.4% of children achieved the recommended average of 60 minutes per day of MVPA. A significantly higher number of boys (97.6%) met the guidelines compared with girls (60.8%).

Table 2: Prevalence of weight and physical activity categories

Categories	All, n (%) 93	Girls, n (%) 51	Boys, n (%) 42	p- value
BMI z-scores				
Underweight	9 (9.7)	6 (11.3)	4 (9.5)	0.67
Normal weight	72 (77.4)	38 (71.7)	34 (81.0)	
Overweight/obese	12 (12.9)	9 (17)	4(9.5)	
DDM				
Underfat	11 (11.8)	1 (2.0)	10 (23.8)	< 0.001
Normal fat	57 (61.3)	29 (56.9)	28 (66.7)	
Overfat	25 (27)	21 (41.2)	4 (9.5)	
MVPA				
≥60 min MVPA	72 (77.4)	31 (60.8)	41 (97.6)	< 0.001
<60 min MVPA	21 (22.6)	20 (39.2)	1 (2.4)	

BMI = Body mass index; DDM = deuterium dilution method; MVPA= average moderate-to-vigorous physical activity; min = minutes

Table 3 shows that children who do not meet the MVPA guideline had significantly higher FM, FM% and FMI compared with those who met the MVPA guideline.

Table 3: Descriptive characteristics of participants according to the moderate-to-vigorous physical activity categories

	MVPA <60 min/day	MVPA ≥60min/day	p-value
Variables	Mean (SD)	Mean (SD)	n (SD)
Weight (kg)	25.71 (±7.56)	23.41 (±5.22)	0.11
BMI z-scores	0.28 (±1.25)	-0.15 (±0.98)	0.11
FFM (kg)	17.90 (±4.40)	17.37 (±3.03)	0.52
FM (kg)	7.81 (±3.95)	6.05 (±2.79)	0.02
FM%	29.09 (±7.78)	24.98 (±6.25)	0.01
FMI	5.07 (±2.29)	4.01 (±1.49)	0.01

BMI = Body mass index; FM = fat mass; FFM = fat free mass; FM% = fat mass percentage; MVPA = moderate-to-vigorous physical activity; kg = kilograms; SD = standard deviation; % = percent.

Table 4 presents the crude and adjusted regression models to assess the association between PA levels and BC variables. In the crude model, time spent in VPA ($\beta=-0.28$; $p= 0.01$), MVPA ($\beta= -0.25$; $p=0.01$) and MPA ($\beta= -0.25$; $p=0.01$) were associated with lower FM and FM%. After adjustments were made, time spent in VPA remained significantly associated with lower FM ($\beta= -.25$; $p=0.01$) in the age-adjusted model and with lower FM% ($\beta= -.20$; $p=0.04$) in the gender-adjusted model. Higher MVPA showed a trend of an association with lower FM in the sex- and school quintile-adjusted model; the association was, however, not significant ($p=0.06$). No significant association was reported between PA and BMI z-scores ($p>0.05$)

Table 4: Associations between body fatness components and physical activity variables

	BMI z-score			FM			FM%			FFM		
	r ²	β	p	r ²	β	p	r ²	β	p	r ²	β	p
SB (Crude)	-.01	-.05	.59	.01	.14	.17	.01	.16	.13	.00	.10	.31
Model 1	.01	-.11	.33	.07	.06	.57	.20	.02	.82	.02	.16	.14
Model 2	.07	-.17	.11	.16	-.03	.90	.02	.11	.33	.55	-.14	.06
Model 3	-.01	-.06	.58	.03	.10	.32	.04	.11	.27	-.01	.11	.29
LPA (Crude)	.02	.17	.10	-.01	-.02	.82	-.01	.01	.94	.01	-.14	.19
Model 1	.10	.19	.06	.07	.03	.74	.21	.10	.28	.02	-.17	.11
Model 2	.03	.13	.20	.18	.15	.14	.02	.08	.44	.54	.14	.06
Model 3	.01	.17	.10	.02	-.02	.88	.03	.02	.86	-.00	-.14	.19
MPA (Crude)	-.01	-.07	.51	.05	-.25	.01	.08	-.30	.003	-.01	-.03	.75
Model 1	-.00	.00	.99	.08	-.13	.25	.20	-.09	.40	.01	-.21	.25
Model 2	.05	-.02	.81	.19	-.18	.06	.09	-.28	.18	.52	.09	.20
Model 3	-.02	-.08	.49	.05	-.21	.06	.09	-.25	.19	-.02	-.04	.71
VPA (Crude)	.02	-.18	.07	.07	-.28	.01	.11	-.35	.001	-.01	.02	.87
Model 1	.02	-.16	.16	.10	-.20	.07	.23	-.20	.04	-.00	-.04	.71
Model 2	.07	-.17	.10	.22	-.25	.01	.13	-.34	.12	.52	.07	.30
Model 3	.01	-.19	.07	.08	-.25	.15	.13	-.32	.08	-.02	.01	.89
MVPA (Crude)	-.01	-.07	.51	.05	-.25	.01	.08	-.30	.003	-.01	-.03	.75
Model 1	-.00	.00	.99	.08	-.13	.25	.20	-.09	.40	.01	-.14	.25
Model 2	.05	-.02	.81	.19	-.18	.06	.09	-.28	.18	.52	.09	.20
Model 3	-.02	-.08	.49	.05	-.21	.06	.09	-.25	.19	-.02	-.04	.71

Model 1 = sex; Model 2 = age; Model 3 = school quintile; BMI = body mass index; SB = sedentary behaviour; LPA = light physical activity; MPA = moderate physical activity, VPA = vigorous physical activity; MVPA = moderate-to vigorous physical activity; FM = fat mass; FFM = fat free mass.

Discussion

The current study, with the aim of determining the relationship between objectively measured PA and BC, found that in line with our expectations, high PA levels were associated with low body fatness. This association was only observed when BC was directly assessed by use of DDM. The use of BMI z-scores as a proxy for adiposity did not yield any significant association. Children who do not meet the recommended MVPA levels have significantly higher adiposity compared with those who meet the guidelines. Girls were more overweight and obese compared with their male counterparts. The prevalence of children who meet the recommended average of 60 minutes per day of MVPA was 77.4%, and more boys than girls met the guidelines.

Although not enough data exist to set the global threshold for time spend in SB or screen time, evidence does suggest that more time spent in SB is associated with adverse health risk factors.¹² It has been reported that children from South Africa and Kenya spend most of their time in SB and LPA.⁵⁰⁻⁵² In the current study, girls spent an average of almost six hours per day in SB; this was compared to five and a half hours spent by boys. Previous studies have reported that spending more time in SB is associated with unfavourable BC indicators in children.^{53,54} Furthermore, it has been reported that MVPA levels did not influence the relationship between SB and adiposity in children.⁵³ This means that spending more time in SB can have detrimental health effects even if recommended MVPA levels are achieved. The results of the current study only show a trend of a positive relationship between SB and FFM which was, however, not significant. This may be as a result of the small sample size. Interventions are needed to reduce SB, and replacing SB with high intensity activity has been reported to have positive health outcomes.⁵⁵

Consistent with other studies in sub-Saharan Africa, children spend more time in LPA than in MVPA.^{50,56,57} Evidence of whether LPA has beneficial effects on BC is scanty and more research on this is needed.^{50,55} The current study does not report any significant relationship between LPA and

BC. In line with our hypothesis, spending more time in MVPA was associated with reduced risk of obesity (FM and FM%). These findings are in accord with findings from numerous studies. Cross-sectional studies, alike with longitudinal studies, have revealed that high intensity PA is associated with reduced odds of obesity.^{26,28,32,58} Research conducted in children aged 6–8 years old from Finland reported that high levels of LPA and MVPA were associated with low levels of FM index; vigorous PA showed the highest magnitude of the association.²⁶ Although it is generally suggested that MVPA is associated with reduced fatness, it appears that VPA plays the bigger role since it is associated with larger energy expenditure.^{59,60} In the present study, high volumes of VPA were associated with reduced FM and FM%, and this finding is confirmed by a study performed by Dencker and colleagues.⁶¹

Although the beneficial effect of high MVPA on BC has been well documented, not all findings agree. Vanderloo and colleagues²⁴ could not show that high PA levels were associated with reduced body fatness. The reason no association was found could be because of the self-reporting of PA in the group of children, which may not have been accurate.^{62,63} In children from Tunisia, no significant association could be found between self-reported PA (PAQ-C) and BC, whereas objectively measured PA showed an inverse significant relationship with adiposity in the same study. The reason no association was found when self-reported PA was used was probably due to the reported poor level of agreement between PA measured by PAQ-C and accelerometer.⁶² Hence, it could conceivably be hypothesised that in populations where self-reports are not in agreement with objective measures, beneficial effects of PA will not be seen if self-reported PA is used. Self-reports and objective measures classify children's PA levels differently in different settings.^{56,62} This issue has grown in importance, considering the detrimental effect of both physical inactivity and excessive fatness if left untreated. The inconsistencies in some studies is also in part due to the use of BMI as a measure of adiposity. A study in 6–8-year-old children from the United Kingdom reported that higher levels of PA were associated with low FM determined by DDM but could not find any significant associations

when adiposity was reported as BMI.⁶⁴ Likewise, we did not pick up any significant relationship between PA and BMI z-scores. This implies that the use of BMI z-scores as a proxy for adiposity in this population masks the beneficial effect of PA on BC and should be used with caution. In vivo methods of BC assessment such as densitometry, DDM, bioelectrical impedance, conductance and dual-energy X-ray absorptiometry are proven to be more accurate with a higher clinical validity.^{21,65} As such, the use of high-quality measures, i.e. objective measures of PA and direct measures of BC are needed in South African children.

The current paper provides evidence that there is a significant difference in adiposity between children who meet the recommended MVPA levels and those that do not. Children who do not achieve recommended MVPA levels have significantly higher levels of adiposity. This highlights the beneficial effect of achieving the recommended PA levels on the prevalence of obesity. The current study reports that over 70% of children achieve recommended levels of PA. Although these levels are higher than those reported in other studies,⁶⁶⁻⁶⁸ almost a third of these children have excessive fatness. Intervention strategies are needed to increase high intensity PA. Emphasis should also be put on eating plan and other variables that might have an impact on childhood adiposity.¹¹ However, with a small sample size, caution must be applied when interpreting these findings. The study does, however, shed light on the role that PA plays on the development of childhood obesity.

Strengths and limitations: The strength of the current study is the use of high-quality methods to record PA levels. Furthermore, adiposity was determined by use of DDM, which is a highly accurate ‘reference’ method of measuring BC.⁶⁴ The limitation is the cross-sectional design, and a small sample size that is not a representative sample of the children in the province. Furthermore, the study only focused on predominately Setswana-speaking children. Future studies should include a larger sample size that is representative of the children from the North West Province, with all ethnicities represented. Longitudinal studies are also needed to assess the causal nature of any associations

identified. It is further also recommended that intervention studies gear towards the reduction of physical inactivity and obesity in children.

Conclusion

Participation in PA, more especially of high intensity, decreased the likelihood of obesity in this sample of predominantly Setswana-speaking children. Furthermore, not achieving the recommended average of at least 60 minutes per day of MVPA was associated with a higher adiposity. Advocacy for behavioural changes such as increasing high intensity PA is warranted.

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CHAPTER 6 Summaries, conclusions, limitations and recommendations

6.1 Introduction

The rising prevalence of non-communicable diseases (NCDs) is partly due to the increasing global burden of obesity (Sahoo *et al.*, 2015:187; WHO, 2020:208). The risk of obesity starts in utero and is perpetuated by environmental factors such as low physical activity (PA) levels. Increasing levels of PA may play an important role in the prevention of obesity (Bull *et al.*, 2020:1456; Choukem *et al.*, 2020:6-7). However, the decreasing levels of PA in children are a global burden in low-, middle- and high income countries (Aubert *et al.*, 2018:265). Numerous attempts have been made to study the association between PA and body composition (BC), but results are often conflicting due to a variety of methods used across studies when measuring both variables (Arhab *et al.*, 2019; Collings *et al.*, 2017:777; Ferrari *et al.*, 2015; Reisberg *et al.*, 2020:2261; Vanderloo *et al.*, 2020:9).

6.2 Summary

Children of sub-Saharan Africa (SSA) are faced with a double burden of malnutrition and overweight / obesity, which runs parallel with stunting (Choukem *et al.*, 2020:3; Melaku *et al.*, 2018:838; Monyeki *et al.*, 2014:117), and a high prevalence of overweight (10.6%) and obesity (2.5%) is reported in school-going children in SSA. Despite the fact that these rates are lower than those reported in high income nations, the risk linked with obesity makes them worrying. (Choukem *et al.*, 2020:6; Thorpe & Ferraro, 2004). In 2019, 6.2 million deaths globally were as a result of cardiovascular disease (CVD) in adults over the age of 30 years (Roth *et al.*, 2020:3020). Obesity is one of the drivers of CVD.

Birth weight, which is used as a proxy for the assessment of intrauterine growth, has been reported to be associated with childhood overweight and obesity (Liu *et al.*, 2019:11; Wilcox, 2001:1242). In addition to factors with an early onset, although this relationship can be directional, low levels

of PA and high levels of sedentary behaviour (SB) have been pinpointed as causes of overweight and obesity in childhood (Choukem *et al.*, 2020:6). It is recommended that children aged 5–17 years old achieve an average of 60 minutes of moderate-to-vigorous PA (MVPA) daily. These guidelines are associated with reduced risk of obesity and general good health (Bull *et al.*, 2020:1456; Choukem *et al.*, 2020:6). Unfortunately, scores of children around the world are not meeting the recommended guidelines (Aubert *et al.*, 2018:265; Draper *et al.*, 2018:407; Zhang *et al.*, 2020:73).

Research carried out to assess the effect of PA levels on overweight and obesity report contradicting findings, with studies reporting relationships ranging from strong to weak or none at all (Ben Jemaa *et al.*, 2018:236; Monyeki *et al.*, 2017:119; Vanderloo *et al.*, 2020:12). This contradiction is probably because of the different methods that are used to measure PA and BC (Biddle *et al.*, 2011:6; Janssen & LeBlanc, 2010:10). A range of techniques are available for the assessment of PA and BC from birth to adulthood. Selecting a method depends on several factors such as the outcome measure of interest, the knowledge of the research team, practicality and cost (Biddle *et al.*, 2011:6). In population studies, using self-reporting methods PA and body mass index (BMI) as a proxy for adiposity is convenient as these are simple and affordable (Ellis, 2001:1590; Loprinzi & Cardinal, 2011:16; Steene-Johannessen *et al.*, 2016:240). However, these methods are subject to limitations and often report inconclusive findings (Ben Jemaa *et al.*, 2018:236; Vanderloo *et al.*, 2020:12). BMI does not differentiate between fat mass (FM) and fat free mass (FFM) (Tewari *et al.*, 2018:4) and self-reporting of PA is subject to recall bias (Moore *et al.*, 2007:16). Robust clinical procedures should be employed in children to combat the rising rates of overweight and obesity. (Ben Jemaa *et al.*, 2018:236; Choukem *et al.*, 10:2020). Current knowledge about the association between objectively measured PA and BC is largely from high income countries, and data from low- to middle income countries is scanty.

Data from the Body Composition–Isotope Study (BC–IT) were used to prove / disprove the hypotheses outlined in chapter 1. The function of each chapter is further outlined as follows:

Chapter 1: This chapter served as an introduction, in which the background, problem statement, objectives and hypothesis were outlined. The references were written using the North-West University (NWU) referencing guidelines.

Chapter 2: Chapter 2 provided an overview of various concepts such as childhood PA levels and their impact on BC. The chapter also touched on the various methods of assessing PA and BC. Although numerous methods exist, only the common methods were reviewed. This information served as the basis for the following three articles, which were prepared according to the guidelines of the journals to which they were submitted or will be submitted for publication. The references were written using the NWU referencing guidelines.

Chapter 3: This chapter comprises Article 1, titled: *Association between birth weight and body composition as determined by deuterium dilution method in 6-8-year-old South African children: BC-IT study*. The article was submitted for publication to *PeerJ*.

Chapter 4: This chapter comprises Article 2, titled: *The level of agreement between physical activity levels determined by accelerometry (ActiGraph) and PAQ-C in 8-year-old children from a black South African population*. The article was formatted to the guidelines of *BMC Public Health*.

Chapter 5: This chapter comprises Article 3, titled: *Association between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC-IT study*. The article was prepared for submission to the *International Journal of Environmental Research and Public Health*.

Chapter 6: Chapter 6 provides general discussions, conclusions and limitations, and recommendations for the future research.

6.3 Conclusions

The conclusions in the thesis (Figure 6.1) are based on the hypotheses outlined in chapter 1:

Hypothesis 1: *Birth weight will be positively associated with adiposity, as determined by stable isotope, in 6–8-year-old children from a black South African population.*

The results indicated that 13% of the total participants were born with low birth weight (LBW). The prevalences of overweight and obesity were 21% and 17%, respectively, when using the deuterium dilution method (DDM) based on body fatness, whereas the prevalences of overweight and obesity were 13% and 5%, respectively, by BMI z-score. Significant sex differences ($p < 0.001$) were found in adiposity measures, with girls presenting with higher fat mass (FM) (8.22 ± 4.19 vs 6.13 ± 2.06) and fat mass percentage (FM%) (30.72 ± 7.52 vs 24.82 ± 5.15). Other variables showed no sex differences ($p > 0.05$).

When descriptive statistics were presented according to birth weight groups, children with normal birth weight (NBW) were significantly taller than the LBW group (122.97 ± 6.13 cm vs. 117.42 ± 10.58 cm; $p = 0.010$). Although not significant, children with LBW showed a trend of being smaller than children with NBW, with a strong trend of lower FM in the LBW group compared with the NBW group ($p = 0.057$).

Correlation coefficients for birth weight and BC measures, as well as partial correlation, controlled for age, sex and selected SES variables, were also reported. Before adjustments were made for confounding factors, birth weight showed a positive correlation with weight ($r = 0.23$, $p = 0.03$), height ($r = 0.33$, $p < 0.001$), FFM ($r = 0.27$, $p = 0.01$) and FM ($r = 0.23$, $p = 0.03$). After adjustment for age and sex, only height showed a significant correlation with birth weight. This correlation was no longer significant after adjustment for parent education level and household income.

Multiple regression analysis modelling reported in the crude model that birth weight positively associated with FFM ($\beta = 0.26$, $p = 0.013$) and FM ($\beta = 0.24$, $p = 0.02$) in girls and boys combined. When the group was separated according to sex, birth weight was positively associated with FFM ($\beta = 0.32$, $p = 0.02$) and showed a trend of positive association with FM ($\beta = 0.27$, $p = 0.054$) in girls. After adjustments were made for age, sex and household income in the total group, only FM remained positively associated with birth weight ($\beta = 0.23$, $p = 0.04$); however, sex ($p = 0.007$) showed a stronger association with FM in the same model. In the adjusted regression model for girls and boys separately, birth weight explained a very low percentage of variance in the BC variables. The hypothesis is therefore **partially accepted**.

