

**Associations between cardiorespiratory fitness and
changes in cardiovascular risk factors in 10-13 year old
children: The NW-CHILD study**

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DECLARATION

Three researchers accomplished this dissertation, and we present it in **article format**. This statement serves as permission by the co-authors that this dissertation may be submitted for fulfilment of the requirements for degree purposes of Master of Health Sciences in Human Movement Sciences within Physical Activity, Sport and Recreation (PhASRec) in the Faculty of Health Sciences at the North-West University. The contribution of each co-author was within acceptable limits and included:

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Solemn statement by supervisor and co-supervisor

We hereby declare that this dissertation and the above articles are approved, and that our roles, as mentioned above, are correct and a true reflection of our contributions to this study. We further give permission that the articles may be submitted as a section of the dissertation by Mrs Lisa Claasen.

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“Trust in the Lord with all your heart, and lean not on your own understanding; In all your ways acknowledge Him, and He shall direct your paths...”

Proverbs 3 (NKJV)

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SUMMARY

Associations between cardiorespiratory fitness and changes in cardiovascular clustered risk factors in 10–13-year-old children: The NW-CHILD Study

International and South African literature indicated two main findings regarding adolescent body composition, blood pressure and cardiorespiratory fitness. Primarily, literature made it evident that as cardiorespiratory fitness decreased, the prevalence of obesity and hypertension increased among children and adolescents. Furthermore, literature confirmed the associations between cardiorespiratory fitness, obesity and hypertension. The concern about increasing obesity and hypertension prevalence along with declining fitness, is amplified when the negative effects for our youth are considered. There is, however, a gap in current research regarding the longitudinal cardiorespiratory fitness, obesity and hypertension prevalence and their associations among South African adolescents from the North West Province.

With this knowledge, this dissertation firstly aims to determine longitudinal changes in cardiorespiratory fitness and two components of cardiovascular risk factors (obesity and hypertension) among South African adolescents. Secondly, this dissertation aims to determine longitudinal associations between cardiorespiratory fitness and two cardiovascular risk components (obesity and hypertension).

The aims were accomplished using the stratified randomised data of South African participants from the NW-CHILD study in 2013 (N = 864, mean age = 9.88 years, boys = 455 and girls = 409) and 2016 (N = 558, mean age = 12.89 years, boys = 290 and girls = 268). We collected measurement values using standardised anthropometric techniques for age-sex-adjusted body mass index cut-off points, body fat percentage and blood pressure results. Maximal oxygen consumption ($\dot{V}O_2$ max) values, used as an indication of cardiorespiratory fitness, were determined from the total laps ran during the FitnessGram 20m Progressive Aerobic Cardiovascular Endurance Run. The laps ran were converted to an estimation of $\dot{V}O_2$ max through Mahar *et al.*'s (2011:119) conversion tables. During data investigation the measurement values were analysed to determine changes in and associations between cardiorespiratory fitness and two clustered cardiovascular disease risk factors by using descriptive statistics, Pearson Product Moment, analysis of covariance, paired sample t-test, Spearman's rank order correlation and practical effect size.

The results of the first aim indicated significant ($p \leq 0.05$) increases in thinness grade one (5.4%–23.3%), standard weight (18.4%–34.4%), and overweight and obesity (4.5%–10.6%). An insignificant ($p > 0.05$) decrease was noted for cardiorespiratory fitness (42.45 mL/kg/min–42.04 mL/kg/min). The insignificant change in cardiorespiratory fitness, with growth or beneficial life-style modifications, may have contributed to decreases in pre-hypertension (15%–7.7%) and hypertension (13%–6.3%). The body composition changes

had high significant ($p \leq 0.05$) developmental correlation coefficients, while blood pressure and cardiorespiratory fitness showed moderate and low coefficients. The results of the second aim indicated high tracking coefficients for body mass index, body fat percentage, and the total sample's $\dot{V}O_2$ max. A moderate tracking correlation was noted for systolic blood pressure; girls' diastolic blood pressure; and $\dot{V}O_2$ max among boys and girls, yet the sample and boy's diastolic blood pressure showed weak correlations. The body fat increase had a significant inverse influence on the insignificant decrease in cardiorespiratory fitness. The insignificant decrease of cardiorespiratory fitness significantly influenced blood pressure; where blood pressure increased among adolescents when adjusted for age and sex.

With this understanding of changes and relationships between cardiorespiratory fitness, hypertension and obesity, it is important to intervene and help adolescents improve their health.

Key words: Adolescents; Blood pressure; Cardiorespiratory fitness; Clustered cardiovascular risk factors; Obesity.

OPSOMMING

Verwantskappe tussen kardiorespiratoriese fiksheid en veranderinge in kardiovaskulêre siekte gegroepeerde risiko faktore in 10–13 jarige kinders: NW-CHILD Studie

Internasionale en Suid-Afrikaanse literatuur het twee hoof bevindinge rakende liggaamssamestelling, bloeddruk en kardiorespiratoriese fiksheid by adolessente bevind. Hoofsaaklik, het literatuur dit duidelik gemaak dat soos kardiorespiratoriese fiksheid verlaag het, het obesiteit en hipertensie tussen kinders en adolessente verhoog. Verder het die literatuur ook die verband tussen kardiorespiratoriese fiksheid, hipertensie en obesiteit bevestig. Die nuwe-effekte van onfiksheid, obesiteit en hoë bloeddruk is kommerwekkend en gevaarlik vir ons kinders en adolessente. Daar is 'n gaping in nuwe lang termyn navorsing rakende veranderinge in en verbande tussen kardiorespiratoriese fiksheid, obesiteit en hipertensie in Suid-Afrikaanse adolessente van die Noord-Wes Provinsie.

Die eerste doel van hierdie verhandeling is om die veranderinge in kardiorespiratoriese fiksheid en twee hoof gegroepeerde kardiovaskulêre siekte risiko faktore (obesiteit en hipertensie) in Suid-Afrikaanse adolessente oor 'n tydperk van drie jaar te evalueer. Die tweede doel van die verhandeling is om die lang termyn verband tussen kardiorespiratoriese fiksheid en twee hoof gegroepeerde kardiovaskulêre siekte risiko faktore (obesiteit en hipertensie) te bepaal.

Die doelstellings is bereik deur die gebruik van gestratifiseerde ewekansige geselekteerde deelnemers se data van die NW-CHILD Studie in 2013 (N = 864, gemiddelde ouderdom = 9.88 jaar, seuns = 455 en meisies = 409) en in 2016 (N = 558, gemiddelde ouderdom = 12.89 jaar, seuns = 290 en meisies = 268). Die data is ingesamel deur gebruik van gestandaardiseerde antropometriese tegnieke vir geslag- en ouderdomsaangepaste liggaamsmassa-indeks afsnypunte, liggaamsvetpersentasie en bloeddrukresultate. Maksimale suurstofverbruikwaardes ($\dot{V}O_2$ maks), wat 'n aanduiding van kardiorespiratoriese fiksheid is, was deur *FitnessGram* se 20m 'Progressive Aerobic Cardiovascular Endurance Run' se aanhaal rondtes bepaal. Die aantal rondtes wat gehardloop is, was na $\dot{V}O_2$ makswaardes omskep deur gebruik van Mahar *et al.* (2011:119) se $\dot{V}O_2$ maks tabelle. Tydens data-analise is die veranderinge en verwantskappe tussen kardiorespiratoriese fiksheid en twee hoof gegroepeerde kardiovaskulêre siekte risiko faktore bepaal deur gebruik te maak van beskrywende statistieke, 'Pearson Product Moment', ontleding van kovariansie, onafhanklike t-toets, Spearman se rangorde korrelasie en praktiese effek groote.

Die eerste doelwit se resultate het betekenisvolle ($p \leq 0.05$) verhogings in slankheid graad een (5.4%–23.3%), standaardgewig (18.4%–34.4%) sowel as oorgewig en obesiteit (4.5%–10.6%) bewys oor drie jaar. $\dot{V}O_2$ maks het verlaag, wat nie statistiese betekenisvol is nie ($p > 0.05$) (42.45 mL/kg/min–42.04 mL/kg/min). Die

statistiese onbetekenisvolle verlaging in fiksheid, tesame met groei of positiewe leefstylverandering, kon bydra tot die vermindering van hipertensie (13%–6.3%). Die verandering in liggaamssamestelling het hoë betekenisvolle ($p \leq 0.05$) korrelasies getoon, terwyl bloeddruk en kardiorespiratoriese fiksheid matige en lae korrelasies getoon het.

Die uitslae van die tweede doelwit het aangedui dat liggaamsmassa-indeks, liggaamsvet persentasie en $\dot{V}O_2$ maks hoë koëffisiënt vir ‘tracking’ oor drie jaar aangedui het. Die groep se sistoliese bloeddruk, meisies se diastoliese bloeddruk en die groep, seuns en meisies se $\dot{V}O_2$ maks het matig vir navolging getoon. Waar die groep en seuns se diastoliese bloeddruk lae navolging gewys het. Die verhoging van liggaamsvet persentasie het ’n betekenisvolle negatiewe invloed op die onstatistiese kardiorespiratoriese fiksheid toename in adolessente. Die toename in kardiorespiratoriese fiksheid het ’n betekenisvolle invloed op die verhoging van bloeddruk getoon, met aanpassing vir ouderdom en geslag. Met hierdie inligting van veranderinge en verwantskappe tussen kardiorespiratoriese fiksheid, obesiteit en hipertensie, is dit belangrik om in te gryp en adolessente te help om hul gesondheid te verbeter.

Kernwoorde: Adolessente; Bloeddruk; Kardiorespiratoriese fiksheid; Gegroepeerde kardiovaskulêresiekte risiko faktore; Obesiteit.

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LIST OF ABBREVIATIONS

ΣSF	Sum of Skinfolts
BC	Body Composition
BF%	Body Fat Percentage
BMI	Body Mass Index
BP	Blood Pressure
CRF	Cardiorespiratory Fitness
CV	Cardiovascular
CVD	Cardiovascular disease
DBP	Diastolic Blood Pressure
HTN	Hypertension
NHBPEP	National High Blood Pressure Education Program Working Group
NW-CHILD	North West Child-Health-Integrated-Learning and Development
NWP	North West Province
OW	Overweight
PA	Physical Activity
SA	South Africa
SBP	Systolic Blood Pressure
SES	Socio-economic Status
$\dot{V}O_2$ max	Maximal oxygen consumption
WC	Waist Circumference
WHO	World Health Organisation

CHAPTER ONE

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Researchers indicated that children and adolescents have decreasing cardiorespiratory fitness (CRF) levels, and that obesity and hypertension (HTN) are increasing, internationally and from South Africa (SA) (HAKSA, 2018:7; Kallerman, 2019:36; Monyeki *et al.*, 2007:551; Moselakgomo *et al.*, 2012:567). These changes in the youth's fitness, weight and blood pressure (BP) can be caused by various influencing factors, like environmental circumstances, life-style choices and health conditions (Nqweniso *et al.*, 2020:8; Ruiz *et al.*, 2015:767; Stabouli & Kotsis, 2018:117). Hypertension, CRF and obesity each have numerous severe negative effects, which may result in premature mortality (Anderssen *et al.*, 2007:529; Pazin *et al.*, 2017:510). Moreover, associations between CRF, obesity and HTN have been confirmed among children and adolescents (Kemp *et al.*, 2011:120; Monyeki *et al.*, 2017:119; Pazin *et al.*, 2017:509).

With these international and South African findings on CRF, obesity and HTN changes and associations, further research is necessary to confirm or refute the findings within a South African context. The outline for this study is set out in the introductory chapter, namely the problem statement, objectives, hypotheses, terminology list and the proposed chapters.

1.2 PROBLEM STATEMENT

Children's health is deteriorating due to decreasing CRF levels and increasing cardiovascular disease (CVD) risk factors like obesity and HTN (Agostinis-Sobrinho *et al.*, 2018:134; World Health Organisation (WHO), 2020).

Cardiorespiratory fitness is a vital component of physical activity (PA) (Brito *et al.*, 2016:685; Nqweniso *et al.*, 2020:8; Pazin *et al.*, 2017:509). Physical activity is any movement of the body caused by the skeletal muscles that produces an outcome of energy expenditure above resting levels (Kallerman, 2019:36). Cardiorespiratory fitness or aerobic fitness is defined as the ability to perform prolonged PA while tolerating fatigue (Kent, 2006). The CRF level is reflected by the duration of time the aerobic activity can be carried out depending on the capability of the heart and lungs to transport adequate amounts of oxygen to the exercising muscles and the muscles' ability to use the oxygen efficiently (Kent, 2006). According to Kent (2006), most scientists view maximal oxygen uptake ($\dot{V}O_2$ max) as the best objective indicator of CRF. Children and adolescents' lack in PA participation leads to CRF levels to decrease (Anderssen *et al.*, 2007:530; Kallerman, 2019:36; Pazin *et al.*, 2017:509).