Hypothesis 2: A poor level of agreement will exist between physical activity levels determined by accelerometry (ActiGraph) and the PAQ-C in 8-year-old children from a black South African population.

The prevalence of overweight in the total group was 27%. Girls (46%) showed significantly higher adiposity compared to boys (11%) ($p < 0.05$). PA was reported using the PAQ-C and ActiGraph. The average PA score using the PAQ-C was 2.54 with a SD of ± 0.56 , with no differences ($p > 0.05$) in PA levels between boys and girls. When ActiGraph was used to determine PA levels, it was revealed that more time was spent in SB (351.34 ± 49.32 minutes) and light PA (359.68 ± 43.12 minutes). On average, children spent 79.88 ± 23.18 minutes in MVPA per day. Boys reported higher levels of MVPA than girls ($p < 0.05$).

The Bland–Altman plots showed that the line of equality was widespread in the 95% confidence interval for the total group. The limits of agreement (LOA) for the mean differences were from 0.23 to 0.59 minutes of MVPA (insignificant) with SEE of 0.17, equivalent (R^2) to 3.8% for total sample of ActiGraph estimates of weekly minutes of MVPA. The Spearman correlation coefficient (r) for the total sample was 0.44, indicating a moderate relationship between the two methods. When analysis was done separately for boys and girls, the results showed the mean bias of 0.38 for boys and 0.29 for girls, and equivalent (R^2) of -0.9% for boys and -1.6% for girls. The insignificant LOA for boys ranged from 0.19 to 0.59, and 0.16 to 0.52 in girls, a narrow agreement interval. The dots were widely spread with some lying below the -1.96 SD. Overall, the results indicated that the PAQ-C underestimates PA levels in this sample population and there is poor level of agreement between PA level determined by the PAQ-C and the ActiGraph. The hypothesis is therefore **accepted**.

Hypothesis 3: Low PA levels will be significantly and negatively associated with adiposity, as determined by stable isotope, in 6–8-year-old children from a black South African population.

Girls were significantly more sedentary ($p < 0.05$) and had higher levels of FM compared to boys when using objective measures. No significant gender differences were reported when adiposity was reported using BMI z-scores ($p > 0.05$). Boys spent significantly more time in moderate- and vigorous PA than girls ($p < 0.05$). There was no significant gender difference in time spent in light PA ($p > 0.05$). Approximately 77% of the children achieved the recommended 60 minutes of MVPA per day.

The crude and adjusted regression models demonstrated the association between PA levels and BC variables. In the crude model, time spent in vigorous PA was associated with reduced FM ($\beta = -0.28$, $p = 0.01$) and FM% ($\beta = -0.35$, $p = 0.001$), and time spent in MVPA and moderate PA was significantly associated with lower FM and FM%. After adjustments were made, time spent in vigorous PA remained significantly associated with lower FM ($\beta = -0.25$, $p = 0.01$) in the age-adjusted model and with lower FM% ($\beta = -0.20$, $p = 0.04$) in the gender-adjusted model. Higher MVPA showed a borderline inverse association with FM in the sex- and school-quintile-adjusted model; however, the association was not significant ($p > 0.05$). When BMI z-score was used as a proxy for BC, no significant association with PA was found. The hypothesis is therefore **accepted**.

In conclusion, findings from this study indicate that birth weight and low levels of PA are associated with overweight and obesity in childhood (Figure 6.1). These findings were apparent when BC was assessed with the DDM, and use of BMI z-score as a proxy for BC is not associated with PA. Furthermore, there was no agreement between the levels of PA determined by accelerometer (ActiGraph) and by the PAQ-C – the PAQ-C underestimates PA levels in 6–8-year-old children in South Africa.

Care should be taken when selecting methods for assessing PA levels and BC. The PAQ-C underestimates PA levels in this child population and may not report the true levels of PA. Objective measurement of PA in this population is required. If not possible due to related costs, the PAQ-C can be adapted for use in South African children. Using BMI and BMI z-scores as measures of adiposity in children fails to show sex difference. Furthermore, when BMI z-score was used as a proxy for adiposity / BC, the impact of PA could not be seen, meaning the groups of children mostly affected will not be effectively identified and the benefits of PA in improving BC may be missed. Direct measures of BC are needed; however, using direct measures is not always feasible, especially in large studies. Therefore, using simpler methods to establish BC such as bioelectrical impedance (BIA) is recommended (Loprinzi & Cardina, 2011:16).

Although as much as over 70% of the children archive the recommended PA levels of an average of 60 minutes per day of MVPA, 30% of participants did not and these were also more likely to have high levels of adiposity. Urgent intervention strategies are needed, as high adiposity and obesity are associated with detrimental health effects and have the potential to be carried to

adulthood if not controlled (Choukem *et al.*, 2020:7). Birth weight is associated with high FM in childhood, and monitoring factors associated with HBW is recommended. These factors include control of maternal pre-pregnancy weight and avoiding excessive weight gain during pregnancy, as these are associated with high birth weight (Larqué *et al.*, 2019:478). PA of high intensity is associated with favourable BC, and increasing the intensity of PA is recommended.

Children spend much of their time in school; therefore, policies on the amount of time spent in PA in schools should be reviewed, with a view to increasing the duration and intensity of PA and decreasing time spent in SB. Intervention studies are needed to explore the types of activities that will increase the intensity of PA, are fun for children to participate in, promote compliance and are sustainable. Educating the children about the benefits of PA and normal BC is also important and teaching them about ways to improve their PA levels and avoid weight gain is also necessary, to ensure that children continue trying to improve their own wellbeing even after the interventions have stopped.

The findings of this research are novel because they are the first, to our knowledge, to use DDM to measure BC and compare it to PA levels determined by ActiGraph. Additionally, BC measured using DDM was also compared with birth weight, to explore the early onset of obesity in children. Evidence on the association between objective PA and direct BC are mainly from high income countries, with paucity in the South African context, especially in the years of school entry. This study therefore adds to the scanty pool of evidence and gives an indication of the state of PA and BC in children. Furthermore, the study provided benefits to the participants and the broader population. A benefit to participants was in objectively measuring PA levels and direct BC, as the children then knew their BC and their level of PA, helping increase their awareness and initiating improvement where necessary. The study further provides benefits to the broader population in that its findings can be used to guide future larger / longitudinal studies on methods of determining PA levels and BC in children.

The findings from the study will be disseminated to the broader public, policy makers and health professionals through publications in scientific journals and presentations at various conferences, both locally and internationally. At the time of writing, preliminary findings from the study had already been presented at conferences, both orally and through poster presentation. The study findings will also be shared with the participants.

6.4. Limitations and recommendations for future studies

This study had limitations that needed considering when interpreting the findings, and the following limitations and recommendations are highlighted for improvements in future studies:

- The small sample size was not representative of all children in the Potchefstroom area, North West Province or South Africa in its entirety. The costs and logistics associated with the use of DDM to determine BC limited the number of participants that could be included. One aim of the larger study was to validate simpler and affordable methods of measuring BC, and these findings are outlined and published elsewhere. Larger studies that will provide information representative of all children of South Africa are needed.
- There was some loss of data due to several children not providing their Road-to-Health cards (RtHC), and exclusion of PA data determined using accelerometer for some participants further impacted the small sample size. Some ActiGraph data were excluded because of not meeting the recommendations for inclusion for analysis, such as data acquired when the ActiGraph was not worn for enough days or hours in a day. In future, oversampling to cover for lost data should be considered.
- The study was cross-sectional in nature and hence could not capture changes over time; however, it did provide an indication of the state of PA and BC in children at the time of school entry. Longitudinal studies are needed to determine the impact of PA on BC and how the association changes over time.
- The study was limited to predominantly Setswana-speaking black children and did not include children of other ethnicities. Studies that include all ethnic groups are needed to give a complete picture.
- The study only looked at the association between birth weight and BC in childhood and did not explore other maternal factors such as pregnancy weight gain. Future studies should examine maternal factors, as they have been reported to affect BC in childhood.

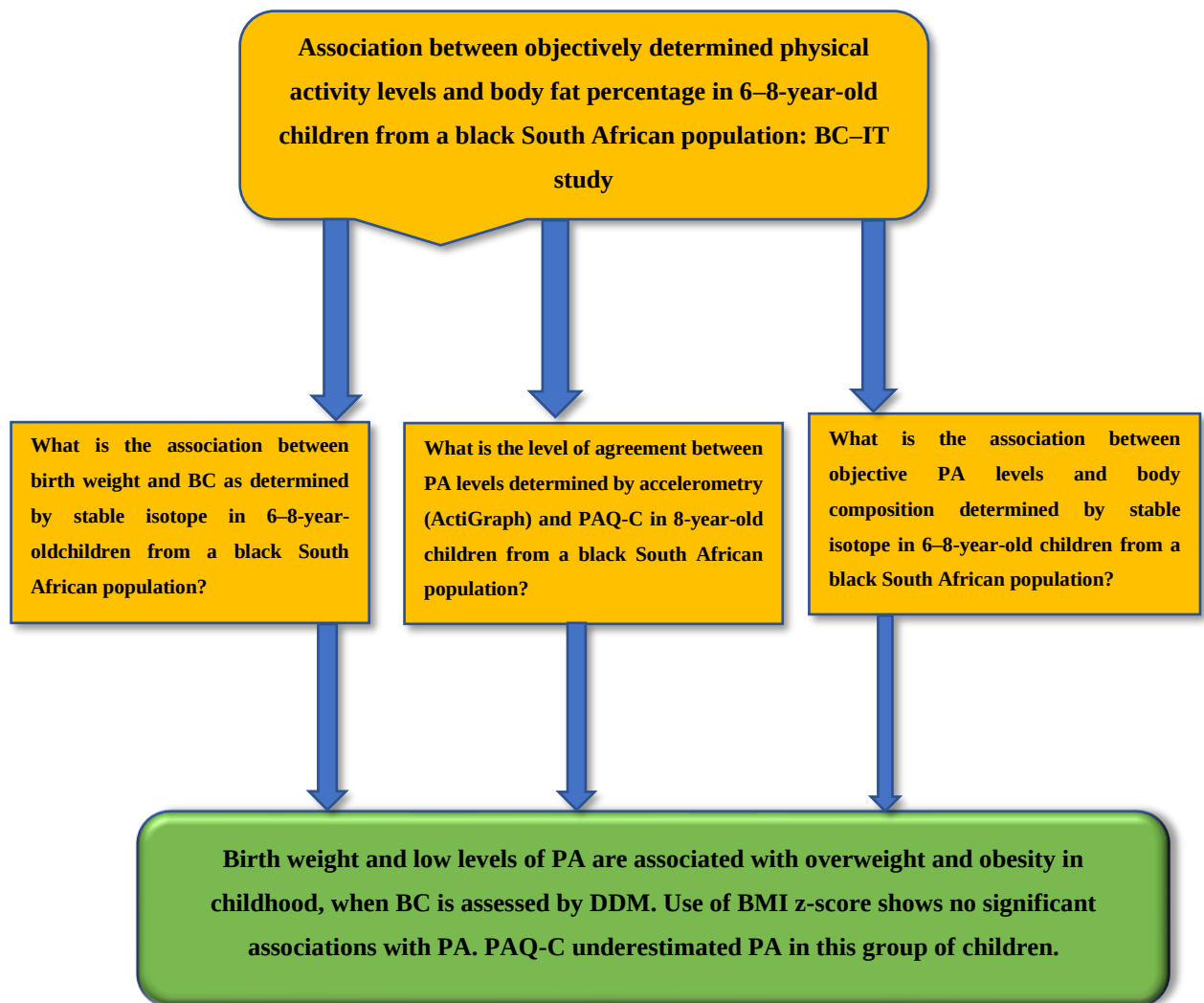


Figure 6.1: Illustration of the study summary.

BC = Body composition; BMI = body mass index; DDM = deuterium dilution method; PA = physical activity; PAQ-C = Physical Assessment Questionnaire for Older Children.

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APPENDIX A

BC-IT STUDY: Ethics documentation



Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: (018) 299-4900

Faks: (018) 299-4910

Web: <http://www.nwu.ac.za>

Research Ethics Regulatory Committee

Tel: +27 18 299 4849

Email: Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by Health Research Ethics Committee (HREC) on 22/02/2018, the North-West University Research Ethics Regulatory Committee (NWU-RERC) hereby approves your study as indicated below. This implies that the NWU-RERC grants its permission that provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Body composition by isotope techniques and objectively assessed physical activity in 6-8 year-old children: BC-IT study

Study Leader: Prof MA Monyeke

Ethics number:

N W U - 0 0 0 2 5 - 1 7 - A 1

Institution Study Number Year Status
Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Larger study

Commencement date: 19/04/2017

Risk:

2

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special conditions of the approval (if applicable):

- Please provide the HREC with permission letters from the school governing bodies and the principals of the schools still outstanding, for approval before recruitment can begin.

General conditions:

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

- The study leader (principal investigator) must report in the prescribed format to the NWU-RERC via HREC:
 - annually (or as otherwise requested) on the monitoring of the study, and upon completion of the study
 - without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.
- Annually a number of studies may be randomly selected for an external audit.
- The approval applies strictly to the proposal as stipulated in the application form. Should any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these amendments at the HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the study may be started.
- In the interest of ethical responsibility the NWU-RERC and HREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the study;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - withdraw or postpone approval if:
 - any unethical principles or practices of the study are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the HREC or that information has been false or misrepresented,
 - the required amendments, annual (or otherwise stipulated) report and reporting of adverse events or incidents was not done in a timely manner and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.
- HREC can be contacted for further information or any report templates via Ethics-HRECApply@nwu.ac.za or 018 299 1206.

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

Yours sincerely

Prof. Refilwe Phaswana-Mafuya

Chair NWU Research Ethics Regulatory Committee (RERC)

APPENDIX B:

District Education Department Research Approval



Education and Sport Development
Department of Education and Sport Development
Departement van Onderwys en Sport Ontwikkeling
Lefapha la Thuto le Tlhabololo ya Metshameko
NORTH WEST PROVINCE

8 O.R. Tambo Street, Potchefstroom
Private Bag X1256,
Potchefstroom 2520
Tel.: (018) 299-8216
Fax: (018) 294-8234
Enquiries: Mr. H. Motara
e-mail: hmotara@nwpg.gov.za

DR KENNETH KAUNDA DISTRICT
OFFICE OF THE DISTRICT DIRECTOR

Enquiries: Mphiliso Tyatya	Tel: (018) 299 8307/ e-mail : ptyatya@nwpg.gov.za	Contact 082 317 4656
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27 June 2017

To: **University of the North West**
Faculty of Health & Science
Physical Activity Sport & Recreation

Attention: **Prof. M. Monyeke (Principal Investigator)**
Prof. H. Moss (Director – PhASRec)

From: **Mr. H. Motara**
District Director

PERMISSION TO CONDUCT RESEARCH:

"Body Composition by Isotope Techniques and Objectively Assessed Physical Activity in 6 – 8 Year old Children: BC-IT Study."

We refer to your e-mailed correspondence regarding your request for permission to conduct research under the above-stated topic in primary schools around Dr. Kenneth Kaunda District.

Accordingly, permission is hereby granted for you to conduct the research as per your request, subject to the following provisions.

- That the onus to contact your target schools about your request and this subsequent letter of permission rests with your good self. Your Target Schools are: Dan Tlome, Pudulogo, Tshupane, Lesego, Potch and Keotshepile Primary Schools
- A parent-consent seeking process must be undertaken via the School Governing Bodies of affected schools, for learners identified to participate in the research.
- Considering that the research work will involve learners, it is requested that you ensure that the general functionality of affected schools is not compromised by the research project, or alternatively, a recovery plan be developed to recoup lost teaching time.
- Your research findings must be made available to the Department of Education & Sport Development in Dr. Kenneth Kaunda District upon request.
- The principle of confidentiality will be observed in its strictest terms in relation to information sourced from the research work conducted.

Thanking you

Mr. H. Motara
District Director
Dr. Kenneth Kaunda District



"Towards Excellence in Education and Sport Development"

APPENDIX C

Recruitment flier, letter to the schools and department of education, and informed and assent consent forms

RECRUITMENT FLYER



RECRUITMENT FLYER

North-West University

TITLE OF THE STUDY: Body composition by isotope techniques and objectively assessing physical activity in 6–8 year-old children: BC–IT study

Your child is been invited to participate in a study aimed at examining birth weight, body composition by BIA and body composition by stable isotope techniques at 6 to 8 years South African children: its relationship to physical activity by Prof. M.A. Monyeki at the North-

West University , (Potchefstroom Campus), Physical Activity, Recreation and Sport Science

Focus Area within the Faculty of Health Sciences. The study involves 4 hour visit on collection of saliva for stable Isotope, questionnaires (i.e. demographic, diet, physical activity) fitness tests,

objective measure of physical activity by wearing Actigraph, body composition by BIA at the Physical Activity, Sports and Recreation (PHASRec) laboratory.

No compensation will be given, except that incentives will be provided during data collection.

If your child is at least 6 to 8 years old, healthy and not on medical drugs, and would like more information about participating, contact:

Principal investigator professor M.A. Monyeki email: andries.monyeki@nwu.ac.za or tel: 018 2991790 or 018 299 1807

LETTERS TO THE SCHOOLS AND DEPARTMENT OF EDUCATION



Faculty of Health Sciences
Private bag X6001
Potchefstroom
2520
Tel: 018 2991790
Fax: 018 2991808
Email: andries.monyeki@nwu.ac.za
<http://www.nwu.ac.za>

Date:

The School Principal and SGB

REQUEST TO RECRUIT PARTICIPANTS FROM YOUR SCHOOL FOR A RESEARCH PROJECT

Dear Sir,

We the researcher from the Physical Activity, Sport and Recreation Focus Area (PHASRec) at the Faculty of Health Sciences, North-West University are hereby making a request to recruit participants from your school for a research project.

Background of the study:

Globally, obesity affects 500 million persons, and is predicted to increase to one billion people by 2030. Obesity occurs due to number of circumstances such as recovery from undernutrition or low birth weight and excessive fatness as well as physical inactivity. In this area especially in adolescents overweight and obesity prevalence is reported to be 13.7%. The observed percentages warrant studies to be done earlier in life to determine the actual causes for effective strategic intervention given the fact that overweight or obese child are likely to become obese adults. It should be noted that over

fatness is detrimental for health. The long term consequences of having excessive fatness in the body is linked with the development of non-communicable lifestyle diseases such as high blood pressure and high glucose levels. Many people also report very little regular physical activity, which contribute to a lack of performance at work. These combinations increase the burden of disease and result in low capital performance. The information we currently have to manage these health issues, have been determined by means of people self-reporting their physical activity and using proxy measurements for over-fatness. Since over-fatness at an early age is known to carry into adulthood, early interventions are now the focus of research. Therefore it is necessary to apply new technologies that have been developed recently to make accurate measurements. These new techniques include stable isotopes as well as objective measures such as, bioelectrical impedance (BIA) and accelerometers (Acti-Graph). The aims of this study is **to examine birth weight, body composition by BIA and body composition by stable isotope techniques in 6–8 years South African children (Potchefstroom areas), and its relationship to physical activity.**

The outcome of this project is to try to come up with the strategic interventions plans which are scientifically based on how to reduce childhood obesity.

We are requesting you a permission to do the project with learners in grades 1 to 3. The project is planned to take place according to the schedule to be given to you upon agreement to take part in the project. The project will have a minimal effect on the school time table. No blood will be drawn from the children, but a saliva sample will be collected with cotton wool.

As the investigator in the project I will be pleased to come to your school and give a briefing about the project.

A token of appreciation will also be given to a learner upon completion of the tests.

The measurements to be done are the following:

1. Demographic information (personal information and family; education of the parents, employment, type of dwelling, household amenities and marital status)
2. Anthropometric measurements (i.e. body height; weight; skinfolds thickness (triceps, subscapular and calf skinfolds), and waist.
3. Cardiovascular risk factor measurements by the use of Finometer
4. Physical activity questionnaire (PAQ-C) for only 8 years old learners
5. ActiGraph for physical activity
6. Health-related physical fitness (i.e. 20m shuttle run, standing broad jump, sit-and-reach, bent arm hang, sit-ups)
7. Dietary questionnaire, health habits and knowledge of food groups
8. Body image
9. Birth weight from the hospital/ clinic card
10. Use of stable isotope to measure percentage body fatness (learners will be subjected to the ingestion of deuterium water and thereafter a saliva will be collected to measure total body water and subsequently percentage body fat). The ingestion of deuterium water is safe as been proven by the International Atomic Energy Agency.
11. Use of bioelectrical impedance analysis (BIA) to measure percentage body fatness. With the bioelectrical impedance a child will be attached with the electrodes which will be connected to Bioimpedance Analyzer. Depending on the monitor, body composition measurements are provided in under 20 seconds.

Data to be collected on these children will be used solely for research purposes, and it will be treated as anonymous in any form of a report.

Your cooperation in this regard will be highly appreciated.

Yours sincerely,
Thank you,

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

Prof. Hanlie Moss
Director: Physical Activity, Sports and
Recreation, NWU-Potchefstroom

Faculty of Health Sciences
Private bag X6001
Potchefstroom
2520
Tel: 018 2991790
Fax: 018 2991808
Email: andries.monyeki@nwu.ac.za
<http://www.nwu.ac.za>

Date:

The District Operational Director

Department of Education
North West Province
Potchefstroom

**REQUEST TO RECRUIT PARTICIPANTS FROM SCHOOL FOR A RESEARCH PROJECT
WITHIN YOUR DISTRICT**

Dear Sir,

We the researcher from the Physical Activity, Sport and Recreation Focus Area (PHASRec) at the Faculty of Health Sciences, North-West University are hereby making a request to recruit participants from school for a research project within your district.

Background of the study:

Globally, obesity affects 500 million persons, and is predicted to increase to one billion people by 2030. Obesity occurs due to number of circumstances such as recovery from undernutrition or low birth weight and excessive fatness as well as physical inactivity. In this area especially in adolescents overweight and obesity prevalence is reported to be 13.7%. The observed percentages warrant studies to be done earlier in life to determine the actual causes for effective strategic intervention given the fact that overweight or obese child are likely to become obese adults. It should be noted that over fatness is detrimental for health. The long term consequences of having excessive fatness in the body is linked with the development of non-communicable lifestyle diseases such as high blood pressure and high glucose levels. Many people also report very little regular physical activity, which contribute to a lack of performance at work. These combinations increase the burden of disease and result in low capital performance. The information we currently have to manage these health issues, have been determined by means of people self-reporting their physical activity and using proxy measurements for over-fatness. Since over-fatness at an early age is known to carry into adulthood, early interventions are now the focus of research. Therefore it is necessary to apply new technologies that have been developed recently to make accurate measurements. These new techniques include stable isotopes as well as objective measures such as, bioelectrical impedance (BIA) and accelerometers (Acti-Graph). The aims of this study is **to examine birth weight, body composition by BIA and**

body composition by stable isotope techniques in 6-8 years South African children (Potchefstroom areas), and its relationship to physical activity.

The outcome of this project is to try to come up with the strategic interventions plans which are scientifically based on how to reduce childhood obesity.

We are requesting you a permission to do the project in learners in grades 1 to 3. The project is planned to take place according to the schedule to be given to you upon agreement to take part in the project. The project will have a minimal effect on the school time table.

No blood will be drawn from the children.

As the investigator in the project I will be pleased to come to your school and give a briefing about the project.

A token of appreciation will also be given to a learner upon completion of the tests.

The measurements to be done are the following:

- Demographic information (personal information and family; education of the parents, employment, type of dwelling, household amenities and marital status)
- Anthropometric measurements (i.e. body height; weight; skinfolds thickness (triceps, subscapular and calf skinfolds), and waist.
- Cardiovascular risk factor measurements by the use of Finometer 4. Physical activity questionnaire (PAQ-C) for only 8 years old learners
- ActiGraph for physical activity
- Health-related physical fitness (i.e. 20m shuttle run, standing broad jump, sit-and-reach, bent arm hang, sit-ups)
- Dietary questionnaire, health habits and knowledge of food groups
- Body image
- Birth weight from the hospital/ clinic card
- Use of stable isotope to measure percentage body fatness (learners will be subjected to the ingestion of deuterium water and thereafter a saliva will be collected to measure total body water and subsequently percentage body fat). The ingestion of deuterium water is safe as been proven by the International Atomic Energy Agency.
- Use of bioelectrical impedance analysis (BIA) to measure percentage body fatness. With the bioelectrical impedance a child will be attached with the electrodes which will be connected to Bioimpedance Analyzer. Depending on the monitor, body composition measurements are provided in under 20 seconds.

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

Month	Duration
April/May 2017	3 hours per child in a selected school
April/May 2017	3 hours per child in a selected school

Identified children will be transported to the North-West University laboratory for the measurements per grade on specific days. Transport will be paid by the University .

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

Data to be collected on these children will be used solely for research purposes, and it will be treated as anonymous in any form of a report.

Hoping for a positive response.

Yours sincerely,

Thank you,

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

Prof. Hanlie Moss
Director: Physical Activity, Sports and Recreation,

APPENDIX D

BC-IT STUDY ANTHROPOMETRIC MEASUREMENTS DATA FORM

Subject number (ID):	
----------------------	--

Name: Sport/Activity:.....

Surname first names

Date of Birth:							
----------------	--	--	--	--	--	--	--

Day Month Year Day Month Year

Box height: Gender:

M

F

			Trail 1	Trail 2	Mean/ Median
	1	Body mass			
	2	Stature			

	3a	Triceps : L			
(SF) (mm)	3b	Subscapular : L			

Girths	4a	Arm (relaxed) : L			
GR	4b	Arm (flexed & tensed) : L			
(cm)	4c	Waist (minimum)			

BIA	5	Impendence			
	4b	Resistance			
	4c	%Fat			
		Fat mass			

1. APPENDIX E

BC-IT STUDY: Actigraph Compliance Verification checklist

	Check if child wearing the ActiGraph correctly: begin the morning of first full day of monitoring Weekend will need to be self-reported								
ID	Act-Non	Child	Day 1	Day 2	Day 3	Day 4	Day 5	Day	Day
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

BC-IT STUDY: ActiGraph control form - SAF 2014005 Project

[illegible]

APPENDIX F

BC-IT: STABLE ISOTOPE DATA FORM

SAMPLE DATA SHEET FOR TBW ESTIMATION BY DEUTERIUM OXIDE DILUTION

Person performing the test: ___ Date: ___/___/___ Day Month Year

1. Participant

Name: _____ Code/ID: _____ Mass: . _____ kg

Stature: _____ cm BMI _____ kg/m²

Date of birth: ___/___/___ Age: ___ years Gender: M Healthy: YES NO |

Notes (health): _____

| F | |

2. Dose Dose bottle number: .

Dose weight: _____ g

Did the participant fast overnight? YES NO |

If not, how long was the fast before the dose? _____ Was the container opened just before the dosage? YES NO |

Was the dose consumed correctly? YES NO |

If not, what was the weight of the dose not consumed. _____ g The container was rinsed with 2 × 50 mL water. YES NO |

The same straw was used. YES NO |

Notes: _____

III. Specimen times

Time of baseline saliva sample: _____ Time dose was taken: .: _____ Pre-dose saliva samples: _____ Post-dose saliva samples:

2 hours: .: _____

APPENDIX G

BC-IT STUDY: BIA DATA FORM

Subject number (ID):	
----------------------	--

Name: Sport:

Surname first names

Date of Birth:							
----------------	--	--	--	--	--	--	--

Day Month Year Day Month Year

Box height: Gender:

M	F
☐	☐

Step 1 Assess hydration level of a child
(Note: specific gravity must be <1.025)

☐	☐
--------------------------	--------------------------

PASS Fail

Step 2 – Assess height

Step 3 – Bioelectrical Impedance Assessment
(Note: Approved Equipment:

☐

Tanita TBF – 300W (Standard Mode)

2. **Record mass at initial assessment**

	Kg
--	----

STABLE ASSEMENT PRINT –OUT HERE



Calculated Body Fat (Fat% on Tanita print-out)

APPENDIX H

3. BC-IT STUDY DEMOGRAPHIC INFORMATION, DIETARY QUESTIONNAIRE AND KNOWLEDGE ON FOOD

Country _____ Country code _____ Name of school _____ School Number _____
Name of _____ Date _____ (dd/mm/yyyy)
interviewer _____ Class/Grade _____
Questionnaire 4-
digit ID _____

4. Section A: Tell us about you and your family

We would like to learn more about you and your family. Please answer all questions. Remember that there are no right or wrong answers, and that every person is different. We will not share any of your personal information with anyone else, and all of your answers will remain private.

5. Participant number: _____ (Write your name in full, do not use abbreviations)

2. Are you a boy or a girl? (tick one) ☐ Boy ☐ Girl

3. How old are you? _____ Years

5. 5 ur house?

.
H
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i
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y
o

rooms

(Including rooms like the kitchen, lounge/sitting room, bedrooms and any outside structures; do not include bathrooms)

6. In your home, what is the main source of water? (tick one)

- ☐ Indoor tap water
- ☐ Outside tap water
- ☐ Other water source

7. What kind of toilet do you usually use at home?

- c Flush toilet inside the house
- c Flush toilet outside the house
- c Pit latrine/bucket

c Other type, Specify __

8. Tick all items that you have in your home now?

Household items	✓ if Yes
Electricity	
Television	
Radio	
Car/motorbike	
Bicycle	
Fridge/refrigerator	
Washing machine	
Telephone/Cell phone	
Computer	
Satellite dish/cable	
Microwave oven	

9. What is used for cooking in your home? **You can circle more than one.**

- c Gas
- c Electricity
- c Wood
- c Charcoal
- c Paraffin stove
- c Other, specify .

- b) Does your mother/guardian work? c Yes c No If yes, what type of work does she do? _____
- c) Does your father/guardian work? c Yes c No
If yes, what type of work does he do? _____

6. Section B. Healthy habits

- d) When you eat too much fat you can become fat
1. Agree
 2. Neutral

- e) 3. Disagree
Fruits are a healthy snack
2. Agree
3. Neutral
4. Disagree
- f) I do not have to worry about the kind of foods I eat because I am still young
1. Agree
2. Neutral
3. Disagree
- g) I do not like sport/physical activity/conducting chores around the house
a) Agree
b) Neutral
c) Disagree
- h) It is important to do sport/exercise everyday in order to keep your body healthy
3 Agree
4 Neutral
5 Disagree

7. Lifestyle and Health

5. In the last 7 days, did you eat in front of the television/computer?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

6. In the last 7 days did you eat your main meal with your family?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

7. In the past 7 days did you eat breakfast before school?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

If no, is it difficult for you to eat breakfast at home because:

8.1 the people at home do not eat breakfast?

Yes		No	
-----	--	----	--

8.2 there is no food in the house to eat for breakfast?

Yes		No	
-----	--	----	--

8. In the past 7 days did you bring a lunchbox to school?

Yes		No		Sometimes (2-3 times per week)	Not allowed lunchboxes at school
-----	--	----	--	--------------------------------	----------------------------------

10. Is it difficult for you to take a lunchbox to school because other children will want your food?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

11. Is it difficult for you to take a lunchbox to school because there is nothing at home to put in your lunchbox?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

12. Is it difficult for you to take a lunchbox to school because no one at home can help you to make a lunchbox?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

4.5 Do you share or exchange what you have in your lunchbox with friends?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

e) How many days in the last 7 days do you bring money to school?

Every day (5 days)		2-3 times/wk	Never
--------------------	--	--------------	-------

6. In the past 7 days did you buy anything from the tuck shop/school canteen/vendor?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

6.4 Do you participate in the school feeding scheme?/Do you receive lunch (a meal) from your school every day?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

7. In the past 7 days did you eat fruit?

Yes		No	
-----	--	----	--

7.1 If you do eat fruit, why do you eat them?

7.2 because you like the taste?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

7.3 because people at home eat fruit

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

7.4 because you are told to eat them

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

1. In the past 7 days did you eat vegetables?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

1.1 If you do eat vegetables, why do you eat them?

1.2 Because you like the taste

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

1.3 because people at home eat vegetables

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

1.4 because you are told to eat them

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

9. When you feel like a snack, what do you eat?

9.1 Chips

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

9.2 Sweets/Candy

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

9.3 Fruit

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

9.4 Sandwich or cereal

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

9.5 Chocolate

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

Other
Yes No Sometimes (2-3 times per week)

- I. In the past 7 days, did you consume sweetened beverages (cold drinks, fizzy drinks, squash, soda, sweet drink)?

Yes(everyday)		No		Sometimes (2-3 times per week)	
---------------	--	----	--	--------------------------------	--

10.1 In the past 7 days have you eaten fast foods (e.g (hot) chips, French fries, burger, hotdog, pizza, shawarma, ikota/Gatsby/rolex)?

Yes		No		Sometimes (2-3 times per week)	
-----	--	----	--	--------------------------------	--

- II. In the last 7 days have you ever gone to bed hungry because there was no food?
How many times

Never		1-2 days		>3 days	
-------	--	----------	--	---------	--

8. Knowledge

1. Do you have school lessons where you talk about healthy eating?

Yes		No	
-----	--	----	--

2. Is eating fruit and vegetables every day good for our bodies to fight against illnesses like colds and flu

Yes		No		I don't know	
-----	--	----	--	--------------	--

a Eating a lot of sugar, sweets and sweet food...

2.1.1 Is good for health

Yes		No		I don't know	
-----	--	----	--	--------------	--

2.1.2 Can make you fat

Yes		No		I don't know	
-----	--	----	--	--------------	--

2.1.3 Is bad for your teeth

Yes		No		I don't know	
-----	--	----	--	--------------	--

3. Look at the following pictures and fill in the LETTER (A, B, C, D, E, F or G) of the food group you think best fits the answer to the questions below (You can choose a group more than once)



- a** Choose the food group that you should eat the **MOST** of every day
- b** Choose the food group that you should eat the **LEAST** of every day
- c** Choose the food group that gives your body the best **ENERGY**
- d** Choose the food group that your **BODY** uses to **BUILD MUSCLES**
- e** Choose the food group that best **PROTECTS THE BODY AGAINST ILLNESSES**

APPENDIX I

BC-IT: PAQ-C DATA FORM

Participant nr: .

9. Physical Activity

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

Remember:

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

1. Physical activity in your spare time outside the school hours: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	1 No	2 1-2	3 3-4	4 5-6	5 7 times or more
Skipping/clapping & jumping	☐	☐	☐	☐	☐
Roller blading/roller skating/skate boarding.....	☐	☐	☐	☐	☐
Tag/on-on/tip/dodge ball	☐	☐	☐	☐	☐
Walking for exercise/hiking	☐	☐	☐	☐	☐
Bicycling	☐	☐	☐	☐	☐
Jogging or running/cross country.....	☐	☐	☐	☐	☐
Aerobics	☐	☐	☐	☐	☐
Swimming	☐	☐	☐	☐	☐
Baseball/rounders	☐	☐	☐	☐	☐
Dance	☐	☐	☐	☐	☐
Rugby	☐	☐	☐	☐	☐
Badminton/tennis/squash	☐	☐	☐	☐	☐
Soccer/football	☐	☐	☐	☐	☐
Volleyball	☐	☐	☐	☐	☐
Hockey	☐	☐	☐	☐	☐

Basketball/netball
 Ice skating..... Cricket
 Running with
 wheels/tyres.....
 Judo/karate/boxing
 Gymnastics.....
 Trampoline.....

Other:

.....

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE

Hardly ever ☐

Sometimes ☐

Quite often ☐

Always ☐

4 In the last 7 days, what did you do most of the time at break? (Check one only.) Sat down (talking, reading, doing schoolwork).....

Stood around or walked around ☐

Ran or played a little bit ☐ Ran around and played quite a bit

..... .. ☐

Ran and played hard most of the time ☐

5 In the last 7 days, what did you normally do at lunch (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)..... Stood around or walked around ☐

..... .. ☐

Ran or played a little bit ☐

Ran around and played quite a bit ☐

Ran and played hard most of the time

6 In the last 7 days, on how many days right after school, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ☐

1 time last week ☐

2 or 3 times last week ☐

1 times last week ☐

2 or more times last week ☐

6. In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active? (Check one only.)

None ☐

8. time last week ☐

..... ☐

9. or 3 times last week ☐

..... ☐

4 or 5 last week 6

or 7 times last week

7. On the last weekend, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ☐

12. time ☐

☐

☐

☐

.....

..

13. — 3 times

..... ..

4 — 5 times

6 or more times

1. Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the one answer that describes you.

a All or most of my free time was spent doing things that did not require much physical effort

..... ..

b I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ☐

c I often (3 — 4 times last week) did physical things in my free time ☐

d I quite often (5 — 6 times last week) did physical things in my free time ☐ E.