Researchers identified various outcomes regarding CRF prevalence changes. Certain results indicated a longitudinal increase in CRF (Agostinis-Sobrinho *et al.*, 2018:132; Kallerman, 2019:36; Monyeki *et al.*, 2007:553), whereas others noted a longitudinal decrease (Kallerman, 2019:36; Monyeki *et al.*, 2007:553) among children and adolescents 7–16 years old. Awotidebe *et al.* (2016:247) and Monyeki *et al.* (2017:119) identified the prevalence of CRF among adolescents of two South African regions, which ranged between 37.36 mL/kg/min and 41.01 mL/kg/min among boys, and between 29.10 mL/kg/min and 29.25 mL/kg/min among girls. The results indicated a lower range in CRF levels among participants classified as overweight (OW) (between 26.66 mL/kg/min and 27.28 mL/kg/min) when compared to participants classified as normal weight (between 31.58 mL/kg/min and 34.12 mL/kg/min) (Awotidebe *et al.*, 2016:247; Monyeki *et al.*, 2017:119). Monyeki *et al.* (2017:119) found that 68.5% of their adolescent participants were sedentary.

As fitness levels decline, young people become more vulnerable for negative effects of poor CRF, like CVD risk factors (Anderssen *et al.*, 2007:529; Brito *et al.*, 2016:683; Monyeki *et al.*, 2017:118). The association between poor CRF with lifestyle choices and with CVD risk factors has been confirmed among children and adolescents independent of age, sex and origin (Anderssen *et al.*, 2007:529; Brito *et al.*, 2016:683; Ruiz *et al.*, 2015:767–768). The lifestyle choices were identified as dietary, smoking and PA participation, whereas several identified CVD risk factors are known as BMI, OW, obesity, plasma triglycerides; the four skinfolds sum, BP as well as total blood cholesterol and high-density lipoprotein cholesterol ratio (Anderssen *et al.*, 2007:529; Brito *et al.*, 2016:683; Ruiz *et al.*, 2015:767–768). Two main CVD risk factors were chosen for analysis in this study, namely obesity and HTN.

Overweight, obesity and poor CRF are strong predictors of adverse CVD risk factors (Agostinis-Sobrinho *et al.*, 2018:132; Anderssen *et al.*, 2007:530; Ekoru *et al.*, 2017:6; Laghi & Rengo, 2017:3). The WHO (2020) defines risk factors as any characteristic, exposure or attribute of a person, which increases the risks of injury or developing a disease. Clustered risk factor is a group of biological risk factors with similar, yet compounded, repercussions as a single risk factor would present (Anderssen *et al.*, 2007:528). Cardiovascular risk factors are characteristics that increase one's risks of developing a CVD (Himmelfarb & Alp Ikizler, 2010:130). Cardiovascular diseases include HTN, excessive fat deposits, dyslipidaemia, left ventricular dysfunction, diabetes and heart failure (Ekoru *et al.*, 2017:6; Gao *et al.*, 2013:2). Four major components of CVD are HTN, diabetes, OW and dyslipidaemia (Gao *et al.*, 2013:2). The clustering of CVD risk factors is the existence of at least two major CVD risk factors in one individual (Gao *et al.*, 2013:2). Several common adult CV risk factors, especially increased rate of excessive fat gain, have now been observed in clusters among children, causing early onset of CVD and manifestation of symptoms from youth throughout adulthood (Anderssen *et al.*, 2007:526; Goon *et al.*, 2013:492; Laghi & Rengo, 2017:3; Moselakgomo & Van Staden, 2017:189; Sinaiko *et al.*, 1999:1474). Research has established that as the body mass index (BMI) of young people increased there

was an additional increase in the CVD risk factors among children and adolescents (Kemp *et al.*, 2011:120; Nqweniso *et al.*, 2020:8; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis, 2018:117).

The WHO (2020) defines OW or obesity as excessive or unusual amounts of fat deposits within one's body that puts one at risk for chronic diseases, namely cancer, diabetes and other CVDs. The prevalence of OW and obesity have nearly tripled, reaching epidemic proportions worldwide, and affecting youth and adults alike (WHO, 2020).

The prevalence of OW and obesity amongst children and adolescents from various South African provinces, ranged between 0.9%–7.8% for OW and between 0.5%–24.5% for obesity (Kemp *et al.*, 2011:119; Moselakgomo & Van Staden, 2017:189; Nqweniso *et al.*, 2020:6; Pienaar, 2015:9). Kemp *et al.* (2011:119) noted the prevalence according to sex for OW (boys = 6.4%; girls = 9.3%) and obesity (boys = 3.3%; girls = 4.3%) amongst South African Grade one learners from the North West Province (NWP). The Healthy Active Kids South Africa Report Card of 2018 (HAKSA, 2018:7) indicated that the rise of OW and obesity is persistent, particularly amongst girls. Several studies have proven and supported significant associations between rising obesity prevalence's and related negative effects on children and adolescents' physical, emotional and social well-being (Agostinis-Sobrinho *et al.*, 2018:132; Anderssen *et al.*, 2007:530; Brito *et al.*, 2016:683; Monyeki *et al.*, 2017:118).

Once a child becomes OW or obese, he or she experiences physical or psychological symptoms and functional limitations, all of which have negative impacts on the child's quality of life (Laghi & Rengo, 2017:3; Pazin *et al.*, 2017:510). An association between poor CRF levels and participants classified as OW or obese has been noted among youth (Awotidebe *et al.*, 2016:247; Brito *et al.*, 2016:683; Monyeki *et al.*, 2017:119). Laghi and Rengo (2017:3) reported that obesity, with its comorbidities and risk factors, may also lead to premature mortality. A high body fat percentage (BF%) predetermines development and severity of HTN (Agostinis-Sobrinho *et al.*, 2018:132; Kemp *et al.*, 2011:120; Moselakgomo & Van Staden, 2017:189; Pazin *et al.*, 2017:511; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis, 2018:117).

The association between BF%, waist circumference (WC), BMI, OW and / or obesity with high BP among children and adolescents has been established by several studies (Kemp *et al.*, 2011:120; Moselakgomo & Van Staden, 2017:189; Pazin *et al.*, 2017:511; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis, 2018:117). For example, Liu *et al.* (2017:811) noted the prevalence of HTN amongst Chinese children changed as their weight classification changed. The HTN prevalence was highest amongst the obese classified boys (40.5%) and girls (45.9%), decreased in the OW boys (27.6%) and girls (30.2%) and was the lowest amongst the non-OW boys (9.0%) and girls (13.8%) (Liu *et al.*, 2017:811). The mean high BP prevalence was 39.5% among boys and 49.5% among girls (Liu *et al.*, 2017:811).

Normal BP is when systolic (SBP) and/or diastolic blood pressure (DBP) values are on or less than the 90th percentile for age, sex and stature according to the cut-off points of the National High Blood Pressure Education Program Working Group (NHBPEP) on high BP in children and adolescents (NHBPEP *et al.*, 2005:8). Prehypertension is diagnosed when SBP and/or DBP are greater than the 90th percentile but less than 95th percentile, while paediatric HTN is when SBP and/or DBP greater than or equal to the 95th BP percentile for age, sex and stature (NHBPEP *et al.*, 2005:8). To date, the prevalence of HTN (being a CVD risk factor) is quite high amongst youth and adults (Agostinis-Sobrinho *et al.*, 2018:132; Goon *et al.*, 2013:493; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567).

Hypertension is a preliminary risk for disability and death, affecting about 874 million adults worldwide (Cifu & Davis, 2017:2133). Kemp *et al.* (2011:120) noted the pre-hypertensive prevalence among South African children from the NWP, to be 8.5% for the group, 9.8% amongst the boys and 6.8% amongst the girls. The prevalence for HTN among children and adolescents of specific regions from SA, ranged between 0% and 35.5%, whereas according to sex the prevalence ranged between 0.2% and 48% among boys and between 0.1% and 52% among girls (Goon *et al.*, 2013:493; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7). Researchers who found an increase in HTN identified that the increase was correlated with age (Goon *et al.*, 2013:493; Moselakgomo *et al.*, 2012:567) and weight status classification (Kemp *et al.*, 2011:120).

Several hypertensive related negative effects were identified among young people (Cifu & Davis, 2017:2133; Pazin *et al.*, 2017:509; Sinaiko *et al.*, 1999:1473). Elevated SBP has been associated with insulin resistance and increased levels of fasting insulin (Sinaiko *et al.*, 1999:1473). Hypertension has been found to be associated with CVD, heart failures, kidney diseases, strokes and premature mortality (Cifu & Davis, 2017:2133). Hypertension and obesity are modifiable and preventable which can be adjusted with various lifestyle changes that include chronic stress reduction; dietary adjustments and exercise or CRF improvements (Cifu & Davis, 2017:2133; Pazin *et al.*, 2017:509).

Although several studies have been performed regarding poor CRF levels, obesity and HTN internationally, a gap in South African research has been identified. The cited South African literature differs from the current study, regarding the cross-sectional study design; intervention objectives; variables selected to observe; ages of participants; gender exclusion; usage of older data; or that the data was collected from provinces other than the NWP. This allows for a specific gap identification of a longitudinal study design, to observe changes and associations between CRF, obesity and HTN, with relatively recent data from 10–13-year-old South African boys and girls attending school in the NWP of SA. Given the prevalence of OW and obesity in children (Pienaar, 2015:5), and findings of adolescent HTN in the NWP (Awotidebe *et al.*, 2016:247), the focus of this

study will be on these two clustered risk factors of CVDs. It is crucial to understand the developments of these two clustered risk factors of CVDs and their associations with CRF during childhood, to reduce the growing burden of CVD (Awotidebe *et al.*, 2016:249).

Based on the background presented, the research question is: What are the longitudinal associations between the changes between CRF and two components of clustered CV risk factors (obesity and hypertension) among school attending adolescents 10–13 years old in living the NWP? By answering this question, health practitioners like researchers, paediatricians, Kinderkineticists and Biokineticists will be informed about new scientific findings of obesity, HTN and CRF levels and their associations with CV health in South African children from the NWP. Although this answer may assist in general representative information of adolescent's health from the NWP, it is crucial to carry out similar studies across the various South African provinces for a clearer representative of country's youths' health. Finding associations between CRF and changes in clustered CVD risks will benefit youth. This benefit may occur when health care providers can identify adolescents who are at higher risk for CVD by referring to this study and similar literature. Once adolescents at risk for CVD are identified, health practitioners can implement early health intervention. The greater impact of the study may be improvement of the South Africans' physical health in general. That knowing about the associations between obesity, HTN and CRF may encourage the younger population to improve their CRF levels and lower their CVD risk to become a healthier nation.

1.3 OBJECTIVES

The objectives of this study are to determine:

- The longitudinal changes in cardiorespiratory fitness and in two CV risk factor components (obesity and hypertension) among school attending adolescents 10–13 years old living in the North West Province.
- The associations between cardiorespiratory fitness with two CV risk factor components (obesity and hypertension) among school attending adolescents 10–13 years old living in the North West Province.

1.4 HYPOTHESES

This study is based on the following hypotheses:

- Significant longitudinal changes will be found in cardiorespiratory fitness to decrease and two CV risk factor components (obesity and hypertension both to increase) among school attending adolescents 10–13 years old living in the North West Province.
- Statistically significant negative associations will be found between cardiorespiratory fitness changes and changes in the two CV risk factor components (obesity and hypertension) among school attending adolescents 10–13 years old living in the North West Province.

1.5 LIST OF TERMINOLOGY

During this study, the below mentioned terms will have been referred to regularly. Therefore, the terms were defined to facilitate easier reading of this chapter.

Cardiorespiratory fitness (CRF) or aerobic fitness: the ability to perform prolonged PA while tolerating fatigue (Kent, 2006). The CRF level is reflected by the duration of time the aerobic activity can be carried out depending on the capability of the heart and lungs to transport adequate amounts of oxygen to the exercising muscles and the muscles' ability to use the oxygen efficiently (Kent, 2006).

Maximal oxygen consumption ($\dot{V}O_2$ max): an estimation of maximum volume of oxygen a participant can consume per unit of time from the atmosphere and use within the muscular tissues during an activity which progressively increases intensity and is stopped when fatigue is reached (Kent, 2006).

Physical activity (PA): any movement of the body that the skeletal muscles cause and produces an outcome of energy expenditure that is above resting levels (Katzmarzyk & Staiano, 2017:779).

Body Mass Index (BMI): a formula, which calculates an estimation of body mass by dividing mass in kilograms (kg) by stature in meters (m) squared or (kg)/m². The Oxford Concise Medical Dictionary (OCMD) (Martin, 2015) specifies that BMI is used to classify people as overweight or obese and is calculated by dividing the person's weight in kg by the stature squared.

Underweight: a classification of a BMI value smaller than the 5th percentile which was developed from the Centers for Disease Control (CDC) Growth Charts for American children and adolescents aged two to 19 years old (Kuczmarski & Flegal, 2000:1079).

Normal Weight or non-overweight and non-obese: a classification of a BMI value from the 5th percentile to smaller than the 85th percentile as developed from the CDC Growth Charts (Kuczmarski & Flegal, 2000:1079).

Overweight (OW): excessive or unusual amounts of fat deposits within one's body (WHO, 2020). According to the CDC (2018), a child categorized as OW when the BMI value is from the 85th percentile up to the 95th percentile for the child's age and sex.

Obesity: excessive or unusual amounts of fat deposits within one's body that puts one at risk for chronic diseases, namely cancer, diabetes and CVD (WHO, 2020). The CDC (2018) indicate that a child is considered as obese when the BMI value is at or above the 95th percentile for the child's age and sex.

Waist Circumference (WC): a measurement taken of the abdomen and is used to determine the abdominal circumference. This measurement is taken at the narrowest aspect between the lower costal rib (10th rib) and the most superior aspect of the Crista Iliaca (Stewart *et al.*, 2011:80).