I very often (7 or more times last week) did physical things in my free time

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

None Little bit Medium Often Very often

Monday			☐		
Tuesday	☐	☐		☐	☐
Wednesday	☐	☐	☐	☐	☐
Thursday	☐	☐	☐	☐	☐
Friday	☐	☐	☐	☐	☐
Saturday	☐	☐	☐	☐	☐
Sunday	☐	☐	☐	☐	☐

3. Were you sick last week, or did anything prevent you from doing your normal

(Check one.)

physical activities?
h
Yes
○
No ○

If Yes, what prevented you? _

4. How do you travel to and from school? (Check only one) By bus, car, van, train/tram

I walk Both
.....

1. What time do you go to bed on a school night?

.....

2. What time do you go to bed on a non-school night (on a weekend or on holiday)?

.....

3. What time do you wake up on a school morning?

.....

4. What time do you wake up on a non-school morning (on a weekend or on holiday)?

.....

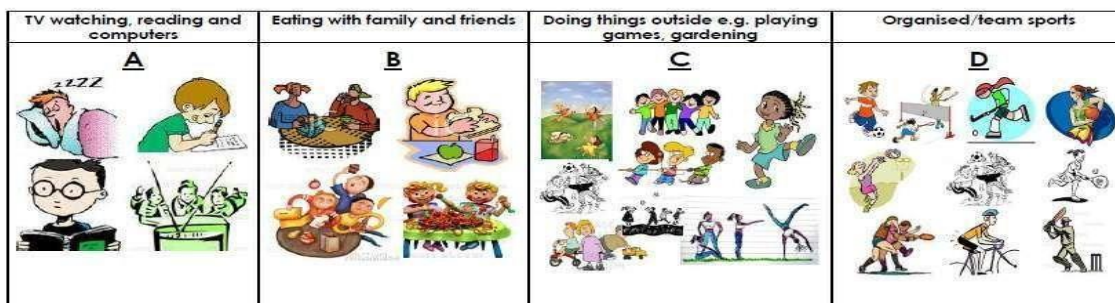
5. How often do you spend time watching TV, playing on the computer, play station, phone, video games? (check only one)

Everyday..... Most

days.....

Only on weekends.....

a) Look at the pictures provided below, and fill in the LETTER (A, B, C or D) of the activities which BEST answers each question



17.1 Choose the activities that YOU like the most

17.2 Choose the activities that you think your friend likes the most

SETSWANA VERSION

BC-IT: FOROMO YA TSHEDIMOSETSO YA DIPOTSO TSA TIRISO YA BOITEKANELO JWA MMELE

Nomoro ya Motsayakarolo: __

10. Tiriso ya mmele

Re leka go fitlhela go lepalepana ga tiriso ya mmele ga gago mo malatsing a 7 a bofelo (mo mafelong a beke). Se se akaretsa motshameko kgotsa gobintsha go go dirang gore o fufule kgotsa go dira maoto a gago a ikutle a lapile, kgotsa metshameko e e dirang gore o fegelwe ka thata, jaaka go tlola, go taboga, go palama, le tse dingwe.

Gopola:

- 3 Ga gona dikarabo tse di siameng le tse di phoso --- se ga se tthatlhobo.
- 4 Tsweetswee araba dipotso tsotlhe ka botshepegi le ka botswerere jo bo kgonagalang – Se se botlhokwa thata.

1. Tiriso ya mmele mo nakong ya gago ya tlaleletso kwantle ga diura tsa sekolo: A na o dirile nngwe ya ditiro tse di latelang mo malatsing a 7 a bofelo (mafelong a beke)? Fa ele eya, nako e e kana kang? (Tshwaya fela sediko se le sengwe ka tsela.)

	1 No	2 1-2	3 3-4	4 5-6	5
Ga 7 kgotsa gofeta					
Gotlola/go opa diatla & matlolo	☐	☐	☐	☐	☐
sekeiti/sekeiti boroto.....	☐	☐	☐	☐	☐
Goamana/mo-mo/ntlha/bolo tla	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Gotsamaya ka ikatisa/go haeka	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Go gata baesekele	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Taboga ka iketlo kgotsa Gosiana/lebelo la kgabaganyetso naga.....	☐	☐	☐	☐	☐
Aerobikisi	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Gothuma	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Beisibolo/motshako bolodikologa	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Motanso	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
Bolo ya maoto	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐

Batemintone/thenese/sekwashe

.....

Kgwele ya dinao

.....

Bolotlowa

Hoki

Baseketebolo/bolotloa

Motshameko wa tsamao mo

kgapetleng..... Kerikete

.....

Gotaboga ka maotwana/thaere..... Juto/karate/mabole

.....

Jiminasetiki.....

Terampolini.....

Nngwe:

.....

.....

2. Mo malatsing a 7 a bofelo, ka nako ya fa o tswelletse ka tlelase ya thuto ya Boitekanelo (PE), gantsi ke ga kae o ne ole matlhagatlhaga (o tshameka thata, o taboga, o tlola, o latlhela)? (lebelela ele nngwe fela.)

3.

Ga ke dire PE ☐

Bonnye jobo a saengkae ☐

..... ☐

Motlha mongwe ☐

.. ☐

Gantsi ga ba bolo ☐

..... ☐

Ka metlha yotlhe ☐

..... ☐

7 Mo malatsing a bofelo a 7, ke eng se o se dirileng bogolo ka nako ya dijo? (Lebelela ele nngwe fela)

O dutse fa fatshe (o bua, o bala, o dira tiro ya sekolo) ☐

..... ☐

Emeletse ka fa kgotsa o tsamaela ka fa ☐

..... ☐

O tabogile kgotsa tshamekile go se kae ☐

..... ☐

O tabogile ka fa mme o tshamekile sentle thatanyana ☐

..... ☐

O tabogile o tshamekile ka thata bogolo ba nako ☐

..... ☐

4. Mo malatsing a bofelo a 7, ke eng se ka gale o neng o se dira ka dijotshegare (kwa ntle ga go ja dijotshegare)? Lebelela ele nngwe fela.)

O dutse fa fatshe (bua, o buisa, o dira tiro ya sekolo)..... O emeletse ka foo or o tsamaile ka foo

☐
☐

.....
O tabogile kgotsa o tshamekile go se kae

☐

.....
O tabogile ka foo mme o tshamekile go se kae

☐

.....
O tabogile mme o tshamekile bogolo ba nako e ntsi ka thata ..

☐

- 8 Mo malatsing a 7 a bofelo, ke malatsi a le makae, morago fela ga sekolo, a o kileng wa dira motshameko, motanso, kgotsa tshameko ya metshameko mo o neng o le matlhagatlhaga? (Lebelela ele nngwe fela.)

Ga di yo

☐

3 Ka nako ya beke ya bofelo.....

☐

4 Kgotsa ga 3 ka beke ya bofelo..... 3 Ka nako ya beke ya bofelo.....

☐

4 kgotsa go feta nako ya beke ya bofelo.....

☐

5. Mo malatsing a 7 a bofelo, ke maitseboa a le makae a o kileng wa dira motshameko, motanso, kgotsa tshameko ya metshamo e o neng o le matlhagatlhaga? (Lebelela e le nngwe fela.)

Ga di yo

☐

10. Nakong ya Beke ya bofelo

.....

☐

11. Kgotsa ga 3 ka nako ya beke ya bofelo

4 kgotsa ga 5 ka beke ya bofelo

☐

..... 6 kgotsa ga 7 ka

☐

nako beke ya bofelo.....

☐

6. Mo mafelong a beke ya bofelo, ke nako e le kae o dira motshameko, motanso, kgotsa tshameko ya metshameko mo o neng o le matlhagatlhaga? (Lebelela ele nngwe fela.)

Ga di yo

☐

14. Ka nako.....

.....

☐

15. — Ga 3

.....ga

☐

4 — 5

☐

6 kgotsa go feta dinako tse

☐

5. Ke efe ya tse di latelang e e go tthalosang ntle bogolo mo

malatsing a 7 a bofelo? Buisa dipolelo dile tlhano pele o tsaya tshwetso ka ga karabo ele nngwe e e go tlhalosang.

a Bogolo kgotsa nako yotlhe ya gololosego e dirisitswe go dirwa dilo tse di neng di sa tlhoke

maiteko a le kalo a

boitekanelo..... ..



41



- b Ke motlhamongwes (ga 1 — 2 beke ya bofelo) ke dirile dilo tsa boitekanelo mo nakong ya ka ya gololosego(sekai. Tshamekile metshameko, ke ile go taboga, gothuma, bike riding, did aerobics)
- c Gantsi ke (ga 3 — 4 beke ya bofelo) ke dirile dilo tsa boitekanelo mo nakong ya ka ya gololosego
- d Go le gantsi ke (ga 5 — 6 beke ya bofelo) ke dirile dilo tsa boitekanelo mo nakong ya ka ya golololosego
- e. Gantsi thata ke (ga 7 kgotsa fo feta dinako tsa beke ya bofelo) ke dirile dilo tsa boitekanelo mo nakong ya ka ya gololosego

6. Supa gore o dirile tiriso ya boitekanelo jwa mmele gaka (jaaka go tshameka motshameko, metshameko, go dira motanso, kgotsa tse dingwe tsa tiriso ya boitekanelo jwa mmele) ka letsatsi lengwe le lengwe beke ya bofelo.

Mosupolgo Bonnye thata

Ga di yo Bonnye nyana

Magareng Gantsi

Gantsi thata

.....	☐				
Labobedi	☐	☐	☐	☐	☐
Laboraro	☐	☐	☐	☐	☐
Labone			☐	☐	☐
Labotlhano	☐	☐		☐	☐
.....	☐	☐	☐	☐	☐
Lamatlhatso	☐	☐	☐		☐

.....



Latshipi

7. A o ne o lwala beke ya bofelo, kgotsa go na le sengwe se se go kgoreleditseng go dira ditiro tsa boitekanelo jwa mmele tsa ka gale? (Lebelela ele nngwe)

Ee



Nnyaa



Fa ele ee, ke eng se se go kgoreleditseng? __

8. O tsamaya jang go ya le go boa go tswa kwa sekolong? (Lebelela ele nngwe fela)

Ka bese, koloi, vene, terena/terempe Ke a tsamaya 



Ka bobedi



6. O robala nako mang ka bosigo jwa sekolo?

7. O robala nako mang ka bosigo bo eseng jwa sekolo (ka mafelo a beke kgotsa ka malatsi a boikhutso)?

8. O tsoga nako mang ka moso wa sekolo?

9. O tsoga nako mang ka moso o eseng wa sekolo (ka mafelo a beke kgotsa ka malatsi a boikhutso)?

10. Ke gaka e o dirisa nako go lebelela TV, o tshameka mo khompiutareng, segatisa metshameko ya natefo ,founo, metshameko ya segatisa setshwantsho? (Lebelela ele nngwe fela)

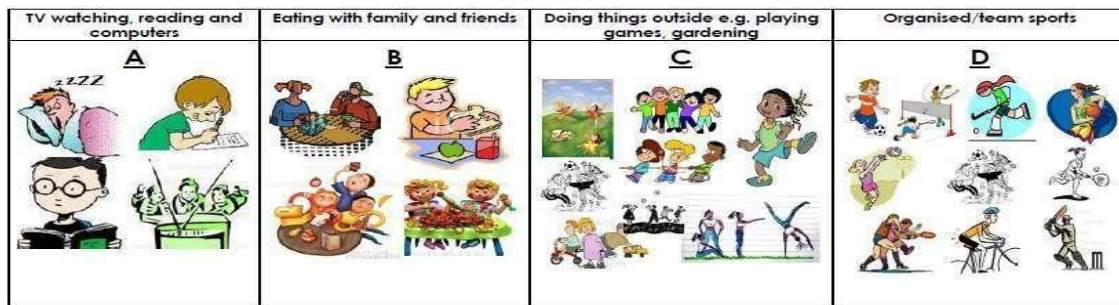
Letsatsi lengwe le lengwe.....

Bogolo jwa

malatsi..... Ka

mafelo a beke fela.....

- a) Lebelela ditshwantsho tse di neetsweng ka fa tlase, mme o tlatse TLHAKA (A, B, C kgotsa D) ya ditiro tse di arabang potso nngwe le nngwe molemo bogolo.



17.1 Tlhopha ditiro tse WENA di ratang bogolo

17.2 Tlhopha ditiro tse TSALA ya gago e di ratang bogolo

PHETOLELO FA TLASE:

- A. Go lebelela TV, Go buisa le Khopiutara
- B. Go ja le ba losika le ditsala

- C. Go dira dilo kwantle sekai: Tshameko ya metshameko, golema masimo
- D. Go ithulaganya/Ditlhopha tsa metshameko

Appendix J

INFORMED CONSENT LETTER / LEKWALO LA GO DUMELA GOITSISIWE



11. PAMPITSHANA YA TSHEDIMOSETSO YA MOTSAKAROLO LE FOROMO YA BANA YA TUMELO



**THAETLELE YA PATLISISO YA POROJEKE: POPO YA MMELE KA MOKGWA WA
SETEGENIKI SA ELEMENTE YA DIKHEMIKALE LE GO SEKA-SEKA KA
MAITLHOMO A TIRISO YA MMELE MO BANENG BA DINGWAGA DI KA NNANG
BOGOLO BA 6-8: DITHUTO BC-IT**

DINOMORO PAPISO:

TLHOGO YA BOTLHOTLHOMISI: Mop. M.A. Monyeki

ATERESE: Tiriso ya mmele, Motshameko le Boitapoloso (PhASRec), Legopo la Disaense le Boitekanelo,

**Yunibesithi ya Bokone Bophirima, Poso ya sephiri X6001, Potchefstroom, 2520 NOMORO
YA KOPANO: 018 2991790**

O lalediwa go tsayakarolo mo porojekeng ya patlisiso e e batlang go tlhotlhomisa popego ya mmele ka mokgwa wa setegeniki wa dielemente tsa dikhemikale le ka go seka-seka maitlhommo a tiriso ya mmele mo baneng ba bogolo bo ka nnang 6 go ya go 8ka dingwaga. Tsweetswee tsaya nako go bala tshedimosetso e e filweng fano, e e tla tlhalosang ngwana. Tsweetswee botsa mmatlisisi dipotso dingwe le dingwe ka ga karolo nngwe le nngwe ya porojeke en aka seo o sa setlhaloganyeng ka botlalo. Go botlhokwa thata gore o kgotsofale ka botlalo le gore o tlhaloganya sentle se patlisiso e e se kenyeletsang le gore o ka amega jang. Ebile, go tsayakarolo ga gago ke ka **boithaopi ka gotlhe** mme o letleletswe go ikgolola mo go tseyengkarolo. Fa o re nnyaa, se se ka se go ame ka boitatolo le ka tsela nngwe le nngwe. Gape o gololesegile go ikgogela kwa morago mo thutong ka ntlha nngwe le nngwe, le fa ele gore o dumela go tsayakarolo.

Thuto e letleletswe ke ba **Komiti ya Boitshwaro ya Patlisiso ya Boitekanelo ya Legoro la Disaense tsa Boitekanelo tsa Yunibesiti ya Bokone-Bophirima(YBB.....)** mme e tla tsamaisiwa go ya ka melao ya motheo le taolo ya Polelo ya Boditshabatshaba ya ga Helsinki le melao ya motheo ya Khansele ya Boitshwaro ya Patlisiso ya Bosetshaba ya Boitekanelo. Go ka tlhokagala gore maloko a komiti ya boitshwaro ya patlisiso kgotsa balaodi ba ba maleba go tlhatlhoba bosupi jwa patlisiso.

12. Thuto e ya Patlisiso ke ka ga eng?

- *Thuto e e tla tsamaisiwa mo dikolong tsa diporaemari mogare ga motse selegae wa masepale wa Tlokwe mme e tla akaretsa bana ba ba kannang 400 ba le dingwaga di le magareng ga 6 go ya dile 8. Tshedimosetso e e kgobokantsweng mabapi le setlhopha se se riling, bokete jwa matsalo, tiriso ya mmele, le kokoannyo ya tiriso ya tsamaiso ya madi. Popego ya mmele ka go dirisa selekanyetsi sa boleele sa anteropometiriki, bokete jwa mmele, menoganoletlalo, le go dikologa go tla lekanyetswa. Bana ba tla neelwa selekanyetso sa elemente ya khemikhale gabedi sa metsi a a kopantsweng mme morago ga moo mathe a tla kgobokangwa go ikaelela mafura a mmele letshobokano ya mesifa ka mokgwa wa elemente ya khemikhale e e tlhomameng. Popego ya mmele e ka itlhome gape ka mokgwa wa seka-seka sekgoreletsi sa motlakase ka maitlhommo a papiso. Kokoano ya tshedimosetsoe tla dirwa ke babatlisisi ba boitekanelo ba ba katisitsweng mo Disaenseng tsa Tsikinyego ya Botho.*

➤ *Maitlhomo a patlisiso e ke ana:*

- i. *ikaelela boima jwa matsalo (kakanyo e fetileng), popego ya mmele ka BIA le popego ya mmele kaelemente ya khemikhale ya setegeniki, le kamano ya tiriso ya mmele mo dingwageng dile 6 go ya go dile 8 mo baneng ba Aforikaborwa.*
- ii. *Tlhotlhomisa tsweletso ya tlhabololo ya nako e erileng ya popego ya mmeleka bokete jwa mmele (kakanyo e fetileng), le tiriso ya mmele mo baneng ba Aforikaborwa.*
- iii. *Itlhomele ditokololo magareng ga antepometiriki, popego ya mmele, tepatepanyo ya tiriso ya mmele, le boitekanelo jwa taolo ya dikhemikhake ya mmele mo boketeng jo bo tlwaelegile, bana ba digompo leba banonneng go dirisiwa mokgwa wa elemente ya khemikhale ya setegeniki le go tlhagisa tebelelo pele e e ntshwafaditsweng ya matshosetsi a boitekanelo a bokamoso.*

13. Goreng o laleditswe go tsayakarolo?

- *O laleditswe go tsayakarolo ka gone o mo magareng a dingwaga dile 6 go ya go dile 8 mo sekolong sa poraemare go tswa mo tikologong e e tlhophilweng go baithaopi. O dumelane gape le mokgwa wa go tsenyeletsa: dingwaga dile 6 go ya go dile 8 tsa itekanelo ba tsena kwa diklong tsa poraemare mogare ga Masepale wa Selegae wa Tlokwe. O tla tswalelwa kwantle fa fela: ga wa itekanela mme, ole ka fat lase ga dingwaga dile 6 le go feta dile 8 o tsena kwa dikolong tsa poraemare mogare Masepale wa Selegae wa Tlokwe. O sa kgone go diragatsa nngwe ya ditiro tsa mmele tse di ikamanyang le boitekanelo.*

14. Ke eng se e tla nnang maikarabelo a gago?

- *O tla be o lebeleletse go araba palo ya dipotso (tshedimosetso ya loago lo lo mabapi, go tsenyeletswa tshedimosetso ya gago le ba lelapa – eleng thuto ya batsadi, tiro, mofuta wa bonno, dilwana tsa legae le maemo a lenyalo) setshwano sa botho, tiriso ya mmele,*

ditlwaelo tsa itekanelo, boitekanelo le mokgwa wa go tshela, kitso ya go tlhopha dijo, di tla kgobokanngwa ka mokgwa wa dipotso tsa IAEA. Dipotso di tla tsaya metsotso ele 15 go e fetsa ka fa tlase ga tebelelo ya barutabana, mme e na le dipotso dile 51; Tsayakarolo mo tekong ya legala ya EUROFIT e e tla tsayang metsotso ele 10, le selekanyetsi sa elemente ya dikhemikhale ya setegeniki ya boleele, bokete jwa mmele, bokgolokwe jwa letheka, bogare jwa letsogo, mesifamegolo ya fa morago mogodimo ga letsogo, mesifamegolo ya letsogo mogodimo kwa pele, menagano ya legetla le go

feteletsa go go tla tsayang metsotso ele 10; mme a neelana ka mathe go elemente ya khemikhale ya setegeniki e e tsepameng (ka mefuta e e farologaneng ya dinako fa ba goroga le morago ga diura dile 2 tsa nno ya mofuta wa haedrojini) le go dira tsheka- tsheko ya popego ya mmele ka sekeleki sa mokgwa wa setegeniki go lekanyetsa motlakase go emisa tsamao ya motlakase metsotso e e ka nnang ele 4-5. Lwa bofelo, sediriswa sa sepotlakisi se a tlhongwa go lebelela ditlwaello tsa tiriso ya mmele le go bewa mo lethekeg la gago ka lebanta diura di le 24 malatsi ale supa.

15. A go sengwe se o tla se boelwang ka go tsayakarolo mo patlisisong e?

- *Dipoelo tse di lebaneng le wena jaaka motsayakarolo e tla nna go lemoga botlhokwa jwa go tshola popego ya mmele o o itekanetseng le dipoelo tse di gokaganang le go tsayakarolo ka gale mo tirisong ya mmele. E tla oketsa le goitse ga bana ga go tsayakarolo ga ka gale mo tirisong ya mmele mo go fokotseng bokima le go tshwarelela bophelo jo bo itekanetseng. O tla kgona go bona katamelo go dipholong tsa tsona. Tshedimosetso e e kokoantsweng e tla dirisiwa gape go tlhalosetsa barutabana ka molomo gore bophelo jwa bone jwa boitekanelo bo ka tokafala jang.*
- *Dipoelo tse di sa lebanang e tla nna phuthologo ya kitso ya botswerere e e leng teng mo dithutong tsa Disaense tsa Tsamaiso ya Botho le dithuto tse di itsalanyang tse di ka fetisetswang kwa baaging ka bophara. Kitso e e kanna ya dirisiwa go tseweletsa dithuto tse pele go bueng ka ga itriso ya diphitlhelelo tsa rona.*

16. A na go nale kotsi e eleng teng go tsaya karolo mo patlisisong e?

- *Ga gona kotsi e e itsagalang e e gokaganang le go tsayakarolo mo porojekeng e ya patlisiso, fela dikotsi tse di solofetsweng mo thutong e di dinnye. Se e kanna ka lebaka la*

gore o kanna wa lapa ka nako ya teko ya tirisommele e nonofileng ya metsotso ele +-10. Go fokotsa golapa babatlisisi bat la ikaelela go godisa dipoelo tsa bokgoni tse di nang le gone gore di kanna le seabe se se matla se se boleng mo baneng e ka nna e e lebaneng kgotsa e sa lebana. Ga gona kotsi go dirisa mokgwa wa khemikhale wa setegeniki fa o kgobokanya mathe, le go dirisa sediriswa sa sepotlakisi (ActiGraph) go diteko tsa tirisommele e nonofileng le BIA mo baneng ya itsagala. Di diriswa tse di bolokesegile go ka diriswa thutong ya patlisiso mo go tsayakarolong ga bana. Ga gona tirisommele,

saekholoji, kgathelelo loago kgotsa dingwe tse di botlhoko le ditlamorago tse di go tla rakanwang le tsona mo thutong ena. Mmatlisisi yo o boiphitlhelo o tla tsaya bana go ya ka tsamaiso ya teko ya dithulaganyo. Ngaka ya ditshipi (Dr,Venter) o tla nna a le mo tebellong ka nakoya tsamao ya porojeke, gore fa go ka nna le kgobalo e e diragalang. Fa go ka diragala gore gonne le kotsi ya tshoganyetso kgotsa golwala, bana ba tla gogelwa kwa morago ka gangwe go tswa mo porojekeng mme ba letlelelwa tlogela le go tsamaya nako enngwe le enngwe fa ba ikutlwa jaalo.

17. **A go na le kotsi e e tlamang ngwana go tsaya karolo mo porojekeng le go re tlhagisetsa tshedimosetso ya gagwe? Fa gontse jalo ke eng se se tla dirwang jaaka dilekanyo tse di tlamelang?**

Go latlhegelwa o sa itsagale	Batsayakarolo botlhe batla neelwa di nomore tseo tshedimosetso ya bona
Tsamaiso ya tshedimosetso le tatlhegelo ya disete tsa motheo wa tshedimosetso	Tshedimosetso e tla beiwa ka tlhokomelo le tshireletso mo di ofising tsa ba neela ditirelo le tshedimosetso ya eleketeroniki (Matlhabaphefo a Dipalopalo le motheo wa eleketeroniki) e tla sireletswa ka lefoko la
Go anamisa disete tsa tshedimosetso ka Bokamoso jo bo senang boitswharo	Tshedimosetso e tla bolokiwa lobaka la dingwaga dile 20 morago ga moo e be e sentswe ka tsela e e bolokosegileng e sa retele
Go latlhegelwa ke nako ya mophato	Ga gona nako ya mophato e e okeditsweng e e tla latlhegang.
Golapa le go gobala	Ditlhokego tsotlhe tsa dilekanyetso di dirisiwa ka nako ya go neelana

➤ **Di poelo dibotlhokwa go na le kotsi**

Di poelo mo thutong e di dbotlokwa go na le dikotsi. Patlisiso e ga ya ikaelelwa go gothusa ka bo wena, le fa gotse jalo o tla amogela tlhatlhobo ya bongaka ya mahala mme o amogele dipholo tsa gago di gi itsise fa ele gore o na le kgatelelo ya madie e kwa godim, mafura a a kwa godimo a mmele. Di phitlhelelo

tša patlisiso e di ka dirisiwa go thusa go thibela, direla le go laola malwetse a a sa tshelaneng(NCDs) a mokgwa wa go tshela o o gokaganang le mahura le bokima mo bathong ba Aforikaborwa.

Go tla diragala eng fa go ka nna le tirafalo ya go tlhorisa go go diragalang ele ditswamorago tsa go tsaya karolo mo thutong e ya patlisiso?

- *Fa o ka nna le tlhoko go tswelletsa dipuisanyo mo tsamaong/morago ga gotsayakarolo mo porojekeng; tshono e tla rulaganngwa gore wena o bueka tolamole mmatlisisi gore re kgonego go thusa.*

18. Ke mang yo o tla nnang le katamelo go tshedimosetso e e kgobokantsweng?

- *Go sa itsagale e tla nna fela ka kgethologo ka gone o tla be o dira teko ya kwa morago ga dilekanyetsao mme o rwele sediriswa sa (ActiGraph) le ditsala ya dithuto. Rona jaaka ba batlisisi re tla dira sengwe le sengwe go dira bo nnete jwa gore dikarabo tse o re neelang tsona mo dipotsong le disampole tse di kokoantsweng di tla dula ele sephiri mme di ka se tlhagise le leina la gago go mongwe le mongwe. Pego ya diphitlhelelo e ka se itsagale mme tshedimosetso ya ditlhopho mme eseng ya phaphathi ka bongwe le ka mokgwa wa go dirisa fela nomoro ya patlisiso ya gago e o tla e neelwang mme e ka se tlhagisi leina la mongwe le mongwe. Ke ba batlisisi fela bat la itseng ke tshedimosetso efe e eleng ya gago.*

19. Go ile go diragalang ka tshedimosetso/disampole?

Tshedimosetso e e kgobokantsweng/disampole di tla dula di bolokesegele di sireletsegele ka go lotlelela dikhopi tsa pampiri mo dirakeng mo ofising ya mmatlisisi mme go tshedimosetso ya elekenotiriki e tla sireletswa ka leinasephiri. Tshedimosetso e tla bolokwa dingwaga dile 7. Tshedimosetso e tla seksekwa mo Aforikaborwa mme e begwe ka dipopego dingwe le dingwe.

Tetlelelo ya batsayakarolo e tla lopiwa ka kabelano ya tshedimosetso le baitshwaraganyi ba bangwe go dipegelo tsa patlisiso.

20. **A na o tlile go duelwa go tsaya karolo mo thutong mme a go na le ditshenyegelo dingwe tse di amegang?**

Ga o kitla o amogela tuelo nngwe ntle le gore, go na le dikgothatso tse o tla di neelwang ka nako ya go kgobokanya tshedimosetso. Ga go kitla go nna jaana le ditshenyegelo tse di amegang go wena, fa gona o tsaya karolo.

21. A mme nka ikgaoganya go tswa mo thutong?

Go tsayakarolo gag ago mo patlisisong e key a boithaopo ka gotlhe. O na le gone go ka tlhopha go se tseye karolo gotlhelele. Fa o tsaya tshwetso ya go tsayakarolo mo patlisisong e, o ka emisa go tsayakarolo nako nngwe le nngwe. Fa o o tsaya tshwetso ya go sa tseyekarolo mo thutong e kgotsa fa o emisa go tsayakarolo nako nngwe le nngwe, o ka seke wa duedisiwa kgotsa wa latlhegelwa ke dipoelo dinngwe jaaka matshwao a sekolo ao le gale letleletsweng go a bona.

22. A go na le sengwe se o ka ratang go se itse?

- O ka kopana le moporofesara M.A. Monyeki mo 018 299 1790 fa o na le dipotsiso dingwe kgotsa o itemogela mathata.
- O ka kopana le Komiti ya Boitshwaro Ya Patlisiso ya Boitekanelo go ya ka Mme Carolien van Zyl mo 018 299 2089; carolie.vanzyl@ac.za fa o na ngongorego kgotsa ditlhobaelo dingwe tse di sa buegang ka go lekanyetsa ke mmatlisisi. Fa o tla rata go tsaya karolo mo thutong, tsweetswee buisa mme o saene foromo ya tumelano.
- O tla amogela khopi ya tshedimosetso e mme foromo ya tumelo go dipegelo tsa gago.

23. O tla itse jang ka ga diphitlhelelo?

- *Diphitlhelelo tsa patlisiso di tla abelanwa le wena ka go go neela tshosobanyo ya dipholo tsa gago.*

24. Kitsiso ka motsayakarolo

Ka gosaena kwa tlase, Nna ke dumela go tsaya karolo mo thutong ya patlisiso e e bidiwang: **Boikaelelo jwa popego ya mmele ka mokgwa wa tiriso khemikhale ya setegeniki le go sekaseka ka maitlhommo tiriso ya mmele mo baneng ba bogolo jwa dingwaga dile 6 go ya go le di 8.**

Ke itsise gore:

- Ke badile tshedimosetso e le foromo ya tumelo mme e kwadilwe ka puo e ke leng boleta le kgomotso ka yona.
- Ke nnile le sebaka sa go botsa dipotso mme dipotso tsotlhe di ne di arabegile ka selekanyetsa.
- Ke tlhaloganya gore go tsaya karolo mo thutong e ke boithaopi mme ga ke a ka gatelelwa go tsaya karolo.
- Nkanna ka tlhopha go tlogela thuto nako nngwe le nngwe mme nka se duedisiwe kgotsa kgethololo ka tsela nngwe.
- Nkanna ka tlhopha go tlogela thuto pele e fela, fa mmatlisisi a ikutlwela gore ke a dikgatlhegelong tsa tse dikgolo, kgotsa fa ele gore ga ke latele maano a thuto, jaaka go dumalanwe.

E saenilwe kwa (tulo) Ka (letlha) 20....

..... Tshaeno ya
motsayakarolo Tshaeno ya paki

25. Kitsiso ka motlhotlhomisi

Nna (Leina) Ke itsise gore:

- Ke tlhalositse tshedimosetso mo lokwalong le go

.....

- o Ke rotloeditse ena go botsa dipotso le go tsaya nako e e lekaneng go di araba.
- o Ke kgotsofetse gore o tlhalogantse ka selekanyo dikarolo tsotlhe tsa patlisiso, jaaka go rerisanwe fa godimo
- Ke dirisitse/ga ke a dirisa mofetoledi.

E saenilwe kwa (tulo) ka (letlha) 20....

.....

26. **Tshaeno ya motlhotlhomisi Tshaeno ya paki**

Appendix K

BC-IT STUDY WRITTEN INFORMED CONSENT AND ASSENT FORMS INFORMED CONSENT LETTER



PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM FOR CHILDREN



**TITLE OF THE RESEARCH PROJECT: BODY COMPOSITION BY ISOTOPE
TECHNIQUES AND OBJECTIVELY ASSESSING PHYSICAL ACTIVITY IN 6–8 YEAR-
OLD CHILDREN: BC-IT STUDY**

REFERENCE NUMBERS:

PRINCIPAL INVESTIGATOR: Prof. M.A. Monyeki

**ADDRESS: Physical activity, Sport and Recreation (PhASRec), Faculty of Health Sciences,
North-West University , Private Bag X6001, Potchefstroom, 2520**

CONTACT NUMBER: 018 2991790

You are being invited to take part in a research project which seeks to investigate body composition by isotope techniques and objectively assessing physical activity in 6 to 8 year-old children. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00025-17-A1)** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.

27. What is this research study all about?

- *This study will be conducted in primary schools within the Tlokwe local municipality and will involve about 400 children aged between 6 to 8 years of age. Data with regards to demographic information, birth weight, physical activity, and cardiovascular function will be collected. Body composition by means of anthropometric measurements of height, body mass, skinfolds, and circumferences will be measured. Water mixed with a deuterium dose will be given to children and afterwards saliva will be collected to determine body fat and muscle mass by means of stable isotope. Body composition will also be determined by means of bioelectric impedance analysis for comparison purposes. Data collection will be conducted by experienced health researchers trained in Human Movement Science.*
- *The objectives of this research are:*

i. determine birth weight (retrospectively), body composition by BIA and body composition by isotope techniques, and its relationship to physical activity in 6 to 8 years of age in South African

- children. ii. investigate a longitudinal development of body composition with birth weight (retrospectively) and physical activity in South African children.
- iii. determine the associations between anthropometry, body composition, physical activity level and metabolic health in normal-weight, overweight and obese children using stable isotope techniques and establish improved predictors of future health risk.

28. Why have you been invited to participate?

- *You have been invited to participate because you are between 6 to 8 years old and in a primary school from the area selected for recruitment. You have also complied with the following inclusion criteria: healthy aged 6 to 8 years attending primary schools within the Tlokwe Local Municipality. You will be excluded if: you are not healthy and, less than 6 years and above 8 years old, and attending primary schools outside Tlokwe Local Municipality. Unable to perform any of the health-related physical activity tests.*

29. What will your responsibilities be?

- *You will be expected to answer a number of questionnaires (a sociodemographic information, including data on personal information and family - i.e. education of the parents, employment, type of dwelling, household amenities and marital status) personal image, physical activity, healthy habits, lifestyle and health, knowledge on food choice, will be collected by means of a IAEA questionnaire. The questionnaire will take about 15 minutes to complete under the supervision of teachers, and consists of 51 questions; Take part in the EUROFIT test battery which will last for 10 minutes, and anthropometric measurements of height, body mass, waist circumference, mid arm circumference, triceps, biceps, supra-iliac and subscapular skinfolds which will last for 10 minutes; and give saliva for stable isotope (at different time zones, at arrival and after 2 hours of the dose of deuterium) and do assessment of body composition by bioelectric impedance analysis for approximately 4–5 minutes. Lastly, an accelerometer will be attached to determine habitual physical activity and be placed on your waist with a belt for 24 hours for seven days.*

30. Will you benefit from taking part in this research?

- *The direct benefits for you as a participant will be to recognize the importance of keeping a healthy body composition and the benefits associated with regular participation in physical activity. It may increase the children's awareness of a regular participation in physical activity in reduction of obesity and keeping a healthy life style. You will be able to gain access to their results. Their data will also be used to explain to teachers orally how to improve their healthy life style.*
- *The indirect benefit will be an expansion of existing expert knowledge in the field of Human Movement Science and related fields which can be transferred to the wider community. This knowledge can be used for further studies addressing applicability of our findings.*

31. Are there risks involved in your taking part in this research?

- *There are no known risks associated with participating in this research project, but the anticipated risks in this study are minimal. This may be due to the fact that you might get tired during the ± 10 minutes of physical fitness testing. To minimised fatigue the researchers will aim to maximise potential benefits that are likely to have a valuable impact on the children either directly or indirectly. No risk for using isotope deuterium when collecting saliva, and use of accelerometry (ActiGraph) for physical fitness tests and BIA in children are known. These instruments are safe to use in field research in children participants. No severe physical, psychological, social stress or other negative consequences will be encountered in this study. An experienced researcher will take the children through the process of all the test items. A medical doctor (Dr. Venter) will be on standby during the total duration of the project, should any injuries occur. In case of illness or injury, children will immediately be withdrawn from the project and will be allowed to leave at any time if they feel so*

32. . Are there risks involved in your child taking part in the project and producing us with his/her data? If so what will be done as precautionary measures?

Risks	Precautionary measures
Loss of anonymity	All participants will be allocated a number to whom their data will be linked to protect their anonymity.
Data management and loss of original data sets	Data will be kept safe and secure in the service provider's office and electronic data (Statistica for Windows and SmartaBase) will be password protected
Unethical future dissemination	Data will be stored for a period of 20 years after which it will be

of data sets	destroyed in the safest way possible.
Loss of class time	No additional class time will be lost.
Fatigue and injury	All necessary measures are put in place during programmes offered to avoid and if necessary manage such risks.

□ ***The benefits outweighs the risk***

The benefits in this study outweigh the risks. This research is not designed to help you personally, however you will receive a free medical examination and receive your own results informing you whether you have high blood pressure, high body fat. The findings of this research can be used to help prevent, treat and manage non-communicable diseases (NCDs) of life style associated with overweight and obesity in South African people.