Normal Blood Pressure: a systolic (SBP) and/or diastolic blood pressure (DBP) <90th percentile for age, sex and stature according to the cut-off points of the NHBPEP on high BP in children and adolescents (NHBPEP *et al.*, 2005:8).

Prehypertension: a SBP and/or DBP from the 90th percentile to <95th percentile (NHBPEP *et al.*, 2005:8).

Paediatric hypertension: a SBP and/or DBP greater than or equal to the 95th BP percentile for age, sex and stature (NHBPEP *et al.*, 2005:8; Paradis *et al.*, 2004:1833).

1.6 PROPOSED CHAPTERS

This study will be prepared according to the article format. The relevant sources will be presented at the end of each chapter and will be formatted in accordance with the North-West University adapted Harvard style.

Chapter One: Introduction, problem statement, objectives, hypotheses, list of terminology, proposed chapters and chapter conclusion.

Chapter Two: Literature overview: Associations between cardiovascular clustered risk factors and cardiorespiratory fitness of adolescents.

Literature regarding cardiorespiratory fitness, obesity and hypertension discussed according to international and South African prevalence; criteria or guidelines; measurement methods; causes and negative effects, and concluded with a chapter summary.

Chapter Three: Article 1: The changes over three years in cardiorespiratory fitness and two components of cardiovascular risk (obesity and hypertension) from the age of 10–13: a NW-CHILD study. Manuscript prepared for the *South African Journal for Research in Sport, Physical Education and Recreation*.

Article introduction, materials and methods, results, discussion, limitations, recommendations and chapter conclusion.

Chapter Four: Article 2: Association between cardiorespiratory fitness and two components of cardiovascular risk (obesity and hypertension) from the age of 10–13: a NW-CHILD study. Manuscript prepared for the *South African Journal for Research in Sport, Physical Education and Recreation*.

Manuscript introduction, materials and methods, results, discussion, limitations, recommendations and chapter conclusion.

Chapter Five: Summary, conclusions, limitations and recommendations.

1.7 CHAPTER CONCLUSION

Chapter One has introduced the dissertation. Through the problem statement the gap in literature was identified which motivates the importance of this study. Researchers have identified that children and adolescents' CRF levels decreased over time and that obesity and HTN increased internationally and within SA. The results have also shown that poor CRF levels negatively associate with obesity and HTN. The gap in research was that further longitudinal investigation regarding changes in and associations between CRF, obesity and HTN is necessary among 10–13-year-old boys and girls who attend school in the NWP of SA. Furthermore, the objectives and hypotheses were formulated and presented according to the gap, followed by the terminology list and chapters proposed for this dissertation. Chapter Two, the literature review will discuss CRF, obesity and HTN as primary topics. The sub-topics will be grouped within international and South African prevalence; the variable criteria or guidelines; measurement tests; causes and negative effects of CRF, HTN and obesity among children and adolescents.

1.8 REFERENCES

- Agostinis-Sobrinho, C., Ruiz, J.R., Moreira, C., Abreu, S., Lopes, L., Oliveira-Santos, J., ... Santos, R. 2018. Cardiorespiratory fitness and blood pressure: a longitudinal analysis. *Journal of Paediatrics*, 192(January):130–135.
- Anderssen, S.A., Cooper, A.R., Riddoch, C., Sardinha, L.B., Harro, M., Brage, S. & Andersen, L.B. 2007. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *European Journal of Cardiovascular Prevention and Rehabilitation*, 14:526–531.
- Awotidebe, A., Monyeki, M.A., Moss, S.J., Strydom, G.L., Armstrong, M. & Kemper, H.C.G. 2016. Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of South African adolescents: the PAHL Study. *Journal of Human Hypertension*, 30:245–251.
- Brito, L.M., Mascarenhas, L.P., Moser, D.C., Titski, A.C., Cat, M.N., Coelho-e-Silva, M.J., ... Leite, N. 2016. Use of physical activity and cardiorespiratory fitness in identifying cardiovascular risk factors in male Brazilian adolescents. *Brazilian Journal of Kinanthropometry and Human Performance*, 18(6):678–689.
- Centers for Disease Control and Prevention. 2018. *BMI for Children and Teens*. <https://www.cdc.gov/obesity/childhood/defining.html> Date of access: 25 Sept. 2019.
- Cifu, A.S. & Davis, A.M. 2017. Prevention, detection, evaluation, and management of high blood pressure in adults. *Journal of American Medical Association*, 318(21):2132–2134.
- Ekoru, K., Murphy, G.A.V., Young, E.H., Delisle, H., Jerome C.S., Assah, F., ... Sandhu M.S. 2017. Deriving an optimal threshold of waist circumference for detecting cardiometabolic risk in sub-Saharan Africa. *International Journal of Obesity*, 2017:1–8.
- Gao, B., Zhang, L. & Wang, H. 2013. Clustering of Major Cardiovascular Risk Factors and the Association with Unhealthy Lifestyles in the Chinese Adult Population. *Public Library of Science One*, 8(6):1–6.
- Goon, D., Amusa, L., Mhlongo, D., Khoza, L. & Any-Anwu, F. 2013. Elevated blood pressure among rural South African children in Thohoyandou, South Africa. *Iranian Journal of Public Health*, 42(5):489–496.
- Healthy Active Kids South Africa (HAKSA). 2018. Healthy active k

ids South Africa report card. Retrieved from <https://www.westerncape.gov.za/westerncape-on-wellness/files/atoms/files/HAKSA-2018-Report-Card-FINAL.pdf> Date of access: 8 June 2019.

Himmelfarb, J. & Alp Ikizler, T. 2010. *Chronic kidney disease, dialysis and transplantation*. 4th ed. USA: Saunders.

Kallerman, P.H. 2019. *Cardiovascular health in children and adolescents with obesity: Prevalence, prediction and supervised exercise*. Stockholm: Karolinska Institute. (Thesis – Ph.D.).

Katzmarzyk, P.T. & Staiano, A.E. 2017. Relationship between meeting 24-hour guidelines and cardiometabolic risk factors in children. *Journal of Physical Activity and Health*, 14(10):779–784.

Kemp, C., Pienaar, A.E. & Schutte, A. 2011. The prevalence of hypertension and the relationship with body composition in Grade 1 learners in the North West Province of South Africa. *South African Journal of Sports Medicine*, 23(4):117–122.

Kent, M. 2006. *The Oxford dictionary of sports science & medicine*. Oxford England: Oxford University Press.
<http://www.oxfordreference.com.nwulib.nwu.ac.za/view/10.1093/acref/9780198568506.001.0001/acref-9780198568506> Date of access: 12 March 2019.

Kuczmarski, R.J. & Flegal, K.M. 2000. Criteria for definition of overweight in transition: background and recommendations for the United States. *American Society for Clinical Nutrition*, 2000(72):1074–1081.

Laghi, A. & Rengo, M. 2017. *Imaging in bariatric surgery*. Switzerland: Springer Nature. Retrieved from <https://link.springer.com/content/pdf/10.1007/978-3-319-49299-5.pdf> Date of access: 9 Mar. 2018.

Liu, W.J., Xiong, L.H., Guo, C.S., Pallan, M., Griffin, T., Cheng, K.K. & Adab, P. 2017. Weight status, cardiorespiratory fitness and high blood pressure relationship among 5–12-year-old Chinese primary schoolchildren. *Journal of Human Hypertension*, 31:808–814.

Martin, E. 2015. *Concise Medical Dictionary*.
<https://www.oxfordreference.com/view/10.1093/acref/9780199557141.001.0001/acref-9780199557141> Date of access: 5 Sept. 2019.

- Monyeki, M.A., Awotidebe, A., Moss, S.J., Sparks, M., Wushe, S., Coetzee, B., ... Twisk, J.W.R. 2017. Relationship between physical activity, body fatness and cardiorespiratory fitness in South African adolescents: The PAHL Study. *African Journal for Physical Activity and Health Sciences*, 23(1.2):111–128.
- Monyeki, M.A., Koppes, L.L.J., Monyeki, K.D., Kemper, H.C.G. & Twisk, J.W.R. 2007. Longitudinal relationships between nutritional status, body composition, and physical fitness in rural children of South Africa: The Ellisras Longitudinal Study. *American Journal of Human Biology*, 19:551–558.
- Moselakgomo, V.K., Toriola, A.L., Shaw, B.S., Goon, D.T. & Akinyemi, O. 2012. Body mass index, overweight, and blood pressure among adolescent schoolchildren in Limpopo province, South Africa. *Revista Paulista de Pediatria*, 30(4):562–569.
- Moselakgomo, V.K. & Van Staden, M. 2017. Predictors of obesity and cardiometabolic disease risk in South African children. *South African Journal of Child Health*, 11(4):186–191.
- National High Blood Pressure Education Program (NHBPEP). 2005. *The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents*. (4th ed.), Philadelphia, PA: U.S. United States Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, National High Blood Pressure Education Program.
- Nqweniso, S., Walter, C., du Randt, R., Aerts, A., Adams, L., Degen, J., ... Gerber, M. 2020. Prevention of overweight and hypertension through cardiorespiratory fitness and extracurricular sport participation among South African schoolchildren. *Sustainability*, 12(16):1–16.
- Pazin, D.C., Rosaneli, C.F., Olandoski, M., Netto de Oliveira, E.R., Pellegrino Baena, C., Figueredo, A.S., ... Faria-Neto, J.R. 2017. Waist circumference is associated with blood pressure in children with normal body mass index: a cross-sectional analysis of 3,417 schoolchildren. *Brazilian Archives of Cardiology*, 2017:509–515.
- Pienaar, A.E. 2015. Prevalence of overweight and obesity among primary schoolchildren in a developing country: NW-CHILD longitudinal data of 6-9-yr-old children in South Africa. *Biomedical Central Obesity*, 2(2):1–10.
- Ruiz, J.R., Huybrechts, I., Cuenca-Garcia, M., Artero, E.G., Labayen, I., Meirhaeghe, A., ... Ortega, F.B. 2015. Cardiorespiratory fitness and ideal cardiovascular health in European adolescents. *Heart Cardiac Risk Factors and Prevention*, 101:766–773.

Sinaiko, A.R., Donahue, R.P., Jacobs, D.R. & Prineas, R.J. 1999. Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults the Minneapolis children's blood pressure study. *Circulation*, 1999(99):1471–1476.

Stabouli, S. & Kotsis, V. 2019. Diagnosis of hypertension in children and adolescents: 2019 update. *Hellenic Journal of Atherosclerosis*, 9(4):111–120.

Stewart, A., Marfell-Jones, M., Olds, T. & De Ridder, H. (2011). *International Standards for anthropometric assessment*. (3rd ed). Lower Hutt: The international society for the advancement of Kinanthropometry.

World Health Organisation (WHO). 2020. *Obesity and overweight*. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight> Date of access: 4 Dec. 2020.

CHAPTER TWO

CHAPTER 2: LITERATURE OVERVIEW OF ASSOCIATIONS BETWEEN CARDIOVASCULAR CLUSTERED RISK FACTORS AND CARDIORESPIRATORY FITNESS OF CHILDREN.

2.1 INTRODUCTION

Children's health is considerably worsening due to declining physical activity (PA) and cardiorespiratory fitness (CRF) levels, which results in increasing cardiovascular disease (CVD) risk factors like obesity and hypertension (HTN) (Agostinis-Sobrinho *et al.*, 2018:134; World Health Organisation [WHO], 2020a). It is important to understand relationships between CRF levels and clustered CV risk factors among children and adolescents, how these relationships influence their bodies and when to intervene to prevent detrimental negative effects (Grace *et al.*, 2021:10; Kemp *et al.*, 2011:121; Monyeki, M.A. *et al.*, 2017:120).

Cardiorespiratory fitness is the ability to tolerate fatigue during prolonged PA. Fitness levels have decreased internationally and in South Africa (SA) amongst young people, bringing about higher unsatisfactory CRF levels (Kent, 2006; Monyeki, M.A. *et al.*, 2017:119; Roldão da Silva *et al.*, 2020:166). Poor CRF levels is a consequence of not maintaining sufficient PA, being 60 minutes of moderate to vigorous intensity PA per day (Monyeki, M.A. *et al.*, 2017:120; Ruiz *et al.*, 2015:767–768). The unsatisfactory CRF levels are harmful for children and adolescents. Well known harmful or negative effects of unsatisfactory CRF levels have been identified as HTN and obesity, these two negative effects have been selected for discussion (Agostinis-Sobrinho *et al.*, 2018:132; Awotidebe *et al.*, 2016:247; Castro-Piñero *et al.*, 2017:1756; Liu *et al.*, 2017:811; Monyeki, M.A. *et al.*, 2017:118; Roldão da Silva *et al.*, 2020:164). Studies have confirmed that participants who have poor CRF levels are at higher risk of CVD (Anderssen *et al.*, 2007:529; Awotidebe *et al.*, 2016:247; Katzmarzyk & Staiano, 2017:782).

Although CVD risk factors become apparent during adulthood, the characteristics that increase one's risk of developing CVD can be present during childhood (Anderssen *et al.* 2007:526; Himmelfarb & Alp Ikizler, 2010:130). Two of the four major components of CVD will be discussed, specifically obesity and HTN (Gao *et al.*, 2013:2).