33. **What will happen in the unlikely event of some harm/form of discomfort occurring as a direct result of your taking part in this research study?**

- *Should you have the need for further discussions during/after the participation in this project; an opportunity will be arranged for you to speak directly with the researcher so that we can help you.*

34. **Who will have access to the data?**

- *Anonymity will be only partial because you will be doing the posttest measurements and wearing ActiGraph with your classmates. We as researchers will do everything to make sure that the answers you gave on the questionnaire and sample collected will be kept secret and we will not disclose your name to anyone. Reporting of findings will be anonymous and the data of the groups and not on an individual level and by means of only using your research number that will be given to you and we will not disclose your name to anyone. Only the researchers will know which data belongs to you.*

35. **What will happen with the data/samples?**

Data/samples will be kept safe and secure by locking hard copies in locked cupboards in the researcher's office and for electronic data it will be password protected. Data will be stored for 7 years. Data will be analysed in South Africa and reported in various forms. Participants' permission will be requested for data sharing with other collaborators for research reports.

Will you be paid to take part in this study and are there any costs involved? You will not receive any payment except that, incentives will be provided to you during data collection. There will thus be no costs involved for you, if you do take part.

36. Can I withdraw from the study?

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits such as school marks to which you otherwise qualify.

37. Is there anything else that you should know or do?

- You can contact professor M.A. Monyeki at 018 299 1790 if you have any further queries or encounter any problems.
- You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher. If you would like to take part in the study, please read and sign the consent form.
- You will receive a copy of this information and consent form for your own records.

38. How will you know about the findings?

- *The findings of the research will be shared with you by giving you a summary of your results.*

39. Declaration by participant

By signing below, I agree to take part in a research study entitled: Determining body composition by isotope techniques and objectively assessing physical activity in 6 to 8 year-old children

I declare that:

- I have read this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) on (*date*) 20....

.....
 40. **Signature of participant** **Signature of witness Declaration by investigator**
 I (*name*) declare that:

- I explained the information in this document to
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use a interpreter.

Signed at (*place*) on (*date*) 20....

.....
 41. **Signature of investigator** **Signature of witness**

CONSENT

Declaration by parent (Informed Consent: 0-13 years)	
Declaration by the participant (Written Assent: 7-13 years)	
Declaration by the participant (Verbal Assent: 0-7 years)	

Declaration by parent (Parental informed Consent: 0-13 years)

Parent contact number:

By signing below, I give consent that my child may take part in the project and that his information may be used for research purposes.

I declare that:

I have read this information and consent form and it is written in a language with which I am fluent and comfortable. I have had a chance to ask questions to both the person obtaining consent, as well as the service provider and all my questions have been adequately answered, if needed. I understand that my child taking part in this project is **voluntary** and I have not been pressurised to give consent. I may choose to withdraw my consent at any time and my child will not be penalised or prejudiced by this in any way. I understand that the data collected during this project may be used for possible future research purposes (as indicated by the objectives) as long as anonymity is ensured. I give consent that data collected may be

used for research
purposes

YES NO

--	--

Signed at (*place*) on (*date*) 20.....

.....
 42. **Signature of participant** **Signature of witness**

Declaration by the participant (Written Assent: 7-13 years)

ID number:

By signing below, I agree to take part in this research project

I declare that:

I have understood instructions given to me verbally. Information and permission was given in a language with which I am fluent and comfortable. I have had a chance to ask questions to my parent and the person obtaining consent, as well as the researcher and all my questions have been adequately answered. I understand that taking part in this study is voluntary (my own decision) and that nobody forced me to do so. I may choose to withdraw my assent at any time and I will not be penalised or discriminate against in any way. I may be asked to leave the study before it is finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to. I am also told that the information or data collected on me will solely be used for research purpose until it is fully analysed.

Signed at (*place*) on (*date*) 20....

.....
43. **Signature of child** **Signature of witness**

VERBAL ASSENT (0-7 years)

ID number:

Do you want to participate in the activities today? Point with your finger to the face that shows how you feel about taking part in today's activities.



YES



NO

Child's choice:

44. **Declaration by person obtaining consent**

I (*name*) declare that:

I explained the information in this document to the teacher, parent (if possible) and the child themselves. I encouraged all parties to ask questions and took adequate time to answer them. I am satisfied that all parties adequately understand all aspects of the project, as discussed above. I did not use any interpreter.

Signed at (*place*) on (*date*) 20....

.....
Signature of person obtaining consent

.....
Signature of witness

Problems and queries to:

1. Professor Andries Monveki: Tel: 018 2991790 or email: andries.monveki2nwu.ac.za

APPENDIX L

INSTRUCTIONS FOR AUTHORS: *PEERJ*

Overview

1

Please use clear, unambiguous, technically and grammatically correct English throughout.

2

Files:

- [Manuscript](#)
- [Figures](#)
- [Tables](#)
- [Raw data or code files](#)
 - Data or code is **almost always** required for review and publication.
 - **Note** Authors not submitting their raw data correctly is the top reason for delay.
 - Choose how you want to submit your raw data:
 1. Upload to PeerJ as a supplemental file.
 2. Upload to an [online repository](#) and submit access details (required for files over 30MB).
 - If owned by a third party, please submit written permission to publish.
 - If you cannot submit on grounds of privacy or safety, please submit a statement from the owners of the raw data or code explaining why.
 - Files must be machine-readable i.e. images, PDFs, Powerpoints etc. not accepted.
- [Supplemental files](#)
 - Files that are not part of your main manuscript:
 - **Files for staff** (as appropriate)

Ethics / Human participant / Field study / Vertebrate animals approval documents.

Example human participant consent form.

CONSORT flow diagram and checklist.

PRISMA flow diagram and checklist.

COREQ checklist.

Trial protocol.

Photo/video consent form.

- **Files for publication**

Raw data or code (required).

Large supplemental datasets.

Figures and tables.

Articles.

Video and audio.

Supplemental Files should not exceed 50 MB in total (30MB individual file limit). If you need more space please contact us.

3

Manuscript formatting:

- US Letter.
- Use [line numbers](#).
- 2.5 cm margin on all edges.
- 12 point Times font for readability.
- 'Normal' style for text, 'Heading' styles for headings.
- Do not use 'unusual' document styles/templates (e.g. 'Normal (Web)').
- Left justify all text to the left margin. Do not 'full width' justify.

- Title guidance:
 - Be clear, appealing, interesting and specific.
 - Match the search queries used to find similar articles.
 - Be concise: ideally 20-60 words (250 character hard limit).
 - Avoid acronyms, abbreviations and jargon.
 - Accurately describe work.

4

Raw data or code submitted as either:

1. A link to a repository where the data and/or code is accessible (e.g. [Github](#), [Gitlab](#)).
2. or Supplemental file(s) containing the raw data or code.
 - Machine-readable (PDF, Powerpoint, images etc. not accepted).
 - Data or code is almost always required:
 - If the data is owned by a third party, please obtain permission to publish. Alternatively, submit a statement from the owners explaining why they cannot publish on the grounds of privacy or safety.
 - If too large, upload it to an online repository (e.g. [Figshare](#), [Dryad](#) etc).

5

LaTeX:

- Submit a single PDF with the full set of LaTeX source files.
- Use line numbers.
- [Overleaf](#) is a great LaTeX editor. Use our [template](#).

6

No cover letters or pre-submission inquiries needed.

7

You cannot publish any materials that have been published in a peer-reviewed journal previously.

[Standard Sections](#)

Use these Standard Sections where possible. Include any methodology or experiment sections appropriate to your field. Do not combine sections.

[Author Cover Page](#) (see below)

Abstract

- 500 word (3,000 character) limit.
- Self-contained, concise description of reason for the work, methodology, results, and conclusions.
- Uncommon abbreviations should be spelled out at first use.
- No footnotes or references (except when referencing a critiqued publication by DOI).
- Subheadings must be bold, followed by a period, and start a new paragraph e.g.

Background. The background section text goes here...

Introduction

Materials & Methods

Results

Discussion

Conclusions

Acknowledgments

- Do not acknowledge funders here, there is a separate Funding Statement for that. Everyone named in the acknowledgments section must be informed that they are named.

References

[Literature Review](#) standard sections

Author Cover Page (see above)

Abstract (see above)

Introduction

- Describe the field and explain why this review is needed.
- Explain relevance to readers in the field, and associated areas.
- Cite previous reviews.

Survey Methodology

- Explain how you ensured comprehensive and unbiased coverage of the literature.

Subheadings

- We recommend that you subdivide your article into a small number of major topic areas.

Conclusions

- Identify unresolved questions / gaps / future directions.

Acknowledgments (see above)

References

Also read the [policies for literature reviews](#).

[Author cover page](#)

1

Included as the first page of your manuscript ([view example](#)).

2

Author info entered online must **exactly match** the author info listed on your Author Cover Page.

3

Author Cover Page structure:

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 - First given names (or first initials in combination with full middle names).
 - Middle name initial(s).
 - Family name (surname).
- Affiliations (indicate multiple affiliations, or current addresses where appropriate).
 - Department, University , or organizational affiliation.
 - Location: city, state/province (if applicable).
 - Country.
- Submission admin
 - First and Last name.
 - Email address.

OR

- If authored by a consortium, list names and affiliations in correct order in the Acknowledgments section.

4

All authors must meet the [ICMJE authorship](#) requirements. Include other contributors in the Acknowledgments section.

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Submit your references in whatever style you like.

Just make sure they're full, clear, and consistent and we'll standardize at production.

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[In-text citations](#)

- For three or fewer authors, list all author names (*e.g. Smith, Jones & Johnson, 2004*). For four or more, abbreviate with 'first author' et al. (*e.g. Smith et al., 2005*).
- Multiple references to the same item should be separated with a semicolon (;) and ordered chronologically.
- References by the same author in the same year should be differentiated by letters (*Smith, 2001a; Smith, 2001b*).
- Cite articles accepted for publication as '*in press*'. Include in reference section and upload as a Supplemental file.
- Cite work unpublished, in preparation or under review as '*unpublished data*'. Supply the author's first initial and surname, and the year of the data collection, in the text citation and do not include the citation in the reference section. Example: (A Castillo, 2000, unpublished data).
- Avoid referencing personal communications. Reference as '*pers. comm.*', including the first initial and surname, and year. Example: (A Castillo, 2000, pers. comm.).

The Reference Section

- Journal reference format: List of authors (with initials). Publication year. Full article title. *Full title of the Journal*, volume: page extents. DOI (if available).

Example journal reference:

Smith JL, Jones P, Wang X. 2004. Investigating ecological destruction in the Amazon. *Journal of the Amazon Rainforest* 112:368-374 DOI: 10.1234/amazon.15886.

- Gray Literature (*e.g.* patents, technical reports from agencies or research groups, working papers, white papers, preprints etc.) described thoroughly: Authors. Page/paper title. Publication date. Publisher name. URL (access date). Identification (*e.g.* patent or series) numbers.

Example gray literature references:

Boettiger C. 2013. knitcitations: citations for knitr markdown files. Available at <https://github.com/cboettig/knitcitations> (accessed 10 July 2012)

Dorch B. 2012. On the Citation Advantage of linking to data. hprints. Available at <http://hprints.org/hprints-00714715> (accessed 5 July 2012)

- Example book reference:

James FY. 2010. *Understanding corn and wheat*. Oxford: Oxford University Press.

- Example book excerpt:

Smith PG. 2011. Behavior in ants. In: Jones HY, ed. *Insect behavior in the Andes*. Berlin: Springer Verlag, 101–200.

- Example thesis:

Blair HJ. 1989. Structural modifications of the fern genus *Lecanopteris* (Polypodiaceae). D. Phil. Thesis, Cambridge University .

- Example webpage:

Johnson S. 2010. Italian Plants. Available at <http://www.italianplants.com> (accessed 22 March 2011).

- Example abstract:

Thomas D, Scharfenecker U, Schiltmeyer B. 2006. Low potential for drug-drug interaction of lacosamide. [Abstract 2.235] *Epilepsia* 47(Suppl 4): 200.

- Reference Section sorted by Author, Year, Title. All citations must be present in the reference section, and all references cited in the text. Place non-cited references in a "Further Reading" section.
- Zotero users please [download PeerJ Zotero style](#).
- EndNote users please [download PeerJ Endnote style](#) and:
 - Open EndNote.
 - Open library (the citation file).
 - Set style to "PeerJ".
 - Go to Edit --> Output Styles --> Edit "PeerJ".
 - Under Bibliography --> Author Lists, set "Abbreviated author list" to "List all author names".

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- Mendeley users in MS Word please change your field codes into plain text by performing the following:
 - **If using Windows:**
Ctrl-A (Selects all the text in the manuscript).
Ctrl-Shift-F9 (Changes the fields codes).
 - **If using OSX:**
Command-A (Selects all the text in the manuscript).
Command-6 (Changes the fields codes).

File Types

Manuscript

Manuscript checks

- Manuscript document formats:
 - **.DOCX (Preferred)** and .DOC
 - .TeX (+ PDF with embedded figures and tables)
 - .ODT
 - .RTF
- US Letter.
- Use [line numbers](#).
- 2.5cm margin on all edges.
- 12 point Times font for readability.
- 'Normal' style for text, 'Heading' styles for headings.
- Do not use 'unusual' document styles/templates (e.g. *'Normal (Web)'*).
- Left justify all text to the left margin. Do not 'full width' justify.

Figures

Figure and Table checks

Figures	Use the original file format and image size whenever possible.
Vector images (e.g. charts, diagrams):	○ PDF ▪ US Letter size ▪ 2.5cm margins ○ EPS

Raster/bitmap images
(e.g. drawings,
screenshots):

- PNG (preferred)
- JPEG (photographs only)

Ideal width/height: 3000px (minimum 900px).

- **Please upload as separate files (i.e. do not embed in manuscript).**
- '*Figure*' refers to graphs, charts, line drawings and photographs.
- Lower quality images may be accepted for review, but these must be replaced with high-quality (300dpi) images on resubmission.
- Include figure numbers in filenames e.g. '*Figure 1.png*'.
- Titles are required for all figures (legends are optional):
 - **Title format**



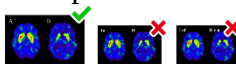
- **Legend format** (optional)



- All figures must be cited in the main text.
- Figure order:
 - Figure 1 appears first in the text, and first cited.
 - Figure 2 appears second, and the next cited after Figure 1.
 - etc...
- When citing use the abbreviation '*Fig.*'. When starting a sentence with a citation, use '*Figure 1*'.
- Minimum white space around each figure/figure part.



- Label with a readable, uniform font. Vertical height of 2mm suggested.
- Multi-part or single images should not span multiple pages.
- Multi-part figures submitted in one file and arranged as they are to be published. Label each part with an uppercase letter.



Tables

Figure and Table checks

- Table document formats:
 - **.DOCX (Preferred)** or .DOC
 - .ODT
 - .TEX

- Please upload as separate files (i.e. do not embed in manuscript).
- Include table numbers in filenames e.g. 'Table 1.png'.
- Titles are required for all tables (legends are optional):
 - **Title**

Table 1:
Model comparison between naïve Bayes, Bayesian network classifiers (BNs), and random forest.

Standard value corresponding to whether the intensity of a pixel was above average. The fitting time and test set accuracy are reported for each algorithm.

Model	Fitting time (s)	Test set accuracy
Naïve Bayes	0.05	0.75
BN	0.15	0.85
Random forest	1.5	0.95

DOI: 10.1111/journal.123456789

- **Legend** (optional)

Table 1:
Model comparison between naïve Bayes, Bayesian network classifiers (BNs), and random forest.

These algorithms were evaluated on the LCD handwritten digits dataset, but in the standard value corresponding to whether the intensity of a pixel was above average. The fitting time and test set accuracy are reported for each algorithm.

Model	Fitting time (s)	Test set accuracy
Naïve Bayes	0.05	0.75
BN	0.15	0.85
Random forest	1.5	0.95

DOI: 10.1111/journal.123456789

- Table order:
 - Table 1 appears first in the text, and first cited.
 - Table 2 appears second, and the next cited after Table 1.
 - etc...
- Cite tables in text as 'Table 1', 'Table 2' etc.
- Include units in column and row headings, in parentheses.
- Tables must fit in a single 21.6 x 28 cm page with 2.5 cm margins.
- Place footnotes below the table; these may be used to explain abbreviations.

Figure and table referencing

- For figures, videos or tables containing copyrighted material not created by one of the authors (e.g. photographs, maps):
 - Upload a document with the copyright owner's permission to publish under a CC BY license ([download photo/video permission letter template](#)).
 - Add a credit attribution in the legend.
- When submitting photographs please indicate the identity of the photographer.
- Examples of credit attributions:

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Photo credit: Ali Smith.

Image credit: the MESH archive at <http://ondemand.nssl.noaa.gov>

3D model credit: Ishmael Kreill

Map data © 2021 Google

- For figures with identifiable human subjects:
 - Written consent from the human subject. If the subject is a minor, consent must be provided from their parent or guardian. ([download human subject permission letter template](#)).
 - Upload a document with the copyright owner's permission to publish under a CC BY license ([download photo/video permission letter template](#)).

If written consent cannot be obtained, then the figure must be replaced by a figure without identifiable human subjects. Per ICMJE, measures such as blurring faces or masking the eye region in the photographs of patients is inadequate protection of anonymity.

- Cite map sources. If using Google Earth or Google Maps also [attribute the third-party data providers](#) used by the map:
 - In the figure legend.
 - On the figure.
- Use maps which allow unrestricted re-use where possible.

TeX / LaTeX users

Submit your complete PDF manuscript, TEX, BIB, hi-res figures and tables.

Raw data or code

- All authors are responsible for making materials, code, raw data and associated protocols relevant to the submission available without delay.
- Data or code should be submitted to a specialist database if appropriate (e.g. [GenBank](#) for sequences, [Morphosource](#) for 3D models and scans, etc.).
- Recommended data or code repositories:
 - An institutional repository
 - [Zenodo](#) (free & unlimited)
 - [Figshare](#) (20GB free)
 - [Dryad](#) data storage
 - [Galaxy server](#) (1GB to 2TB+)
 - [Git Large File Storage](#) (1GB free)
 - [Github](#) (code)
 - [Gitlab](#) (code)
 - For review only (move to a persistent depository on publication):
 - [Google Drive](#) (15GB)
 - [Dropbox basic account](#) (2GB free)
 - [OneDrive basic account](#) (50GB per dataset)
 - **pan.baidu.com** cannot be used.

Supplemental Information (SI)

Supplemental Figures	Submit as JPG (use maximum quality settings), EPS (for vector images), or PNG (for lossless images).
Supplemental Tables	Submit as PDF, DOC, Excel, RTF or TeX / LaTeX files.
Supplemental Articles	Submit as PDF.
Supplemental Videos	Submit as AVI, MOV, WMV, and MP4 files. For widest compatibility, we suggest authors provide video files as 128 kbit/s AAC audio and 480p H.264 video in an MPEG-4 (mp4) format. Regardless of format submitted, authors should double check that their videos open and play in recent versions of both QuickTime and Windows Media Player.

Supplemental Audio

Submit as WAV or MP3 files. Please include a legend.
Ensure that the files open and play in common audio players such as iTunes or Windows Media Player.

Large Supplemental Data sets Submit in a compressed format (e.g. zip or tar.gz).

- Supplemental files are those published alongside the article, that are not an integral part of it.
- Supplemental files may include information or data too large to include in the main article.
- File naming format: '*Supplemental [Item] S[number]*' e.g. 'Supplemental Data S1'.
- Titles are required for all figures (legends are optional).
- Supplemental Files should not exceed 50 MB in total (30MB individual file limit). If you need more space please contact us.
- Use the following style when citing Supplemental files in the text:
Fig. S1, Table S1, Data S1, Video S1, Article S1, Audio S1.
- Files intended for review but not publication can be uploaded as *Review-only info* Supplemental Files.
- Data or code files must be understandable by an English language reader.

Style Considerations

Units, Symbols, Mathematics, Abbreviations

- Where possible and appropriate, use the [International System of Units](#).
- Use discipline specific (non-SI) units only where they are widely adopted within the field.
- Symbols should be used in lieu of abbreviations for mathematical expressions & defined at first use.
- Spell out the numbers 1-9 unless used with units.

Manuscript Text

- Please use clear, unambiguous, technically and grammatically correct English.
- If the final typeset page count of your article PDF exceeds 40 pages, an additional service charge will be required to help offset the production costs of a manuscript of this size. This is not an additional APC and discount codes cannot be used to pay for this fee. If you have a manuscript of this extent then please email editor@peerj.com to discuss.
- The established norms of academic writing within your field should be followed.
- Either English or American spelling is acceptable provided it is consistently used throughout.
- Nomenclature: Biological & medical nomenclature should adhere to recognized guidelines set forth by international committee regulations or authoritative bodies for specific fields, as applicable.

Tables

- Table text should be roman black text.
- Special significance can be placed on certain values in the table (e.g., p-values) by bolding, italicizing or underlining the text. Explain in the table legend what the formatting represents.

Figures

- Image manipulation:
 - Figures should be minimally processed/manipulated, to add labels, arrows, or change contrast (applied to whole image inc. controls).

- Do not adjust in any way that could lead to misinterpretation of the information in the original image.
- Unprocessed figure files and data must be retained for editorial review upon request.
- Descriptions of changes and hardware and software used to take the images and make adjustments must also be provided.
- Inappropriate figure manipulation is grounds for article retraction and reporting to institutional oversight boards.
- Electrophoretic gels, blots, and chromatograms: Use cropped gels, blots, paper and thin-layer chromatographs, etc in your article only if it improves clarity. Upload full-length images of gels, blots, and chromatograms as Supplementary Files if doing so.
- Titles and legends below the image can be included in the image file for first review. Titles and legends must be removed for re-review.
- Include scales, abbreviations, limits etc. in the graphical area the image.
- Figure legends should be self contained and clearly describe the figure and its contents.
- When creating figures and images consider the accessibility of your chosen color schemes to those with non-normal color vision. Wherever possible avoid using color alone to distinguish between parts of images. When color is used, we suggest that you consult the following resources to ensure maximum accessibility: [J*FLY](#), [Mapbox](#) and [ColorBrewer](#).

Linnean Binomials

- Authors are encouraged to provide taxonomic authors of Linnean binomials when first used in the text, particularly for taxa that are the focus of the paper in question. Where several taxa are named, citation of taxonomic authors in Tables is regarded as an adequate substitute for citation in the body of the text. Authors of zoological names should consist of initials plus full surnames, whereas authors of botanical names should be abbreviated following Brummitt & Powell's (1992) 'Authors of plant names'. In either case, binomials carrying more than three authors should be abbreviated to 'et al.' subsequent to the name of the third author.

Species formatting

- When a species is first mentioned, write out the full name (i.e., genus followed by species):
 - Use both the genus and species name (e.g., *Felis catus*).
 - Italicize the whole name.
 - Capitalize only the genus name.
- The next time that species is mentioned, abbreviate the name (i.e., the first letter of the genus followed by a period and the species), unless:
 - There are two species that belong to different genera that nevertheless start with the same letter (e.g., *Leopardus pardalis*, the ocelot, and *Lynx canadensis*, the Canada lynx). Do not abbreviate the genus name.
 - There are multiple species with the same species name, but different genera (e.g., *Trigonopterus attenboroughi*, a beetle, and *Prethopalpus attenboroughi*, a spider). You can refer to the species by just the genus name, or write the species name in full.
 - There are two or more species that are being compared in the same sentence. In this case, you can refer to the species by just the genus name, or write the species name in full.

- When you introduce the name of another species in the same genus, you can use the abbreviated genus name for the new species. For example: The domestic cat is species *Felis catus*. Both *F. catus* and its wild relative, *F. silvestris*...
- The names of higher taxonomic levels (family, order, class, phylum or division, and kingdom) should be capitalized but not italicized. Common names derived from taxon names, for instance “felines” for members of the family Felidae, should not be capitalized. A common name that is derived from a genus name, such as gorilla, should not be capitalized.

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PeerJ welcomes submissions directly from external services. We have a "one click" submission route from [bioRxiv](#), [Overleaf](#), and [Peerage of Science](#) and we encourage authors to take advantage of these linkups. Once your submission is transferred to us, staff will initiate the submission for you and contact you to complete the final information and confirm your submission.

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Reference: <https://peerj.com/about/author-instructions/>

APPENDIX M

Submission letter for publication to *PeerJ*

Dear Caroline Molete,
Makama Andries Monyeki has added you as a co-author of the article - **Association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children : BC-IT study** - submitted to the peer-reviewed journal PeerJ on 18th February 2021.
Please confirm (or decline) authorship:
Confirm or Decline Authorship
If you already have a PeerJ account please use that to confirm (you can reset your password if forgotten).
If you are new to PeerJ you will create a free account during the confirmation process.
And of course we would like to warmly welcome you into the PeerJ community!
With kind regards,
The PeerJ Team

Acknowledgement:

From: PeerJ <info@peerj.com>
To: Makama Andries Monyeki <andries.monyeki@nwu.ac.za>
Date: 2021/02/18 21:05
Subject: [PeerJ] We've received your submission: "Association between birth weight..." (#2021:02:58205:0:0:CHECK)

PeerJ

Dear Makama Andries,

Thank you for submitting your article for review - **Association between birth weight and body composition as determined by deuterium dilution method in 6- to 8-year-old South African children : BC-IT study**.

It will now be checked by PeerJ staff, who will email you if any changes are required.

Many of our staff are on lockdown in response to COVID-19, therefore there may be a delay in processing your revision submission. We thank you for your patience in this difficult time.

After passing checks, it will be assigned to an Academic Editor, who will invite reviewers to carry out peer-review.

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The PeerJ Team

Article number: 58205

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Appendix N

Instruction for authors: BMC Public Health

- **Preparing your manuscript**

This section provides general style and formatting information only. Formatting guidelines for specific article types can be found below.

- [Research article](#)
- [Technical advance article](#)
- [Database article](#)
- [Software article](#)
- [Study protocol](#)
- [Review](#)
- [Research in practice](#)

General formatting guidelines

- [Preparing main manuscript text](#)
- [Preparing illustrations and figures](#)
- [Preparing tables](#)
- [Preparing additional files](#)

Preparing figures

[Back to top](#)

When preparing figures, please follow the formatting instructions below.

- Figures should be numbered in the order they are first mentioned in the text, and uploaded in this order. Multi-panel figures (those with parts a, b, c, d etc.) should be submitted as a single composite file that contains all parts of the figure.
- Figures should be uploaded in the correct orientation.
- Figure titles (max 15 words) and legends (max 300 words) should be provided in the main manuscript, not in the graphic file.
- Figure keys should be incorporated into the graphic, not into the legend of the figure.
- Each figure should be closely cropped to minimize the amount of white space surrounding the illustration. Cropping figures improves accuracy when placing the figure in combination with other elements when the accepted manuscript is prepared for publication on our site. For more information on individual figure file formats, see our detailed instructions.
- Individual figure files should not exceed 10 MB. If a suitable format is chosen, this file size is adequate for extremely high quality figures.
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Figure file types

We accept the following file formats for figures:

- EPS (suitable for diagrams and/or images)
- PDF (suitable for diagrams and/or images)
- Microsoft Word (suitable for diagrams and/or images, figures must be a single page)
- PowerPoint (suitable for diagrams and/or images, figures must be a single page)
- TIFF (suitable for images)

- JPEG (suitable for photographic images, less suitable for graphical images)
- PNG (suitable for images)
- BMP (suitable for images)
- CDX (ChemDraw - suitable for molecular structures)

For information and suggestions of suitable file formats for specific figure types, please see our [author academy](#).

Figure size and resolution

Figures are resized during publication of the final full text and PDF versions to conform to the BioMed Central standard dimensions, which are detailed below.

Figures on the web:

- width of 600 pixels (standard), 1200 pixels (high resolution).

Figures in the final PDF version:

- width of 85 mm for half page width figure
- width of 170 mm for full page width figure
- maximum height of 225 mm for figure and legend
- image resolution of approximately 300 dpi (dots per inch) at the final size

Figures should be designed such that all information, including text, is legible at these dimensions. All lines should be wider than 0.25 pt when constrained to standard figure widths. All fonts must be embedded.

Figure file compression

- Vector figures should if possible be submitted as PDF files, which are usually more compact than EPS files.
- TIFF files should be saved with LZW compression, which is lossless (decreases file size without decreasing quality) in order to minimize upload time.
- JPEG files should be saved at maximum quality.
- Conversion of images between file types (especially lossy formats such as JPEG) should be kept to a minimum to avoid degradation of quality.

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Preparing main manuscript text

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Quick points:

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- Include line and page numbering
- Use SI units: Please ensure that all special characters used are embedded in the text, otherwise they will be lost during conversion to PDF
- Do not use page breaks in your manuscript

File formats

The following word processor file formats are acceptable for the main manuscript document:

- Microsoft word (DOC, DOCX)
- Rich text format (RTF)
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Please note: editable files are required for processing in production. If your manuscript contains any non-editable files (such as PDFs) you will be required to re-submit an editable file when you submit your revised manuscript, or after editorial acceptance in case no revision is necessary.

Additional information for TeX/LaTeX users

Please use BioMed Central's TeX template and BibTeX stylefile if you use TeX format. Submit your references using either a bib or bbl file. When submitting TeX submissions, please submit both your TeX file and your bib/bbl file as manuscript files. Please also convert your TeX file into a PDF (please do not use a DIV file) and submit this PDF as a supplementary file with the name 'Reference PDF'. This PDF will be used by our production team as a reference point to check the layout of the article as the author intended.

The Editorial Manager system checks for any errors in the Tex files. If an error is present then the system PDF will display LaTeX code and highlight and explain the error in a section beginning with an exclamation mark (!).

All relevant editable source files must be uploaded during the submission process. Failing to submit these source files will cause unnecessary delays in the production process.

TeX templates
BioMedCentral_article (ZIP format) - preferred template
article (part of the standard TeX distribution)
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- Visiting the [English language tutorial](#) which covers the common mistakes when writing in English.
- Asking a colleague who is proficient in English to review your manuscript for clarity.
- Using a professional language editing service where editors will improve the English to ensure that your meaning is clear and identify problems that require your review. Two such services are provided by our affiliates [Nature Research Editing Service](#) and [American Journal Experts](#). BMC authors are entitled to a 10% discount on their first submission to either of these services. To claim 10% off English editing from Nature Research Editing Service, click [here](#). To claim 10% off American Journal Experts, click [here](#).

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- 使用专业语言编辑服务，编辑人员会对英语进行润色，以确保您的意思表达清晰，并提出需要您复核的问题。例如我们的附属机构 [Nature Research Editing Service](#) 以及合作伙伴 [American Journal Experts](#) 都可以提供此类专业服务。BMC作者享受首次订单10%优惠，该优惠同时适用于两家公司。您只需点击以下链接即可开始。使用 Nature Research Editing Service的编辑润色10%的优惠服务，请点击[这里](#)。使用 American Journal Experts的10%优惠服务，请点击[这里](#)。

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- 귀하의 원고의 표현을 명확히 해줄 영어 원어민 동료를 찾아서 리뷰를 의뢰합니다
- 리뷰에 대비하여, 원고의 의미를 명확하게 해주고 리뷰에서 요구하는 문제점들을 식별해서 영문 수준을 향상시켜주는 전문 영문 교정 서비스를 이용합니다. [Nature Research Editing Service](#)와 [American Journal Experts](#)에서 저희와 협약을 통해

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For all manuscripts, information about data availability should be detailed in an 'Availability of data and materials' section. For more information on the content of this section, please see the Declarations section of the relevant journal's Instruction for Authors. For more information on BioMed Centrals policies on data availability, please see our [editorial policies].

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The following format for the 'Availability of data and materials' section of your manuscript should be used:

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- Project name: e.g. My bioinformatics project
- Project home page: e.g. <http://sourceforge.net/projects/mged>
- Archived version: DOI or unique identifier of archived software or code in repository (e.g. enodo)
- Operating system(s): e.g. Platform independent
- Programming language: e.g. Java
- Other requirements: e.g. Java 1.3.1 or higher, Tomcat 4.0 or higher
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References

See our [editorial policies](#) for author guidance on good citation practice.

Please check the submission guidelines for the relevant journal and article type.

What should be cited?

Only articles, clinical trial registration records and abstracts that have been published or are in press, or are available through public e-print/preprint servers, may be cited.

Unpublished abstracts, unpublished data and personal communications should not be included in the reference list, but may be included in the text and referred to as "unpublished observations" or "personal communications" giving the names of the involved researchers. Obtaining permission to quote personal communications and unpublished data from the cited colleagues is the responsibility of the author. Only footnotes are permitted. Journal abbreviations follow Index Medicus/MEDLINE.

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How to format your references

Please check the Instructions for Authors for the relevant journal and article type for examples of the relevant reference style.

Web links and URLs: All web links and URLs, including links to the authors' own websites, should be given a reference number and included in the reference list rather than within the text of the manuscript. They should be provided in full, including both the title of the site and the URL, as well as the date the site was accessed, in the following format: The Mouse Tumor Biology Database. <http://tumor.informatics.jax.org/mtbwi/index.do>. Accessed 20 May 2013. If an author or group of authors can clearly be associated with a web link, such as for weblogs, then they should be included in the reference.

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Preparing tables

[Back to top](#)

When preparing tables, please follow the formatting instructions below.

- Tables should be numbered and cited in the text in sequence using Arabic numerals (i.e. Table 1, Table 2 etc.).
- Tables less than one A4 or Letter page in length can be placed in the appropriate location within the manuscript.
- Tables larger than one A4 or Letter page in length can be placed at the end of the document text file. Please cite and indicate where the table should appear at the relevant location in the text file so that the table can be added in the correct place during production.
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- Tabular data provided as additional files can be uploaded as an Excel spreadsheet (.xls) or comma separated values (.csv). Please use the standard file extensions.
- Table titles (max 15 words) should be included above the table, and legends (max 300 words) should be included underneath the table.
- Tables should not be embedded as figures or spreadsheet files, but should be formatted using 'Table object' function in your word processing program.
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Preparing additional files

[Back to top](#)

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All Additional files will be published along with the accepted article. Do not include files such as patient consent forms, certificates of language editing, or revised versions of the main manuscript document with tracked changes. Such files, if requested, should be sent by email to the journal's editorial email address, quoting the manuscript reference number. Please do not send completed patient consent forms unless requested.

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Additional files should be named "Additional file 1" and so on and should be referenced explicitly by file name within the body of the article, e.g. 'An additional movie file shows this in more detail [see Additional file 1]'.

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Ref: <https://bmcpublichealth.biomedcentral.com/submission-guidelines/preparing-your-manuscript>

Appendix O

Guidelines for authors: International Journal of Environmental Research and Public Health

Instructions for Authors

Shortcuts

Manuscript Submission Overview

Manuscript Preparation

Preparing Figures, Schemes and Tables

Supplementary Materials, Data Deposit and Software Source Code

Research and Publication Ethics

Reviewer Suggestions

English Corrections

Preprints and Conference Papers

Authorship

Editorial Independence

Conflict of Interests

Editorial Procedures and Peer-Review

Promoting Equity, Diversity and Inclusiveness Within MDPI Journals

Resource Identification Initiative

Submission Checklist

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use the Microsoft Word template or LaTeX template or Free Format Submission to prepare your manuscript;

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Authors are encouraged to add a biography (optional) to the submission and publish it.

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Authors must use the Microsoft Word template or LaTeX template to prepare their manuscript. Using the template file will substantially shorten the time to complete copy-editing and publication of accepted manuscripts. The total amount of data for all files must not exceed 120 MB. If this is a problem, please contact the Editorial Office ijerph@mdpi.com. Accepted file formats are:

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Education background including institution information and year of graduation (type and level of degree received);

Work experience;

Current and previous research interests;

Memberships of professional societies and awards received.

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Authors do not need to separately submit their papers through the NIH Manuscript Submission System (NIHMS, <http://nihms.nih.gov/>).

[Return to top]

Manuscript Preparation

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Research manuscripts should comprise:

Front matter: Title, Author list, Affiliations, Abstract, Keywords

Research manuscript sections: Introduction, Materials and Methods, Results, Discussion, Conclusions.

Back matter: Supplementary Materials, Acknowledgments, Author Contributions, Conflicts of Interest, References.

Review manuscripts should comprise the front matter, literature review sections and the back matter. The template file can also be used to prepare the front and back matter of your review manuscript. It is not necessary to follow the remaining structure. Structured reviews and meta-analyses should use the same structure as research articles and ensure they conform to the PRISMA guidelines.

Case reports should include a succinct introduction about the general medical condition or relevant symptoms that will be discussed in the case report; the case presentation including all of the relevant de-identified demographic and descriptive information about the patient(s), and a description of the symptoms, diagnosis, treatment, and outcome; a discussion providing context

and any necessary explanation of specific treatment decisions; a conclusion briefly outlining the take-home message and the lessons learned.

Graphical Abstract:

A graphical abstract (GA) is an image that appears alongside the text abstract in the Table of Contents. In addition to summarizing content, it should represent the topic of the article in an attention-grabbing way.

The GA should be a high-quality illustration or diagram in any of the following formats: PNG, JPEG, EPS, SVG, PSD or AI. Written text in a GA should be clear and easy to read, using one of the following fonts: Times, Arial, Courier, Helvetica, Ubuntu or Calibri.