The prevalence of excessive amounts of body fat, better known as overweight (OW) and obesity, has been growing tremendously in young people worldwide (He *et al.*, 2011:110; Palomäki *et al.*, 2015:591; Roldão da Silva *et al.*, 2020:164; WHO, 2020a). Similarly, SA is not exempt from this harmful high prevalence of OW and obesity (Grace *et al.*, 2021:6; HAKSA, 2018:7; Monyeki, M.A. *et al.*, 2017:119; Van Staden *et al.*, 2019:94). Several main factors have been identified (namely lifestyle habits; social and environmental influences; education; psychological factors and menarche), which cause a child or adolescent to gain

excessive body fat resulting in threatening negative effects like pulmonary diseases; digestive issues; emotional or social impediments, CVD and premature mortality (Balentine, 2019; Kruger *et al.*, 2006:355; Monyeke, M.A. *et al.*, 2017:118; Moselakgomo & Van Staden, 2017:187). Numerous researchers have found and supported that unhealthy weight gain places a child at a higher risk of adverse effects (Balentine, 2019; Kemp *et al.*, 2011:120; Pazin *et al.*, 2017:510; Sinaiko *et al.*, 1999:1473; Shokeen & Aeri, 2017:1394; Stabouli & Kotsis, 2019:117).

The rise in prevalence of HTN amongst children has been observed in various countries around the world, as well as in SA (Grace *et al.*, 2021:6; Kallerman, 2019:32; Kemp *et al.*, 2011:120; Nqweniso *et al.*, 2020:7; Roldão da Silva *et al.*, 2020:164). Several negative effects (such as CVD; pulmonary illnesses; nervous system disturbances and premature mortality), as consequence of HTN, have been identified in young people (Adil *et al.*, 2016:26; Cifu & Davis, 2017:2133; National High Blood Pressure Education Program Working Group [NHBPEP], 2005:18; Goon *et al.*, 2013:492). With the growing reality of the deterioration of children's health, this study will work towards new findings in South African adolescents from the North West Province (NWP).

Chapter Two is purely a literature review of important literature identified to set the context for Chapters Three and Four. We grouped the topics of the literature review to discuss the literature according to three main samples, namely CRF, OW and obesity, as well as HTN. Firstly, we will discuss CRF concerning its prevalence among various countries and within SA, the criteria or guidelines, the measurements or tests used to measure CRF, the negative effects low of CRF levels and the benefits of sufficient CRF levels for children and adolescents. We selected two of the four major components of CVD to evaluate in this study, obesity and HTN. Secondly, we will elaborate on OW and obesity, the criteria or cut-off points, methods of measurement, possible causes and the negative effects that OW and obesity have on children according to international and South African literature. Thirdly, we will discuss HTN, concerning its prevalence around the world and within SA, the criteria or cut-off points, appropriate measurement methods, possible causes and the negative effects HTN has on children.

2.2 CARDIORESPIRATORY FITNESS IN CHILDREN AND ADOLESCENTS

This section will address CRF in young people: the prevalence; criteria and classification; measurement methods, positive effects of sufficient CRF levels and negative effects of poor CRF. CRF is a key factor in PA as it indicates the overall capacity of the respiratory and CV systems to transport and exchange oxygen from the air, through the lungs to the muscles, so that the muscles can carry out prolonged or strenuous exercise (Plowman & Meredith, 2013:6-3).

Several researchers have found that the levels of PA and CRF have decreased in young people of various countries worldwide (Castro-Piñero *et al.*, 2017:1756; He *et al.*, 2011:111; Kallerman, 2019:36; Roldão da

Silva *et al.*, 2020:162; Stratton *et al.*, 2007:1173). Similarly, literature has identified the PA and CRF levels in children and adolescents from SA as unsatisfactory (Awotidebe *et al.*, 2016:247; Monyeki, M.A. *et al.*, 2017:119).

To maintain satisfactory CRF levels young people need to adhere to movement criteria, better known as movement guidelines, and they need to measure their CRF levels using reliable methods at regular intervals of time (Katzmarzyk & Staiano, 2017:779; Ruiz *et al.*, 2015:768). By adhering to movement guidelines, young people reap the benefits of improved fitness and reduced risk for the most common poor CRF negative effects: obesity and obesity related HTN (Agostinis-Sobrinho *et al.*, 2018:132; Awotidebe *et al.*, 2016:247; Katzmarzyk & Staiano, 2017:779; Monyeki, M.A. *et al.*, 2017:118).

2.2.1 Prevalence of cardiorespiratory fitness worldwide

The levels of CRF are decreasing amongst children and adolescents due to their low PA participation (Castro-Piñero *et al.*, 2017:1756; He *et al.*, 2011:111; Kallerman, 2019:36; Roldão da Silva *et al.*, 2020:162; Stratton *et al.*, 2007:1173). Stratton *et al.* (2007:1172) performed a serial cross-sectional, population-based study on 15 621 nine- to 11-year-old participants (7 767 boys and 7 654 girls) from Liverpool, England. The aim was to assess the changes of body mass index (BMI) and CRF, using the 20m Progressive Aerobic Cardiovascular Endurance Run (PACER) multiple stage run over a six-year period from 1998–2004 (Stratton *et al.*, 2007:1173). The PACER laps decreased in boys from 47 laps to 36 and in girls from 34 to 26 (Stratton *et al.*, 2007:1173). Elaborating on the above findings, the fitness scores also decreased from 1998 to 2004 by 10.6% in boys and 11.8% in girls, and further decreased during 2004 to 23.0% in boys and 23.5% in girls (Stratton *et al.*, 2007:1175). The percentage of participants classified as unfit increased by 50% in boys and 36% in girls over the six-year period (Stratton *et al.*, 2007:1173–1175). The decrease in CRF was amongst participants classified as lean, OW and obese alike (Stratton *et al.*, 2007:1175).

He *et al.* (2011:110) performed a longitudinal study with 1 795 eight- to 13-year-old Chinese participants (901 boys and 894 girls) with the aim to determine the relationships between PA, CRF and obesity, as well as if change in body composition (BC) affects PA and CRF. The participants' base line CRF levels for the normal weight sample (46.7 mL/kg/min) was significantly higher than that of the obese sample (39.6 mL/kg/min) (He *et al.*, 2011:111). The follow-up CRF levels of the obese sample declined (38.7 mL/kg/min), whereas the normal weight sample indicated an insignificant change (46.9 mL/kg/min) (He *et al.*, 2011:111). Palomäki *et al.* (2015:589) examined longitudinal changes in CRF levels, BMI and leisure-time PA, then further compared CRF levels between Finnish adolescents classified as normal weight and obese, 15–16 years old (N = 1 301, boys = 661 and girls = 640). No significant longitudinal changes were noted in CRF level amongst the boys (shuttle metres ran in 2003: 466m and 2010: 484m) and the girls (shuttle metres ran in 2003: 693m and 2010: 707m), this finding may likely have been as an influence of BMI and leisure time activities increasing

(Palomäki *et al.*, 2015:591). Castro-Piñero *et al.* (2017:1755) carried out a cross-sectional and longitudinal study with 236 Spanish schoolchildren six to 12 years old. The aim of the study was to examine the association between CRF and CVD risk factors and to evaluate whether CRF changes are associated with CVD risk longitudinally (Castro-Piñero *et al.*, 2017:1755). The CRF results indicated a significant decrease amongst boys and girls (Castro-Piñero *et al.*, 2017:1756).

A longitudinal study was carried out by Agostinis-Sobrinho *et al.* (2018:130) with 734 Portuguese participants 12–18 years old to investigate associations between CRF and CV indices at a two-year follow-up measurement (boys $n = 385$ and girls $n = 349$). The participants CRF levels were determined according to the PACER shuttle run (20m) (Agostinis-Sobrinho *et al.*, 2018:132). The mean shuttle laps the participants reached at baseline measurement were 58.09 laps for boys and 31.05 laps for girls; and increased at the follow-up measurement, where the boys reached 71.25 laps and girls reached 38.05 laps (Agostinis-Sobrinho *et al.*, 2018:132). Roldão da Silva *et al.* (2020:163) carried out a longitudinal study with 93 Brazilian participants with a mean age between 13.5–16.5 years old, during 2014 and 2017. The aim of this study was to examine the relationships between health-related physical fitness indicators and clustered cardiometabolic risk factors in adolescents (Roldão da Silva *et al.*, 2020:162). Roldão da Silva *et al.* (2020:165) reported a significant decrease in CRF within the sample.

Kallerman (2019:21) performed a four-part study, of which study IV was a longitudinal intervention study with the objective of evaluating CRF amongst eight 13–19-year-old Swedish participants classified as obese and were part of an intervention program. A personal coach supervised the exercise sample with aerobic exercise within the guidelines of ≥ 150 bpm for ≥ 30 minutes three times a week for three months, thereafter, the sample was responsible to keep these guidelines for at least nine months (Kallerman, 2019:22). The initial CRF levels of the exercise sample improved from 34.5 mL/kg/min to 40.5 mL/kg/min during the three-month period as compared to the control sample (Kallerman, 2019:36). No further improvement took place during the nine-month period of self-regulated exercise (Kallerman, 2019:36). On the contrary, the improved CRF levels of the exercise sample dropped by 9.2 mL/kg per minute, below the initial levels present prior to the supervised exercise period (Kallerman, 2019:36). With an insight into what the CRF levels look like in young people around the world, we will elaborate on the local prevalence of CRF levels in South African children and adolescents next.

2.2.2 Prevalence of cardiorespiratory fitness in South Africa

Most literature studies available regarding CRF prevalence amongst South African children and adolescents are cross-sectional and from specific provinces; thus, there is a need for more South African research concerning longitudinal changes in CRF from more provinces (Awotidebe *et al.*, 2016:247; Monyeki *et al.*, 2007:552; Monyeki, M.A. *et al.*, 2017:119). Monyeki *et al.* (2007:552) tracked the longitudinal prevalence of

and associations between the physical fitness, nutritional status and BC amongst seven to 14-year-old South African youths from Lephalale, Limpopo Province, SA. The study included 702 participants and formed part of the Ellisras Longitudinal Study (Monyeki *et al.*, 2007:552). Monyeki *et al.* (2007:551) used a 1 600m run time in seconds (s) as an indicator for physical fitness and grouped the participants according to pre-adolescent (seven to 10 years) and adolescent (11–15 years) samples. The pre-adolescent boys (from 489.8s during 2001 to 475.3s during 2002) and girls (from 531.2s during 2001 to 514.6s during 2002) performed better than the low performance of the adolescent boys (from 452.9s during 2001 to 460.7s during 2002) and girls (from 511.8s during 2001 to 529.3s during 2002) (Monyeki *et al.*, 2007:553). Monyeki *et al.* (2007:551) observed that even though the pre-adolescents' physical fitness decreased over time, they still performed better than the adolescents who had increasing but low physical fitness values.

Awotidebe *et al.* (2016:247) carried out a cross-sectional study in SA. The researchers noted that their 14-year-old participants that classified as OW had CRF levels of 26.66 mL/kg/min, compared to the normal weight participants with better CRF levels of 31.58 mL/kg/min (Awotidebe *et al.*, 2016:247). They found that boys' (37.36 mL/kg/min) CRF levels were higher than that of the girls (29.25 mL/kg/min) (Awotidebe *et al.*, 2016:247). Monyeki, M.A. *et al.* (2017:119) carried out a cross-sectional study on 149 adolescents (boys n = 58 and girls n = 91) as part of the five-year Physical-Activity and Health Longitudinal Study (PAHLS) in the NWP, SA. As a sample, the mean maximal oxygen uptake ($\dot{V}O_2$ max) was 33.67 mL/kg/min and a significant difference was noticed between the mean $\dot{V}O_2$ max of the boys (41.01 mL/kg/min) and the girls (29.1 mL/kg/min) (Monyeki, M.A. *et al.*, 2017:119). Monyeki, M.A. *et al.* (2017:119) found that 68.5% of their adolescent participants were sedentary, 19.5% were inactive and 20% were active. As South African studies regarding longitudinal CRF changes are limited, understanding the criteria and guidelines for CRF measurements will be useful to measure South African youth.

2.2.3 Guidelines for cardiorespiratory fitness

Cardiorespiratory fitness is a critical part of PA, which requires age specific guidelines and criteria for young people to meet. Physical activity is frequencies of different types of movement at a certain intensity for a duration that causes an energy expenditure above resting levels (Kallerman, 2019:36; Rhodes *et al.*, 2017:943). Katzmarzyk and Staiano (2017:779) encouraged 24-hour movement guidelines, which recommend that children five to 13 years old perform at least 60 minutes of moderate to vigorous PA per day, have less than two hours recreational, sedentary screen time and have nine to 11 hours of uninterrupted sleep per night. The World Health Organisation (2020b) similarly suggests that children and adolescents five to 17 years old should accumulate at least 60 minutes of moderate to vigorous intensity PA daily. Any PA above 60 minutes will provide additional health benefits and vigorous activities should include muscle and bone strengthening activities three times a week (for example running, climbing and jumping games) (WHO, 2020b). Cardiorespiratory fitness or aerobic fitness is the ability to carry out extended PA while tolerating fatigue

(Kent, 2006). The CRF level is reflected by the duration of time the aerobic activity can be carried out (Kent, 2006). The activity duration depends on the heart and lungs' capability to transport adequate amounts of oxygen to the exercising muscles; and the muscles' ability to use the oxygen efficiently (Kent, 2006). According to Kent (2006), most scientists view maximal oxygen uptake ($\dot{V}O_2$ max) as the best objective indicator of CRF. Ruiz *et al.* (2015:768) determined the CRF or $\dot{V}O_2$ max cut-off levels (43.8 mL/kg/min in boys and 34.6 mL/kg/min in girls from Europe) that are associated with meeting four or more ideal health components (four behaviours: never smoked before, ideal BMI, sufficient PA, healthy diet; and three factors: ideal total blood cholesterol, BP and fasting blood glucose). These CRF cut-off levels were also determined eligible for American adolescents by the American Heart Association (AHA) (Ruiz *et al.*, 2015:768). With clear guidelines and criteria identified, various CRF tests or $\dot{V}O_2$ max measurement methods will be considered next.