The minimum required size for the GA is 560×1100 pixels (height $\times$ width). When submitting larger images, please make sure to keep to the same ratio.

Acronyms/Abbreviations/Initialisms should be defined the first time they appear in each of three sections: the abstract; the main text; the first figure or table. When defined for the first time, the acronym/abbreviation/initialism should be added in parentheses after the written-out form.

SI Units (International System of Units) should be used. Imperial, US customary and other units should be converted to SI units whenever possible.

Accession numbers of RNA, DNA and protein sequences used in the manuscript should be provided in the Materials and Methods section. Also see the section on Deposition of Sequences and of Expression Data.

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[Return to top]

Front Matter

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Author List and Affiliations: Authors' full first and last names must be provided. The initials of any middle names can be added. The PubMed/MEDLINE standard format is used for affiliations: complete address information including city, zip code, state/province, and country. At least one author should be designated as corresponding author, and his or her email address and other details should be included at the end of the affiliation section. Please read the criteria to qualify for authorship.

Abstract: The abstract should be a total of about 200 words maximum. The abstract should be a single paragraph and should follow the style of structured abstracts, but without headings: 1) **Background:** Place the question addressed in a broad context and highlight the purpose of the study; 2) **Methods:** Describe briefly the main methods or treatments applied. Include any relevant preregistration numbers, and species and strains of any animals used. 3) **Results:** Summarize the article's main findings; and 4) **Conclusion:** Indicate the main conclusions or interpretations. The abstract should be an objective representation of the article: it must not contain results which are not presented and substantiated in the main text and should not exaggerate the main conclusions.

Keywords: Three to ten pertinent keywords need to be added after the abstract. We recommend that the keywords are specific to the article, yet reasonably common within the subject discipline.

Research Manuscript Sections

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Materials and Methods: They should be described with sufficient detail to allow others to replicate and build on published results. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited. Give the name and version of any software used and make clear whether computer code used is available. Include any pre-registration codes.

Results: Provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

Discussion: Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible and limitations of the work highlighted. Future research directions may also be mentioned. This section may be combined with Results.

Conclusions: This section is mandatory, and should provide readers with a brief summary of the main conclusions.

Patents: This section is not mandatory, but may be added if there are patents resulting from the work reported in this manuscript.

[Return to top]

Back Matter

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Funding: All sources of funding of the study should be disclosed. Clearly indicate grants that you have received in support of your research work and if you received funds to cover publication costs. Note that some funders will not refund article processing charges (APC) if the funder and grant number are not clearly and correctly identified in the paper. Funding information can be entered separately into the submission system by the authors during submission of their manuscript. Such funding information, if available, will be deposited to FundRef if the manuscript is finally published.

Please add: “This research received no external funding” or “This research was funded by [name of funder] grant number [xxx]” and “The APC was funded by [XXX]” in this section. Check carefully that the details given are accurate and use the standard spelling of funding agency names at <https://search.crossref.org/funding>, any errors may affect your future funding.

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References: References must be numbered in order of appearance in the text (including table captions and figure legends) and listed individually at the end of the manuscript. We recommend preparing the references with a bibliography software package, such as EndNote, ReferenceManager or Zotero to avoid typing mistakes and duplicated references. We encourage citations to data, computer code and other citable research material. If available online, you may use reference style 9. below.

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

In the text, reference numbers should be placed in square brackets [], and placed before the punctuation; for example [1], [1–3] or [1,3]. For embedded citations in the text with pagination, use both parentheses and brackets to indicate the reference number and page numbers; for example [5] (p. 10). or [6] (pp. 101–105).

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1. Author 1, A.B.; Author 2, C.D. Title of the article. Abbreviated Journal Name Year, Volume, page range.

Books and Book Chapters:

2. Author 1, A.; Author 2, B. Book Title, 3rd ed.; Publisher: Publisher Location, Country, Year; pp. 154–196.

3. Author 1, A.; Author 2, B. Title of the chapter. In Book Title, 2nd ed.; Editor 1, A., Editor 2, B., Eds.; Publisher: Publisher Location, Country, Year; Volume 3, pp. 154–196.

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Websites:

9. Title of Site. Available online: URL (accessed on Day Month Year).

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[Return to top]

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All Figures, Schemes and Tables should have a short explanatory title and caption.

All table columns should have an explanatory heading. To facilitate the copy-editing of larger tables, smaller fonts may be used, but no less than 8 pt. in size. Authors should use the Table option of Microsoft Word to create tables.

Authors are encouraged to prepare figures and schemes in color (RGB at 8-bit per channel).

There is no additional cost for publishing full color graphics.

[Return to top]

Supplementary Materials, Data Deposit and Software Source Code

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Data Availability Statements provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study.

Below are suggested Data Availability Statements:

Data available in a publicly accessible repository

The data presented in this study are openly available in [repository name e.g., FigShare] at [doi], reference number [reference number].

Data available in a publicly accessible repository that does not issue DOIs

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Data available on request due to restrictions eg privacy or ethical

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to [insert reason here]

3rd Party Data

Restrictions apply to the availability of these data. Data was obtained from [third party] and are available [from the authors / at URL] with the permission of [third party].

Data sharing not applicable

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Data is contained within the article or supplementary material

The data presented in this study are available in [insert article or supplementary material here]

Data citation:

[dataset] Authors. Year. Dataset title; Data repository or archive; Version (if any); Persistent identifier (e.g., DOI).

Computer Code and Software

For work where novel computer code was developed, authors should release the code either by depositing in a recognized, public repository such as GitHub or uploading as supplementary information to the publication. The name, version, corporation and location information for all software used should be clearly indicated. Please include all the parameters used to run software/programs analyses.

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

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

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

Remote Hosting and Large Data Sets

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

Deposition of Sequences and of Expression Data

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

New nucleic acid sequences must be deposited in one of the following databases: GenBank, EMBL, or DDBJ. Sequences should be submitted to only one database.

New high throughput sequencing (HTS) datasets (RNA-seq, ChIP-Seq, degradome analysis, ...) must be deposited either in the GEO database or in the NCBI's Sequence Read Archive (SRA).

New microarray data must be deposited either in the GEO or the ArrayExpress databases. The "Minimal Information About a Microarray Experiment" (MIAME) guidelines published by the Microarray Gene Expression Data Society must be followed.

New protein sequences obtained by protein sequencing must be submitted to UniProt (submission tool SPIN). Annotated protein structure and its reference sequence must be submitted to RCSB of Protein Data Bank.

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

Deposition of Proteomics Data

Methods used to generate the proteomics data should be described in detail and we encourage authors to adhere to the "Minimum Information About a Proteomics Experiment". All generated mass spectrometry raw data must be deposited in the appropriate public database such as ProteomeXchange, PRIDE or jPOST. At the time of submission, please include all relevant information in the materials and methods section, such as repository where the data was submitted and link, data set identifier, username and password needed to access the data.

[Return to top]

Research and Publication Ethics

Research Ethics

Research Involving Human Subjects

When reporting on research that involves human subjects, human material, human tissues, or human data, authors must declare that the investigations were carried out following the rules of the Declaration of Helsinki of 1975 (<https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/>), revised in 2013. According to point 23 of this declaration, an approval from an ethics committee should have been obtained before undertaking the research. At a minimum, a statement including the project identification code, date of approval, and name

of the ethics committee or institutional review board should be stated in Section ‘Institutional Review Board Statement’ of the article. Data relating to individual participants must be described in detail, but private information identifying participants need not be included unless the identifiable materials are of relevance to the research (for example, photographs of participants’ faces that show a particular symptom). Editors reserve the right to reject any submission that does not meet these requirements.

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

A written informed consent for publication must be obtained from participating patients who can be identified (including by the patients themselves). Patients’ initials or other personal identifiers must not appear in any images. For manuscripts that include any case details, personal information, and/or images of patients, authors must obtain signed informed consent from patients (or their relatives/guardians) before submitting to an MDPI journal. Patient details must be anonymized as far as possible, e.g., do not mention specific age, ethnicity, or occupation where they are not relevant to the conclusions. A template permission form is available to download. A blank version of the form used to obtain permission (without the patient names or signature) must be uploaded with your submission.

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Ethical Guidelines for the Use of Animals in Research

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

Replacement of animals by alternatives wherever possible,

Reduction in number of animals used, and

Refinement of experimental conditions and procedures to minimize the harm to animals.

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

Manuscripts containing original descriptions of research conducted in experimental animals must contain details of approval by a properly constituted research ethics committee. As a minimum, the project identification code, date of approval and name of the ethics committee or institutional review board should be stated in Section ‘Institutional Review Board Statement’.

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

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

Research Involving Cell Lines

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

An example of Ethical Statements:

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

Research Involving Plants

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

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

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

An example of Ethical Statements:

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

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

Clinical Trials Registration Registration

MDPI follows the International Committee of Medical Journal Editors (ICMJE) guidelines which require and recommend registration of clinical trials in a public trials registry at or before the time of first patient enrollment as a condition of consideration for publication.

Purely observational studies do not require registration. A clinical trial not only refers to studies that take place in a hospital or involve pharmaceuticals, but also refer to all studies which involve participant randomization and group classification in the context of the intervention under assessment.

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

Approval to conduct a study from an independent local, regional, or national review body is not equivalent to prospective clinical trial registration. MDPI reserves the right to decline any paper without trial registration for further peer-review. However, if the study protocol has been published before the enrolment, the registration can be waived with correct citation of the published protocol.

CONSORT Statement

MDPI requires a completed CONSORT 2010 checklist and flow diagram as a condition of submission when reporting the results of a randomized trial. Templates for these can be found here or on the CONSORT website (<http://www.consort-statement.org>) which also describes several CONSORT checklist extensions for different designs and types of data beyond two group parallel trials. At minimum, your article should report the content addressed by each item of the checklist.

[Return to top]

Sex and Gender in Research

We encourage our authors to follow the ‘Sex and Gender Equity in Research – SAGER – guidelines’ and to include sex and gender considerations where relevant. Authors should use the terms sex (biological attribute) and gender (shaped by social and cultural circumstances) carefully in order to avoid confusing both terms. Article titles and/or abstracts should indicate clearly what sex(es) the study applies to. Authors should also describe in the background, whether sex and/or gender differences may be expected; report how sex and/or gender were accounted for in the design of the study; provide disaggregated data by sex and/or gender, where appropriate; and discuss respective results. If a sex and/or gender analysis was not conducted, the rationale should be given in the Discussion. We suggest that our authors consult the full guidelines before submission.

[Return to top]

Borders and Territories

Potential disputes over borders and territories may have particular relevance for authors in describing their research or in an author or editor correspondence address, and should be respected. Content decisions are an editorial matter and where there is a potential or perceived dispute or complaint, the editorial team will attempt to find a resolution that satisfies parties involved.

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Any facts that might be perceived as a possible conflict of interest of the author(s) must be disclosed in the paper prior to submission.

Authors should accurately present their research findings and include an objective discussion of the significance of their findings.

Data and methods used in the research need to be presented in sufficient detail in the paper, so that other researchers can replicate the work.

Raw data should preferably be publicly deposited by the authors before submission of their manuscript. Authors need to at least have the raw data readily available for presentation to the referees and the editors of the journal, if requested. Authors need to ensure appropriate measures are taken so that raw data is retained in full for a reasonable time after publication.

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If errors and inaccuracies are found by the authors after publication of their paper, they need to be promptly communicated to the editors of this journal so that appropriate actions can be taken. Please refer to our policy regarding Updating Published Papers.

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

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

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

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

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Authors should not copy references from other publications if they have not read the cited work.

Authors should not preferentially cite their own or their friends', peers', or institution's publications.

Authors should not cite advertisements or advertorial material.

In accordance with COPE guidelines, we expect that "original wording taken directly from publications by other researchers should appear in quotation marks with the appropriate citations." This condition also applies to an author's own work. COPE have produced a discussion document on citation manipulation with recommendations for best practice.

[Return to top]

Reviewer Suggestions

During the submission process, please suggest three potential reviewers with the appropriate expertise to review the manuscript. The editors will not necessarily approach these referees. Please provide detailed contact information (address, homepage, phone, e-mail address). The proposed referees should neither be current collaborators of the co-authors nor have published with any of the co-authors of the manuscript within the last five years. Proposed reviewers

should be from different institutions to the authors. You may identify appropriate Editorial Board members of the journal as potential reviewers. You may suggest reviewers from among the authors that you frequently cite in your paper.

[Return to top]

English Corrections

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

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

[Return to top]

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

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[Return to top]

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Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
Drafting the work or revising it critically for important intellectual content; AND
Final approval of the version to be published; AND
Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
Those who contributed to the work but do not qualify for authorship should be listed in the acknowledgments. More detailed guidance on authorship is given by the International Council of Medical Journal Editors (ICMJE).

Any change to the author list should be approved by all authors including any who have been removed from the list. The corresponding author should act as a point of contact between the editor and the other authors and should keep co-authors informed and involve them in major decisions about the publication. We reserve the right to request confirmation that all authors meet the authorship conditions.

For more details about authorship please check MDPI ethics website.

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Adequacy of reviewer comments and author response;

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[Return to top]

Editorial Procedures and Peer-Review Initial Checks

All submitted manuscripts received by the Editorial Office will be checked by a professional in-house Managing Editor to determine whether they are properly prepared and whether they follow the ethical policies of the journal, including those for human and animal experimentation. Manuscripts that do not fit the journal's ethics policy or do not meet the standards of the journal will be rejected before peer-review. Manuscripts that are not properly prepared will be returned to the authors for revision and resubmission. After these checks, the Managing Editor will consult the journals’ Editor-in-Chief or Associate Editors to determine whether the manuscript fits the scope of the journal and whether it is scientifically sound. No judgment on the potential

impact of the work will be made at this stage. Reject decisions at this stage will be verified by the Editor-in-Chief.

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Reconsider after Major Revisions:

The acceptance of the manuscript would depend on the revisions. The author needs to provide a point by point response or provide a rebuttal if some of the reviewer's comments cannot be revised. Usually, only one round of major revisions is allowed. Authors will be asked to resubmit the revised paper within a suitable time frame, and the revised version will be returned to the reviewer for further comments.

Reject and Encourage Resubmission:

If additional experiments are needed to support the conclusions, the manuscript will be rejected and the authors will be encouraged to re-submit the paper once further experiments have been conducted.

Reject:

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

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

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

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Production and Publication

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

[Return to top]

Promoting Equity, Diversity and Inclusiveness Within MDPI Journals

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[Return to top]

Resource Identification Initiative

To improve the reproducibility of scientific research, the Resource Identification Initiative aims to provide unique persistent identifiers for key biological resources, including antibodies, cell lines, model organisms and tools.

We encourage authors to include unique identifiers - RRIDs- provided by the Resource Identification Portal in the dedicated section of the manuscript.

To help authors quickly find the correct identifiers for their materials, there is a single website where all resource types can be found and a 'cite this' button next to each resource, that contains a proper citation text that should be included in the methods section of the manuscript.

[Return to top]

Appendix P

Submission letter for publication to *IJERPH*

Acknowledgement:

From: Editorial Office <ijerph@mdpi.com>
To: Monyeki Makama Andries <andries.monyeki@nwu.ac.za>
CC: Caroline M Sedumedi <mmalekgotlha@gmail.com>, Xanne Janssen <xanne.janss...>
Date: 2021/05/24 17:05
Subject: [IJERPH] Manuscript ID: ijerph-1252797 - Submission Received

Dear Professor Makama Andries,

Thank you very much for uploading the following manuscript to the MDPI submission system. One of our editors will be in touch with you soon.

Journal name: International Journal of Environmental Research and Public Health

Manuscript ID: ijerph-1252797

Type of manuscript: Review

Title: Association between objectively determined physical activity levels and body composition in 6–8-year-old children from a black South African population: BC–IT study

Authors: Caroline M Sedumedi, Xanne Janssen, John J Reilly, Herculina S Kruger, Andries Monyeki *

Received: 24 May 2021

E-mails: mmalekgotlha@gmail.com, xanne.janssen@strath.ac.uk, john.j.reilly@strath.ac.uk, Salome.Kruger@nwu.ac.za, Andries.Monyeki@nwu.ac.za

Submitted to section: Adolescents,

<https://www.mdpi.com/journal/ijerph/sections/adolescents>

24-Hour Movement Behaviors (Physical Activity, Sedentary Behaviour and Sleep) in the under 5s, Children and Adolescents

https://www.mdpi.com/journal/ijerph/special_issues/24H_MB

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The following points were confirmed during submission:

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If you have any questions, please do not hesitate to contact the IJERPH editorial office at ijerph@mdpi.com

Kind regards,

IJERPH Editorial Office

St. Alban-Anlage 66, 4052 Basel, Switzerland

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Fax: +41 61 302 89 18

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Appendix Q

Proof of language editing

STATEMENT ON EDITORIAL ASSISTANCE

I hereby confirm that I, Helen Elizabeth ROBINSON, edited the doctoral thesis written by Caroline Sedumedi, titled 'Association between objectively determined physical activity levels and body fat percentage in 6–8-year-old children from a black South African population: BC–IT study'. Corrections were made in respect of grammar, punctuation, spelling, syntax, tense and language use. The content remains entirely the work of the author. My edit may not be identical to that submitted. At their discretion, the author has the prerogative to accept, delete or change, before submission, amendments made by the editor.

Helen Robinson

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Appendix R

TURNITIN REPORT

Interpretation of a TURNITIN SUMMARY: The similarity index of 26% which is 1% higher than the cut off of less than 25% is attributed to by the NWU matching documents for formatting of thesis, subject terminology and the methodology in BC – IT study (larger study) on isotopes protocol as published PLOS One paper: Moeng-Mahlangu LT, Monyeki MA, Reilly JJ, Mchiza ZJ, Moleah T, Loechl CU, et al. (2020). Level of agreement between objectively determined body composition and perceived body image in 6- to 8-year-old South African children: The Body Composition–Isotope Technique study. PLoS ONE 15(8): e0237399.

<https://doi.org/10.1371/journal.pone.0237399>, etc; also IAEA for isotopes measurements protocol. To bring down the similarity index, amendments in the form of rephrasing the work has been made.

See included summary report:

11939044:Thesis_draft_1_Caroline_Sedumedi_HR_25_may_L... ITIN.docx

ORIGINALITY REPORT

26%

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BRICSCESS ABSTRACTS. "BRICSCESS ABSTRACTS - JOINT SASMA BRICSCESS CONGRESS 2019", South African Journal of Sports Medicine, 2019

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"Handbook of Anthropometry", Springer Science and Business Media LLC, 2012

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Publication

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worldwidescience.org

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Appendix S

Article 3 published in *International Journal of Environmental Research and Public Health*

Int. J. Environ. Res. Public Health 2021, 18(12), 6453; <https://doi.org/10.3390/ijerph18126453>