2.2.4 Measurements of cardiorespiratory fitness

There are various methods to test a participant's CRF levels, methods including the PACER 20m shuttle run, the 1-mile walk or run, and tests carried out in laboratories (Anderssen *et al.*, 2007:527; Mahar *et al.*, 2011:117; Plowman & Meredith, 2013:6-4).

The PACER is a multi-stage progressive aerobic endurance field evaluation for four to 15-year-old children that is part of the Fitnessgram testing protocol (Plowman & Meredith, 2013:6-4). Children must run across a 20m distance back and forth, and turn on the sound of a beep (Plowman & Meredith, 2013:6-4). The test begins with an easy pace and progressively becomes more difficult as the time between the beeps become shorter (Plowman & Meredith, 2013:6-4). A participant must run until he fails to reach the line at the sound of the beep for a second time. The recorded score is the total amount of laps completed (Plowman & Meredith, 2013:6-4). The reliability and validity of the PACER are 0.95 and 0.92, respectively. The lap results, seen in Table 2.1, are used to determine the estimates of $\dot{V}O_2$ max that was developed in a study by Mahar *et al.* (2011:119). The study performed had 244 participants (126 girls and 118 boys) and was aimed at developing and cross-validating prediction models to estimate $\dot{V}O_2$ max from the PACER 20m shuttle run in participants that are 10–16 years of age (Mahar *et al.*, 2011:117). For validity of the PACER, Mahar *et al.* (2011:118) made use of a prediction equation to form validation ($n = 174$) and cross-validation ($n = 70$) sample groups to test according to these prediction models.

Table 2.1: The Progressive Aerobic Cardiovascular Endurance Run $\dot{V}O_2$ max conversions for boys and girls aged 10–16 years by Mahar *et al.* (2011:119)

$\dot{V}O_2$ max Conversion from 20-meter PACER Test											
Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max
4	25	26.8	6	45	34.3	8	65	41.1	10	85	47.4
4	26	27.2	6	46	34.0	8	66	41.5	10	86	47.7
4	27	27.6	6	47	35.0	8	67	41.8	10	87	48.0
4	28	28.0	6	48	35.4	8	68	42.1	10	88	48.4
4	29	28.3	6	49	35.7	8	69	42.4	10	89	48.7
4	30	28.7	6	50	36.1	8	70	42.7	10	90	49.0
4	31	29.1	7	51	36.4	9	71	43.0	10	91	49.3
4	32	29.5	7	52	36.8	9	72	43.3	10	92	49.6
5	33	29.9	7	53	37.1	9	73	43.6	11	93	49.9
5	34	30.2	7	54	37.5	9	74	43.9	11	94	50.2
5	35	30.6	7	55	37.8	9	75	44.2	11	95	50.5
5	36	31.0	7	56	38.2	9	76	44.5	11	96	50.8
5	37	31.4	7	57	38.5	9	77	44.9	11	97	51.1
5	38	31.8	7	58	38.9	9	78	45.2	11	98	51.4
5	39	32.2	7	59	39.2	9	79	45.5	11	99	51.7
5	40	32.6	7	60	39.6	9	80	45.8	11	100	51.9
5	41	32.9	8	61	39.9	9	81	46.2	11	101	52.2
6	42	33.3	8	62	40.2	10	82	46.5	11	102	52.5
6	43	33.6	8	63	40.5	10	83	46.8	11	103	52.8
6	44	34.0	8	64	40.8	10	84	47.1	11	104	53.1

$\dot{V}O_2$ max = maximal oxygen uptake

The Fitnessgram One-Mile walk or run are two alternative methods for the Fitnessgram 20m PACER run, to assess aerobic capacity in children or adolescents in the field (Plowman & Meredith, 2013:6-4). The goal of the one-mile test is to walk or run the one-mile as fast as possible, then aerobic capacity is predicted through the Fitnessgram software from age, sex, mile time, weight, heart rate and BMI using equations developed for this assessment (Plowman & Meredith, 2013:6-4). The Fitnessgram One-Mile walk requires immediate measurement of the heart rate after the walk, which can be indicative of the aerobic capacity (Plowman & Meredith, 2013:6-4). With regards to the Fitnessgram One-Mile Run, the pace sustained is associated to the rate of oxygen uptake; therefore, the average pace sustained could be an indication of the highest rate of possible oxygen uptake (Plowman & Meredith, 2013:6-4). Beets and Pitetti (2006:21) indicated the criterion referenced reliability for the Fitnessgram 1-mile walk or run for boys ($Pa = 77\%$, $k_q = 0.53$) and for girls ($Pa = 83\%$, $k_q = 0.67$), which had a similar test consistency to the PACER 20m run for boys ($Pa = 77\%$, $k_q = 0.55$) and girls ($Pa = 83\%$, $k_q = 0.67$). Therefore, the researchers can decide which test best suit their circumstances in terms of admin ease, environmental influence and comparison of related literature (Beets & Pitetti, 2006:21).

Healthy Fitness Zones (HFZ) are used by Fitnessgram to classify the evaluation of fitness performance amongst the children (Plowman & Meredith, 2013:6-8). The HFZ are grouped into three levels indicating aerobic capacity associated with a possible risk of metabolic risk in youth (Plowman & Meredith, 2013:6-8). The first level is “Healthy Fitness Zone (HFZ)”, this level has a sensitive cut-off line, which guarantees that the participants on this level have a low risk of metabolic syndrome, as they have a good level of fitness, and that most children with metabolic syndrome have a fitness level below this level (Plowman & Meredith, 2013:6-8). The intermediate zone or “Needs Improvement (NI)” is the level representing the child’s aerobic capacity, which is associated with a moderate risk of metabolic syndrome, and the child should be encouraged to move up to the HFZ (Plowman & Meredith, 2013:6-8). The third zone, “Needs Improvement-Health Risk (NI-HR)” is the level with high specificity of its cut-off point (>95%), which guarantees that children with low fitness levels will be classified in this zone. Children in this zone require urgent feedback and warning of the health risks they are facing (Plowman & Meredith, 2013:6-8).

Laboratory methods for CRF assessment are the cycle or treadmill test (Anderssen *et al.*, 2007:527). An electronically braked cycle ergometer, where the participants cycle with their legs or a treadmill for running is used and the work rate (W) is progressively increased until the participant reaches exhaustion (Anderssen *et al.*, 2007:527; Plowman & Meredith, 2013:6-3). The initial and incremental increase work rates are set according to participant’s age or weight, as the participant cycles, the work rate is increased in pre-set rates at intervals of time; for example, every third minute the work rate is increased: by 20 W for children weighing less than 30 kg; 25 W for children weighing more than 30 kg; by 40 W for girls 15 years old or 50 W for boys aged 15 years (Anderssen *et al.*, 2007:527; Plowman & Meredith, 2013:6-3). The rate of oxygen uptake is measured continuously (Plowman & Meredith, 2013:6-3). As the work rate is increased, the rate of oxygen uptake and aerobic metabolism similarly increases until the aerobic capacity is reached and oxygen uptake plateaus in ratio to the work rate (Plowman & Meredith, 2013:6-3). This plateau is known as aerobic capacity (Plowman & Meredith, 2013:6-3). Additionally, the heart rate can be measured every 5 seconds throughout this test to help determine maximal effort as a heart rate above 185 beats per minute and the observer can see that the participant can no longer endure after encouragement (Anderssen *et al.*, 2007:527). The level of CRF is then determined by the maximal power output per kg, which can be validated against the oxygen consumption ($\dot{V}O_2$) value of the participant (Anderssen *et al.*, 2007:527).

The laboratory methods are not practical for large sample or school settings as they require expensive equipment, trained technicians and sufficient time, as only one participant can be tested per treadmill or cycle at a time (Plowman & Meredith, 2013:6-3). As the Fitnessgram One-Mile walk requires an immediate measurement of the heart rate after the walk, this measurement test was also not practical with large groups of participants, limited researchers and restricted measurement time available (Plowman & Meredith, 2013:6-4). Therefore the preferred CRF measurement method of this study was the Fitnessgram 20m PACER run.

Irrespective of knowing how to evaluate CRF levels, if the health of a child is ignored and their CRF levels continue to deteriorate, they are left exposed to a higher risk of various negative conditions (Awotidebe *et al.*, 2016:247; He *et al.*, 2011:111; Katzmarzyk & Staiano, 2017:782; Palomäki *et al.*, 2015:591).

2.2.5 Negative effects of poor cardiorespiratory fitness levels

Numerous cross-sectional and longitudinal studies have determined the relationship between CRF and negative effects, such as obesity and HTN among children and adolescents (Agostinis-Sobrinho *et al.*, 2018:132; Awotidebe *et al.*, 2016:247; Castro-Piñero *et al.*, 2017:1756; Liu *et al.*, 2017:811; Monyeki, M.A. *et al.*, 2017:118; Roldão da Silva *et al.*, 2020:164).

Hypertension as a negative effect of poor CRF

If CRF levels are not maintained and it declines, young people are at higher risk for HTN (Agostinis-Sobrinho *et al.*, 2018:132; Anderssen *et al.*, 2007:529; Liu *et al.*, 2017:811; Monyeki, M.A. *et al.*, 2017:118; Ruiz *et al.*, 2015:767–768). Anderssen *et al.* (2007:530) carried out a cross-sectional study which observed the CRF levels in 2 845 Portuguese, Danish and Estonian children (1 445 nine-year-old participants, boys $n = 716$ and girls $n = 729$) and adolescents (1 400 15-year-old participants, boys $n = 675$ and girls $n = 725$). A strong association was found between CVD and CRF levels, independent of age, sex and origin (Anderssen *et al.*, 2007:529). Ruiz *et al.* (2015:767–768) investigated CRF and its association with ideal CV health in adolescent participants. The ideal health components included four behaviours: never smoked before (self-reported questionnaire), ideal BMI (according to British BMI z-scores and categories), sufficient PA (self-reported questionnaire: 60 minutes of moderate to vigorous intensity PA every day), healthy diet (according to the HELENA-Dietary Assessment Tool, a self-reported 24-hour dietary recall assessment); and three factors: ideal total blood cholesterol (mmol/L), BP and fasting blood glucose (mmol/L) (Ruiz *et al.*, 2015:767). They found a positive relationship between CRF and BP, where CRF levels were lower among adolescents who met less than four ideal CV health components (13% lower in boys and 6% lower in girls), compared to participants meeting more components (Ruiz *et al.*, 2015:767–768).

Liu *et al.* (2017:811) and Anderssen *et al.* (2007:529) identified that participants classified as obese in the lower fitness level category have a higher prevalence of CVD, namely HTN, than participants who are classified as normal weight with high fitness levels. Agostinis-Sobrinho *et al.* (2018:132) determined an inverse association between the SBP and CRF. The participants' SBP decreased from baseline measurement (boys = 121.93mmHg and girls = 117.32mmHg) to follow-up measurement (boys = 121.38mmHg and girls = 113.9mmHg) as their shuttle run laps increased from baseline measurement (boys = 58.09 laps and girls = 31.05 laps) to follow-up measurement (boys = 71.25 laps and girls = 38.05 laps) (Agostinis-Sobrinho *et al.*, 2018:132). It was additionally noted that participants who started with higher CRF levels had lower SBP values

compared to participants who started with lower CRF levels (Agostinis-Sobrinho *et al.*, 2018:132). Hypertension is a modifiable and preventable CVD risk factor that can be improved or prevented with various lifestyle changes that include chronic stress reduction; dietary adjustments, exercise to improve CRF levels and weight reduction or management (Cifu & Davis, 2017:2133; Palomäki *et al.*, 2015:591).

Obesity as a negative effect of poor CRF levels

The argument has been confirmed that CRF is a significant predictor of body weight and when participants have poor CRF levels they are at higher risk for obesity (Awotidebe *et al.*, 2016:247; Castro-Piñero *et al.*, 2017:1756; He *et al.*, 2011:111; Katzmarzyk & Staiano, 2017:782; Nqweniso *et al.*, 2020:7; Palomäki *et al.*, 2015:591; Roldão da Silva *et al.*, 2020:164; Stratton *et al.*, 2007:1173). Participants who had low baseline CRF levels were 6.9 to 8.7 times at higher risk to remain or become OW or obese over an 18-month period than participants with higher CRF levels at the baseline (He *et al.*, 2011:111). Monyeki, M.A. *et al.* (2017:119) and Palomäki *et al.* (2015:591) found results that revealed the CRF levels of participants classified as OW and obese (27.28 mL/kg/min and 465 m) were significantly lower in comparison to those classified as underweight (37.64 mL/kg/min) and normal weight (34.12 mL/kg/min and 740 m), because participants classified as OW and obese were considerably less active.

Nqweniso *et al.* (2020:6) conducted a longitudinal study to examine whether CRF and PA could assist in prevention of obesity and HTN amongst 757 eight to 13-year-old South African participants (boys n = 386 and girls n = 371) from Port Elizabeth. Participants who had lower CRF levels at baseline or who significantly decreased in CRF levels over time, were more likely to become OW or obese at follow-up (Nqweniso *et al.*, 2020:7). Although obesity and HTN are two main risk factors of poor CRF levels, there are several positive effects of maintaining sufficient CRF levels which will be discussed in the subsequent paragraph (He *et al.*, 2011:111; Palomäki *et al.*, 2015:591; Roldão da Silva *et al.*, 2020:166; Rhodes *et al.*, 2017:948).

2.2.6 Positive effects of sufficient cardiorespiratory fitness levels

Modest, achievable adjustments in PA will positively influence CRF to bring about life changing mental, emotional and physiological benefits among youth (Grace *et al.*, 2021:7; Kallerman, 2019:36; Palomäki *et al.*, 2015:591; Roldão da Silva *et al.*, 2020:166; Rhodes *et al.*, 2017:948–950). When activity was used as primary prevention, the risk for chronic medical conditions was reduced by 33% for CVD, 32% for HTN, 40% for type two diabetes and 31% for stroke; in addition to noticeable reductions in blood coagulation, improved cardiac function, blood glucose homeostasis and insulin sensitivity (Grace *et al.*, 2021:7; Kallerman, 2019:36; Palomäki *et al.*, 2015:591; Rhodes *et al.*, 2017:948–950; Roldão da Silva *et al.*, 2020:166). Prescribed personal activity programs should also be used as secondary prevention to reduce chronic conditions not caused by physical inactivity (e.g., psychological conditions like stress, depression and anxiety), and to improve cognition and well-being (Rhodes *et al.*, 2017:948–949).

Further benefits of regular PA are reduced inflammation; improved health-related fitness; better exercise tolerance; and improved BC (protection against obesity, reduction of abdominal fat and improved weight management) (Grace *et al.*, 2021:7; Kallerman, 2019:36; Palomäki *et al.*, 2015:591; Rhodes *et al.*, 2017:950). A higher level of PA benefited children to the extent that participants who were very active and obese tolerated exercise far better than moderately active normal weight participants (Palomäki *et al.*, 2015:591). Yet Kallerman (2019:36) stated that CRF benefits only profited if children and adolescents took part regularly in sufficient PA since declines in CRF were evident within three months of physical inactivity. Researchers also observed that 90 minutes of moderate intensity PA per week decreased the risk of all-cause mortality by 31% and brisk walking for 75 minutes per week, could lengthen life expectancy by nearly two years (Rhodes *et al.*, 2017:949). The benefits of sufficient PA and CRF levels are numerous, however, with the prevalence of youth not achieving PA guidelines, the negative effects of clustered CVD risk factors have larger, rippling effects (Awotidebe *et al.*, 2016:247; Palomäki *et al.*, 2015:591; Rhodes *et al.*, 2017:952).

2.3 CLUSTERED CARDIOVASCULAR DISEASE RISK FACTORS

Hypertension and obesity, two major components of CVD risk, will be discussed in the following two sections. The WHO (2020a) defines risk factors as biological characteristics, exposure or attributes of a person that increase the risk of injury or developing a disease. Clustered risk factor is a sample of risk factors. Cluster risk factors have similar, yet compounded, repercussions than a single risk factor (Anderssen *et al.*, 2007:528). Cardiovascular risk factors are characteristics that increase one's risks of developing a CVD (Himmelfarb & Alp Ikizler, 2010:130). The four major components of CVD are HTN, diabetes, dyslipidaemia and OW (Gao *et al.*, 2013:2). The clustering of CVD risk factors is defined as the existence of at least two major CVD risk factors in one individual (Gao *et al.*, 2013:2). Anderssen *et al.* (2007:526) reported that CVDs mainly manifest during adulthood, even though it's already present in children and adolescents. Risk factors during childhood have been observed in clusters; have been noted to persist with age; and have been associated with earlier onset and higher risk for adult CVDs (Moselakgomo & Van Staden, 2017:187; Sinaiko *et al.*, 1999:1474). These risk factors are either non-modifiable (sex, race and ethnicity, genetic factors and age) or modifiable (physical inactivity, diabetes mellitus, high BP, smoking, poor diet and childhood obesity) (Himmelfarb & Alp Ikizler, 2010:130).

2.4 OBESITY IN CHILDREN AND ADOLESCENTS

In this section OW and obesity were identified for discussion, as it is a harmful and modifiable characteristic that increases CVD risk among children and adolescents (Moselakgomo & Van Staden, 2017:187; Himmelfarb & Alp Ikizler, 2010:130). A general rise in OW and obesity has been observed across the world and in SA over time (HAKSA, 2018:7; Monyeke, M.A. *et al.*, 2017:119; Pazin *et al.*, 2017:510; Pienaar, 2015:9; WHO, 2020a). Due to children's growth changing rapidly with age, the classifications for OW and obesity should be

age and sex adjusted (Cole *et al.*, 2000:4; Kemp *et al.*, 2011:121). Measurement methods used to determine a child's adiposity levels vary between digital and anthropometric methods, which will be elaborated on (Balentine, 2019; Pazin *et al.*, 2017:511). In combination with classification and measurement methods, researchers, medical staff and parents must be aware of OW and obesity causes in youth, which will be discussed (Agarwal, 2016; Kruger *et al.*, 2006:355; Moselakgomo & Van Staden, 2017:187; Shokeen & Aeri, 2017:1394; WHO, 2020a). The burdensome negative effects of OW and obesity considered for discussion, included HTN, sleep apnoea, insulin resistance as a form of prediabetes and increased risk for premature mortality during adulthood (Dietz & Robinson, 2005:2103; Goon *et al.*, 2013:492; Laghi & Rengo, 2017; Moselakgomo & Van Staden, 2017:189; Stratton *et al.*, 2007:1175). The prevalence of OW and obesity will be addressed in the next paragraphs.

2.4.1 Prevalence of obesity worldwide

Obesity has increased nearly fivefold from, 4% (1975) to slightly over 18% (2016), reaching epidemic proportion worldwide and resulted in 340 million obese children and adolescents between five to 19 years old during 2016 (WHO, 2020a). Stratton *et al.* (2007:1173) identified that the longitudinal prevalence of OW and obesity was 20.5% amongst the boys and 25.5% amongst the girls. Not only was there a high prevalence in OW and obesity, but a significant increase over the 6-year period in boys from 15–26% and in girls from 20–31%, which resulted in a total prevalence increase of 80% in boys and of 56% in girls (Stratton *et al.*, 2007:1174–1175). He *et al.* (2011:110) identified over a period of two years that the Chinese participants classified as the normal weight group decreased by 1.7%, contributing to an increase in the group classified as OW and obese by 1.7% from 14.3% to 16%. Palomäki *et al.* (2015:591) observed that Finnish adolescent boys indicated a longitudinal increase in obesity prevalence from 17% to 21%, whereas the girls' prevalence remained at 12% between 2003 and 2010. Roldão da Silva *et al.* (2020:164) highlighted a significant increase in BMI and a moderately significant increase in WC in the adolescent participants from their longitudinal study. This familiar tendency of OW and obesity increase, spreading throughout the world, leaves SA as no exception (HAKSA, 2018:7; Nqweniso *et al.*, 2020:11; Pienaar, 2015:9; WHO, 2020a).

2.4.2 Prevalence of obesity in South Africa

A longitudinal study by Pienaar (2015:9) confirmed the rise of obesity prevalence with an increase of 4%, from 12.5% to 16.7%, in children over a span of three years from six years old to nine years old in the NWP. Monyeki, K.D. *et al.* (2017:419) observed the longitudinal development of abdominal obesity amongst 2 225 South African children six to 14 years old, from Ellisras (newly named Lephalale), Limpopo Province, SA, which is an area classified as rural or to have a low social-economic status, between 1996 and 2003. The prevalence for abdominal obesity was 6%, yet according to waist-to-height ratio, a decreasing prevalence of abdominal obesity was observed, which ranged amongst South African boys (0% to 6.2%) and girls (0% to 5%) (Monyeki, K.D. *et al.*, 2017:424). Van Staden *et al.* (2019:98) conducted a longitudinal study with the

aim to evaluate how obesity affects the academic performance, concerning socio-economic status (SES), of South African boys from the NWP. One hundred and eighty-one boys seven to 13 years old participated in this study; they were grouped into SES groups, classified according to BMI categories and their academic grading scales were evaluated over a seven-year period (Van Staden *et al.*, 2019:89). Van Staden *et al.* (2019:98) observed an increase in OW prevalence amongst South African boys from 9.9% to 12.7% and obesity prevalence from 3.3% to 6.6%.

Nqweniso *et al.* (2020:11) noted the total sample showed an obesity prevalence of 18.8% at baseline, and an additional 5.7% of children initially classified as normal weight became OW or obese during the post-intervention measurements. A large effect size for BMI was noted among the participants (Nqweniso *et al.*, 2020:6). Grace *et al.* (2021:2) carried out a 10-week intervention for 13–16-year-old OW and obese South African high school children from the KwaZulu Natal Province. The aim was to evaluate the impact of PA and nutrition intervention on obese participants' BMI, BP and other obesity related factors (Grace *et al.*, 2021:2). During phase two, they identified 656 participants to partake in the intervention, but only included 247 (37.7%) because their BMI values were above the 85th percentile or they were classified as OW or obese (Grace *et al.*, 2021:6). The final sample size of OW or obese South African adolescents partaking in the intervention was 41 participants (Grace *et al.*, 2021:6). As the prevalence of OW and obesity rise worldwide and in SA, it is important to classify children accurately according to scientifically recognised criteria (Cole *et al.*, 2000:4; Kemp *et al.*, 2011:121; Taylor *et al.*, 2000:492).

2.4.3 Criteria for obesity classification

For the correct classification of OW or obesity among young people, proven criteria should be used (Cole *et al.*, 2000:4; de Onis *et al.*, 2007:660; Kuczmarski & Flegal, 2000:1074). The following criteria have been identified as reliable and commonly used from Centres for Disease Control and Prevention (CDC) (2018), Cole *et al.* (2000:4) and WHO (2020a).

Kuczmarski and Flegal (2000:1079) developed BMI age and sex specific percentiles by using the CDC Growth Charts for American children two to 19 years old. Firstly, the BMI value is calculated as an estimation of body mass by dividing mass in kilograms (kg) by stature in metres (m) squared or (kg)/m². Normal weight according to BMI is classified from the 5th percentile to smaller than the 85th percentile, OW is classified between the 85th percentile to smaller than the 95th percentile and obesity according to BMI is classified from the 95th percentile and up (Kuczmarski & Flegal, 2000:1079). Cole *et al.* (2000:4) established internationally acceptable age and sex specific definitions for children and adolescents classified as OW and obese. Each age year between two and 18 years old was given a BMI cut-off point, which was calculated according to an adult's cut-off points of 25 and 30 kg/m² for OW and obesity, respectively (Cole *et al.*, 2000:4). The age and sex-specific BMI cut-off points adapted from Cole *et al.* (2000:4) are indicated in **Table 2.2**.

Table 2.2: Determination of body mass index: international age and sex-specific cut-off points for overweight and obesity by Cole *et al.* (2000:4)

Age (years)	Overweight BMI 25 kg/m ²		Obese BMI 30 kg/m ²	
	Males	Females	Males	Females
9	19.10	19.07	22.77	22.81
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76

De Onis *et al.* (2007:660) developed criteria using of the WHO growth standards and Multicentre Growth Reference Study. A child or adolescent aged five to 19 years can be classified OW when the BMI value is more than one standard deviation above the WHO growth standard median (De Onis *et al.*, 2007:665). The child or adolescent can be classified as obese if the BMI value is more than two standard deviations above the WHO growth standard median (De Onis *et al.*, 2007:665). With scientifically proven criteria available to classify OW or obesity among young people, child health care practitioners and researchers should use the correct measurement techniques to obtain values for the criteria (Cole *et al.*, 2000:4; Kemp *et al.*, 2011:121; Taylor *et al.*, 2000:492).

2.4.4 Measurements methods for obesity

There are various methods of determining the child's BC and classification (underweight, normal, OW or obese). Because children carry their weight differently from each other and differently at various stages of development, it is important to make use of reliable measurement methods and consider the child's growth history, family history and local growth charts (Mayo Clinic, 2018). The Digital methods of composition determination are Hydrostatic weighing (underwater weighing), Bod Pod, Bioelectric impedance analysis (BIA) and Dual-energy X-ray absorptiometry (DEXA) (Balentine, 2019). The anthropometric methods are WC, mid-upper arm circumference, waist-to-hip ratio, BMI and skinfold methods. The system most frequently used is an index of weight-for-height, known as BMI (Balentine, 2019).

Digital measurement methods

Hydrostatic weighing is a costly but accurate digital BC measurement method that weighs a person (underwater by weight displacement of the water) and calculates their whole-BC, including lean muscle mass and fat mass (Balentine, 2019). Bod Pod is another digital BC measuring method that, similarly to hydrostatic weighing, measures a person's whole-BC but rather with air displacement in a digital, oval chamber and can also differentiate between lean and fat mass (Balentine, 2019). Bioelectric impedance analysis (BIA) determines a person's BC by transferring innocuous electrical currents through the body from an entry point to an exit point, measuring the change in voltage as the current passes through different bodily tissues (Balentine, 2019). There are two methods, the first uses a special scale with foot pads releasing the electrical currents and the second uses electrodes placed on the wrist and ankle, and on the dorsal aspect of the right hand and foot (Balentine, 2019). Dual-energy X-ray absorptiometry (DEXA) is the digital BC measuring method that analyses bone density and the amount and placement of adipose tissue (Balentine, 2019). As these digital measurement methods require large machines, specific usage knowledge and training, as well as more time for measurement per participant, these methods were not practical for this study regarding the amount of participants, time available and limited researchers and post-graduate students available to help.

Anthropometric measurement methods

Body Mass Index, an approximate body fat percentage (BF%) calculation, is one measurement method commonly used as an indication of OW or obesity (Balentine, 2019; Mayo Clinic, 2018). This method uses stature and mass values, where BMI equals to mass in kg divided by stature in metres squared ($BMI = kg/m^2$) (Balentine, 2019). The WHO (2020a) emphasises that age and sex must be acknowledged before using BMI among children. Cole *et al.* (2000:4) developed age and sex-specific cut-off points for young people between two and 18 years old by grouping BMI into OW or obese categories. However, BMI alone is insufficient in its classification of the degree and placement of body fat or distinguishing between adipose mass and muscle mass (Balentine, 2019; Pazin *et al.*, 2017:511). Growth charts, which require weight and stature or BMI as a guideline, can also be used to determine whether a young person may be classified as OW or obese (Balentine, 2019; Mayo Clinic, 2018).

Likewise, WC is a measurement method used to classify a person as under or normal weight, OW or obese (Taylor *et al.*, 2000:492). Waist circumference is reliable in identifying children with high BMI values or excess weight (Lean *et al.*, 1995:10; Pazin *et al.*, 2017:511). Taylor *et al.* (2000:492–493) developed WC cut-off points for identifying high trunk-fat mass (age and sex-specific) for participants three to 19 years old from New Zealand. The WC identified >90% of participants as truly positive (high trunk-fat mass and high WC) or truly negative (low trunk fat mass and low WC) (Taylor *et al.* 2000:492–493). Further research is required to determine whether WC will effectively identify high trunk-fat mass among international children as it did with participants from New Zealand (Taylor *et al.*, 2000:492).

Skin fold measurements are another anthropometric method of determining a person's BC by using a skinfold calliper to find values in millimetres (mm) (Balentine, 2019). The subcutaneous adipose tissue (fat layer) under specific points of skin is measured and the fat percentage is calculated using specific values and formulae (Balentine, 2019).

For ease of admin, time available for measurements and the size of the participant sample, the measurement methods chosen for this study were BMI and skinfold measurements. The causes of various obesity measurement methods previously discussed, will be addressed next.

2.4.5 Causes of childhood obesity

Primary causes and secondary causes such as environmental causes, social factors, emotions, diet, physical inactivity, lifestyle choices and hormones all have some or other influence which cause a child to become OW or obese (Kruger *et al.*, 2006:354; Laghi & Rengo, 2017; Pazin *et al.*, 2017:510; Stratton *et al.*, 2007:1174).

Primary causes of obesity

The primary causes of children becoming OW or obese are grouped within the categories of society or environment, the role of parents, physical inactivity and dietary choices (Monyeki, K.D. *et al.*, 2017:419; Pazin *et al.*, 2017:510; Roldão da Silva *et al.*, 2020:166; Stratton *et al.*, 2007:1174; WHO, 2020a).

Lifestyle habits

Role of the parents or family

Mayo Clinic (2018) and Balentine (2019) described that a child with parents or family classified as OW or obese, are at higher risk of being classified as OW or obese. The customs and activities the parents form in the home are the customs and activities the child will follow, often being confused as genetic inheritance when it comes to negative health conditions like unhealthy weight gain and sedentary behaviour (Agarwal, 2016; Balentine, 2019; Mayo Clinic, 2018). Some parents are required to work long hours, leaving children to make their own meals, often being less healthy, convenient, pre-packaged meals or microwave meals (Mayo Clinic, 2018). Kruger *et al.* (2006:355) identified that children who come from families with few members (five or less family members) have a higher risk for being classified with obesity as compared to children who come from families with more members. This is likely due to more finances and food being available for the fewer family members rather than the same amount of food being shared amongst more members (Kruger *et al.*, 2006:355).

Physical inactivity and sedentary behaviour

The nature of children's activities has become more sedentary over time (Agarwal, 2016; Rossouw *et al.*, 2012:6; WHO, 2020b). For example, instead of walking to school, children are transported; urbanisation transforms enjoyable playing spaces into limited, unsafe environments; and recreational activities used to require lots of climbing and running, whereas digital time is now considered as recreation (Mayo Clinic, 2018; WHO, 2020b). With the developments in technology, children spend too much time on digital, sedentary activities like watching television, playing videos games or lying down while listening to music (Mayo Clinic, 2018). When children expend too little energy due to a lack of PA, they burn fewer calories and excess energy is stored as fat (Balentine, 2019; WHO, 2020b). Significant associations between sedentary behaviour or poor CRF, and OW and obesity, were determined amongst international and South African children (Monyeki, M.A. *et al.*, 2017:118; Nqweniso *et al.*, 2020:8; Pazin *et al.*, 2017:509; Roldão da Silva *et al.*, 2020:164; Stratton *et al.*, 2007:1174–1175). Researchers have confirmed that an imbalance between calories expended through PA and calories consumed through poor dietary choices is a crucial contributor to childhood obesity (Agarwal, 2016; Pazin *et al.*, 2017:509; Shokeen & Aeri, 2017:1394; WHO, 2020a).

Dietary habits

A lifestyle of healthy eating is crucial for children who require quality nutrients and sufficient calories for growth and maturation (Chu & Timmons, 2015:463–464). Regrettably, many children do not consume the necessary nutrients, and their daily caloric intake exceeds their daily expenditure (Agarwal, 2016; Chu & Timmons, 2015:465; Rossouw *et al.*, 2012:5). Several studies noted associations between overeating or high calorie, processed diets and weight gain in young people (Balentine, 2019; Mayo Clinic, 2018; Pazin *et al.*, 2017:509; Shokeen & Aeri, 2017:1394). Processed foods and food high in saturated or animal fat is often considered part of a modern or Western diet and is target marketed towards children and adolescents (Mayo Clinic, 2018; Shokeen & Aeri, 2017:1394; WHO, 2020a). Many processed foods marketed as healthy are concealed causes for weight gain among children (Agarwal, 2016; Mayo Clinic, 2018; Rossouw *et al.*, 2012:5; WHO, 2020a). Monyeki, K.D. *et al.* (2017:425) has observed the significant link between the nutritional status of young children with abdominal obesity later during adolescence and adulthood. The high rate of under nutrition according to BMI (7.1%–63%), revealed the low prevalence of obesity (0%–6.2%) in children from a rural setting in SA (Monyeki, K.D. *et al.*, 2017:425). Moselakgomo and Van Staden (2017:187) stated that the South African population is one of the African populations experiencing industrialisation and urbanisation, which allows for a dietary profile transition from a traditional, more natural and smaller diet to the Westernised, more processed, larger and meat rich diet.

Society, environment and education

Socio-economic development and environment

A country's agricultural development and policies largely determine which foods are available in stores (WHO, 2020a). Some families have limited access to resources or stores due to lower SES or social issues like insufficient finances or unsafe exercise environments (Mayo Clinic, 2018). Associations between SES and weight has been identified where participants from high SES groups have higher OW prevalence (during 2010 between 14.3%–17.9%) and obesity (during 2010 between 4.5%–7.1%), as compared to participants from lower SES groups (during 2010, OW 2.2%–4.1% and obesity 2.2%–3%) (Balentine, 2019; Pienaar, 2015:4–9; Van Staden *et al.*, 2019:94). This relationship between high SES and increased obesity prevalence remained similar over the three-year (between 2010 at 7.1% and 2013 at 12.4%) and six-year periods (from 4.5% during 2010 to 12.4% during 2013 and 8.9% during 2016) (Pienaar, 2015:4; Van Staden *et al.*, 2019:94).

Young people are restricted in their choice of environment, as they need to live where their parents or guardians decide, and eat the food provided (Rossouw *et al.*, 2012:6; WHO, 2020a). Another concern regarding the environment is whether there are safe recreational spaces available for PA in the community or not (Balentine, 2019). Kruger *et al.* (2006:355) identified that South African participants living in and near urban areas have an increased prevalence of OW and obesity compared to participants from rural areas. Kruger *et al.* (2006:355) noted the influences of Western lifestyle (abundant fast-food outlets, endless energy-dense food options available, sedentary environments, commuting with vehicles and PA limited to indoor or safer locations) were the main reason for this increase in OW and obesity prevalence.

Lack of education or understanding

The education on living healthy, which is critical for understanding health choices and optimal growth, is not up to standard (Agarwal, 2016; Chu & Timmons, 2015:463; Shokeen & Aeri, 2017:1394; WHO, 2020a). Part of understanding health choices is to learn how to read food labels, differentiate in serving sizes and to be able to evaluate approximate calories per serving (Balentine, 2019). Children are continuously growing and learning about life's experiences; thus, they have partial understanding of the long-term effects of their eating or exercise habits (WHO, 2020a). It is important that children receive direction to what healthy eating habits, suitable exercise guidelines and appropriate long term weight loss and management solutions are (Balentine, 2019; WHO, 2020a).

With these societal problems of obesity spanning from policies to education, it is vital that the community work together and a multi-disciplinary approach is presented to the parents, who give the most basic lifestyle habit education at home (WHO, 2020a). Secondary causes of OW and obesity, such as psychological factors and menarche, will be elaborated on in the following paragraphs (Agarwal, 2016; Balentine, 2019; Cameron & Getz, 1997:778).

Secondary causes of obesity

Psychological factors

The stress perceived by the child from personal, parental or family pressures can result in the child gaining weight, either by rising cortisol levels or by comfort eating to deal with related emotions (Agarwal, 2016; Mayo Clinic, 2018). Some children may also walk past the fridge regularly for food because of boredom, anger or despondency resulting in overeating (Balentine, 2019; Mayo Clinic, 2018). Agarwal (2016) indicates that depression or attention seeking could be a possible cause for children gaining unwanted weight. Balentine (2019) stated that around 30% of people who seek health care for severe weight problems also struggle with binge eating disorder.

Menarche

Cameron and Getz (1997:776) conducted a cross-sectional study based on a mixed-longitudinal study design to evaluate the prevalence and sex differences of obesity in 447 rural African adolescents seven to 18.9 years old from Mpumalanga, SA. The prevalence of OW was higher in girls than in boys (Cameron & Getz, 1997:778). As girls reach the age of menarche, the prevalence for OW or obesity also increases (Cameron & Getz, 1997:778; Kruger *et al.*, 2006:355; Rossouw *et al.*, 2012:2). Although OW and obesity is higher amongst adolescent girls, than in younger girls, OW or obesity did not occur throughout adolescence but rather OW and obesity was associated with menarche (Cameron & Getz, 1997:778; Rossouw *et al.*, 2012:2). The increase in adipose tissue in females during menarche has attributed to the change and increase in hormones that increase the susceptibility for adipose deposition (Cameron & Getz, 1997:778). The various causes of OW and obesity can directly or indirectly lead to different negative effects in children or adolescents. Therefore, the negative effects of OW and obesity will be discussed here-after (He *et al.* (2011:110; Kemp *et al.*, 2011:120; Laghi & Rengo, 2017).

2.4.6 Negative effects of obesity

With this rise in obesity prevalence among children, there is a rise in comorbidities. Once a child becomes OW or obese, he/she experiences physical or emotional symptoms and or social limitations and these have negative impacts on the child's quality of life (Laghi & Rengo, 2017). Obesity or OW, being independent risk factors, also leads to other more severe risk factors and comorbidities, such as CV disorders, digestive negative effects and pulmonary diseases (He *et al.*, 2011:110; Kemp *et al.*, 2011:120; Monyeki, M.A. *et al.*, 2017:118; Chungag *et al.*, 2019:260). Laghi and Rengo (2017) and Stratton *et al.* (2007:1175) reported that obesity, with its comorbidities and risk factors, might also lead to premature mortality.

Pulmonary diseases

Pulmonary diseases that are risk factors of obesity are asthma, sleep apnoea and exercise intolerance (Balentine, 2019; Dietz & Robinson, 2005:2103; Mayo Clinic, 2018; Rossouw *et al.*, 2012:2). Excessive

tiredness during the day may occur in children as a symptom of obstructive sleep apnoea caused by OW or obesity, which may contribute to lower PA participation (Dietz & Robinson, 2005:2103). A form of exercise intolerance could be identified when Monyeki, M.A. *et al.* (2017:118) and He *et al.* (2011:110) similarly found that when considering CRF and PA within the various BMI categories, the participants classified as OW or obese were heavier and had significantly lower CRF levels, whereas the participants classified as normal weight had higher CRF levels ($\dot{V}O_2$ max). The link between the heavier body mass and lower CRF ability could be explained by the concept that OW and obese children have more fat mass to carry when exercising; therefore, they struggle with weight-dependant movements (Malina *et al.*, 2004:539; Monyeki, M.A. *et al.*, 2017:118–120). Yet another explanation the excessive visceral adipose tissue and adipose tissue around the ribs makes breathing more difficult through the pressure exerted on the airway (Salome *et al.* 2010:206).

Digestive related negative effects

The digestive related diseases that are symptoms of OW or obesity are type 2 diabetes, insulin resistance and metabolic syndrome (Balentine, 2019; Dietz & Robinson, 2005:2103; Goon *et al.*, 2013:492; Mayo Clinic, 2018; Rossouw *et al.*, 2012:1). Mayo Clinic (2018) described that Metabolic Syndrome is a group of conditions or components such as high BP, high blood glucose levels, excess abdominal fat, high triglycerides and increased level of low-density lipoprotein and a decrease in high-density lipoprotein. A brutal cycle is that children classified as obese have a higher risk for metabolic syndrome and metabolic syndrome is a major risk factor for obesity (Mayo Clinic, 2018; Rossouw *et al.*, 2012:5). Children classified as OW often have a form of insulin resistance as a prediabetes condition; consequently, HTN results as a component thereof (Balentine, 2019; NHBPEP, 2005:16). Similarly, researchers have found that OW or obesity increases a child's risk for type 2 diabetes and the risk multiplies if the child is primarily sedentary (Mayo Clinic, 2018; Rossouw *et al.*, 2012:2). Balentine (2019) reported that fat cells resist insulin more than muscle cells, which may be a crucial cause of insulin resistance in people with higher levels of adiposity. Some adverse symptoms of OW or obesity in young people with type 2 diabetes that have been identified, are nocturia (urge to urinate frequently at night), polyuria (large volumes of urine), polydipsia (excessive thirst) and a more frequent urge to urinate (Dietz & Robinson, 2005:2103).

Emotional or social impediments

Rossouw *et al.* (2012:2), and Dietz and Robinson (2005:2103) explain that a youth classified as OW or obesity may struggle to sleep, feel depressed or lose the capacity to experience pleasure due to the emotions he or she experiences with regards to their weight. Low self-esteem develops in youths classified as OW or obese, because they are made fun of, ignored or bullied by peers, this negative interaction may lead to depression if overwhelming feelings or hopelessness are not addressed (Dietz & Robinson, 2005:2103; Mayo Clinic, 2018; Rossouw *et al.*, 2012:2; Shokeen & Aeri, 2017:1394). At times, the overwhelming feelings or anxiety caused by the bullying may direct a child to react out of anger or frustration, resulting in behavioural problems or

psychosocial barriers if it persists (Chu & Timmons, 2015:463; Mayo Clinic, 2018). The child acting out behaviourally may disrupt lessons at school and can lead to learning problems; or portray the child as socially uncooperative and result in poor social skills or the child pulling out of social events (Mayo Clinic, 2018).

Premature mortality

Premature mortality, or an earlier death than the recorded average life expectancy for a specific population group, has been proven to be a negative effect of obesity with its comorbidities and risk factors (Laghi & Rengo, 2017; Pazin *et al.*, 2017:510; Rossouw *et al.*, 2012:2; Stratton *et al.*, 2007:1175).

Cardiovascular Disorders

The effects that obesity have on a child's CV system are numerous and detrimental (Chungag *et al.*, 2019:260; Kemp *et al.*, 2011:120; Rossouw *et al.*, 2012:2). Researchers have identified the CV disorders associated with OW or obesity as HTN, ischaemic heart disease, high cholesterol and heart attack (Balentine, 2019; Chungag *et al.*, 2019:260; Rossouw *et al.*, 2012:2). The argument has been established by several studies that when children gain weight; increase their WC or have a higher BMI value, they are at a higher risk for HTN (Chungag *et al.*, 2019:260; Kemp *et al.*, 2011:120; Moselakgomo & Van Staden, 2017:189; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis, 2019:117). Pazin *et al.* (2017:511) noted that as WC increased, the BP prevalence also increased, resulting in a 57% higher risk for HTN amongst the fourth quartile participants compared to the first quartile participants (BP prevalence from 8.1% in the first quartile to 12.1% in the fourth quartile). The non-OW boys (9.0%) and girls (13.8%) had a lower prevalence for HTN than the OW classified boys (27.6%) and girls (30.2%), and the obese classified boys (40.5%) and girls (45.9%) had the highest HTN prevalence (Liu *et al.*, 2017:811). Balentine (2019) reported on similar trends that weight gain intensified HTN more severely in females than in males. The link between obesity and HTN amongst young people has been identified and it is concerning, therefore, research articles about HTN in young people will be discussed in the section below.

2.5 HYPERTENSION IN CHILDREN AND ADOLESCENTS

This section will address literature on HTN in young people: the prevalence; criteria; measurement methods, causes and negative effects of HTN. A familiar rise in HTN has been recognised over different population samples worldwide (Agostinis-Sobrinho *et al.*, 2018:132; Liu *et al.*, 2017:811). The prevalence of HTN amongst children ranges between six to 10.7%, with an indication of SBP prevalence of 8.7% and DBP prevalence of 16.1% (Adil *et al.*, 2016:27; Musa & Williams, 2012:1981; Pazin *et al.*, 2017:510). Similarly, various cultures in SA have seen this increase in HTN (Goon *et al.*, 2013:491; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567). For an accurate identification of HTN, accurate criteria should be considered, and the correct measuring equipment and methods should be used (NHBPEP, 2005:8; OCMD, 2015).

Although there are several possible primary and secondary causes for HTN in children, these causes vary according to the age of the child (Felman, 2019; Gidding, 2017; Mayo Clinic, 2019; OCMD, 2015). The secondary HTN causes are often identified as other health related conditions, like prematurity, CV or kidney problems, hormonal imbalances or use of medications or substances (Adil *et al.*, 2016:27; NHBPEP, 2005:15). Weight gain has been identified to be one of the most common primary causes of HTN, which paired with lack of exercise and excessive dietary sodium intake, results in destructive effects on a child's overall well-being (Kemp *et al.*, 2011:120; Mayo Clinic, 2019; Webb, 2017; Stabouli & Kotsis, 2019:117).

Hypertension causes several negative effects in children, some being minor and other effects being severe (NHBPEP, 2005:17; Moselakgomo *et al.*, 2012:566). It has been noted that the heart, arteries and veins, brain, nerves, lungs, throat, kidneys, skin, muscles and eyes are all affected by HTN (Adil *et al.*, 2016:27; Alloubani *et al.*, 2018:578–579; DelRosso *et al.*, 2018:105; Enright *et al.*, 2003:901; NHBPEP, 2005:20). The following two sections will discuss the prevalence of HTN amongst international and South African children and adolescents.

2.5.1 Prevalence of hypertension worldwide

To date, the prevalence of HTN (being a CVD risk factor) is increasing amongst children and adults (Castro-Piñero *et al.*, 2017:1755; Kallerman, 2019:32; Roldão da Silva *et al.*, 2020:164). Musa and Williams (2012:1979) investigated the independent and merged associations between CRF, fatness and BP in a cross-sectional study that involved 3 243 children and adolescents nine to 15 years old from Benue, Nigeria. The participants were grouped according to their ages, namely children (total group $n = 1\,017$, boys = 485 and girls = 532) and adolescents (total group $n = 2\,226$, boys = 1038 and girls = 1188) (Musa & Williams, 2012:1981). A participant was classified with HTN when the BP value was above the levels of the specified SBP value (≥ 130 mmHg) and DBP value (≥ 85 mmHg) (Musa & Williams, 2012:1980). Musa and Williams (2012:1979) found that the prevalence of systolic HTN amongst the children was 8.7% (boys = 5.6% and girls = 11.5%) and 16.7% amongst adolescents (boys = 12.5% and girls = 20.4%). The prevalence of diastolic HTN in the children was 16.1% (boys = 16.3% and girls = 16.0%) and 14% amongst adolescents (boys = 13.4% and girls = 14.5%) (Musa & Williams, 2012:1981).

Castro-Piñero *et al.* (2017:1755) found that SBP significantly increased in their longitudinal study on six- to 12-year-old Spanish participants. Brazilian children six to 11 years old classified with normal BMI levels indicated a cross-sectional prevalence for HTN of 10.7% according to Pazin *et al.* (2017:510). Liu *et al.* (2017:809) carried out a cross-sectional study to 4 926 Chinese primary school children five to 12 years old. The researchers investigated associations between mass, HTN and CRF (Liu *et al.*, 2017:811). Liu *et al.* (2017:811) identified that the prevalence of HTN amongst Chinese boys and girls was 14.6% and 16.1%, respectively. Kallerman (2019:18) carried out a four-part study in which study III was longitudinal with the

objective to evaluate HTN amongst 49 Swedish participants 23 years old, who were part of an intervention program for severe childhood obesity since the age of 14 years. The participants indicated an increase in daytime HTN from zero percent during childhood to 24% during young adulthood (Kallerman, 2019:32). Roldão da Silva *et al.* (2020:164) noted a longitudinal increase in diastolic BP amongst adolescents. As the prevalence of HTN accelerates around the world, several studies indicate that there is also a moderate to high prevalence of HTN amongst the children and adolescents from SA (Goon *et al.*, 2013:489–490; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7).

2.5.2 Prevalence of hypertension in South Africa

South African literature about HTN in children and adolescents is mostly cross-sectional and partially representative, yet it indicates that HTN is similarly prevalent (Grace *et al.*, 2021:6; Kemp *et al.*, 2011:120; Nqweniso *et al.*, 2020:7). Kemp *et al.* (2011:118) performed a cross-sectional study with the aim of determining the prevalence of HTN and its association to BC in 816 (boys = 419 and girls = 397) Grade 1 learners of the NWP, SA. The total prevalence of prehypertension was 8.5%; the prehypertension prevalence amongst the boys was 9.8% and 6.8% amongst the girls (Kemp *et al.*, 2011:120). The total prevalence of HTN was 24.9%; the HTN prevalence amongst the boys was 24.8% and 24.9% amongst the girls (Kemp *et al.*, 2011:120). Moselakgomo *et al.* (2012:567) made use of a cross-sectional study design to evaluate the relationship between BMI, obesity and HTN among 1 172 South African children (boys = 541 and girls = 631) 10–13 years old from the Limpopo Province. The researchers observed an overall HTN prevalence of 3.5% in the group, and when considering sex, the prevalence was 4.1% in boys and 2.8% in girls (Moselakgomo *et al.*, 2012:567).

Goon *et al.* (2013:489–490) conducted a cross-sectional study that examined the relationship between BP and BMI amongst 269 South African children and adolescents (boys = 134 and girls = 135), seven to 13 years old from Thohoyandou, Limpopo Province, which is classified as a rural area. They found that the mean SBP value for the sample was 94 mmHg and the mean DBP value was 57.7 mmHg, where the HTN prevalence was 0.4% in the boys and 0.2% in the girls (Goon *et al.*, 2013:489–490). Chungag *et al.* (2019:259) noted the cross-sectional prevalence of HTN amongst South African participants (20.7%), and amongst boys (15.6%) and girls (26.2%). Nqweniso *et al.* (2020:7) noted in a longitudinal study that the sample baseline prevalence of HTN (participants who had systolic and diastolic hypertension) was 13.5% amongst South African children; 48% in boys and 52% in girls. A decrease in HTN prevalence during the post-intervention period was noted when 91 of the 99 (91.9%) children initially classified with HTN improved to being classified as having normal BP (Nqweniso *et al.*, 2020:7). Grace *et al.* (2021:7) identified a cross-sectional prevalence of raised BP as 59% and the longitudinal prevalence for elevated BP decreased (20% to 15%); the prevalence for HTN stage one remained at 24%; and HTN stage two decreased from 15% to 2% during a 10-week PA intervention.

Most literature available on HTN amongst South African children and adolescents is either from low SES areas or a mix of SES areas, which indicate a sample HTN prevalence that varied from 2.6% to as high as 20.7% (Chungag *et al.*, 2019:259; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7). The South African literature from specific provinces also indicated a vast cross-sectional prevalence range of HTN amongst boys (between 0.4%–48%) and girls (between 0.2%–52%) (Chungag *et al.*, 2019:259; Goon *et al.*, 2013:489–490; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7). Whereas, Nqweniso *et al.* (2020:7) identified a longitudinal decrease in HTN within the sample. With the knowledge that the South African HTN prevalence is generally high, one needs to understand what the criteria entails for a correct classification about whether a child is pre-hypertensive or hypertensive (NHBPEP, 2005:8; Kemp *et al.*, 2011:120; Nqweniso *et al.*, 2020:7).

2.5.3 Criteria of hypertension

The NHBPEP (2005:8) indicated that a normal BP value for children and adolescents should have the SBP and/or DBP values less than the 90th percentile for age, sex and stature. The BP value is prehypertensive when the child or adolescent's SBP and/or DBP values are greater than the 90th percentile but less than the 95th percentile (NHBPEP, 2005:8). According to NHBPEP (2005:8), paediatric HTN is characterised as SBP and/or DBP greater than or equal to the 95th BP percentile for age, sex and stature. Before classifying a child with normal BP, prehypertension or HTN, accurate BP readings should be taken using the correct measurement techniques and equipment.

2.5.4 Measurements of hypertension

The various measuring methods and guidelines for BP and HTN in children is very specific and differs from the measurement methods of adults. The manual and digital methods of BP and HTN measurements will be discussed in the subsequent paragraphs.

The following descriptions are basic guidelines on how to measure BP for a child. According to NHBPEP (2005:5) the child should be in a seated position with both feet on the floor, back rested against the back of the chair and quietly resting for approximately 5 minutes. The arm that is to be measured should rest on a supported surface at heart level, the child's right arm is preferred for measurements that need to be repeated due to the likelihood that the aorta may lead to lower BP values (NHBPEP, 2005:5–6). The BP cuff should be the correct size to fit the child's arm. The most accurate manual method of measuring BP under most circumstances in children is auscultation (NHBPEP, 2005:6). Auscultation is when the Korotkov sounds or the sounds of the blood in the arteries are listened to by using a stethoscope with a BP cuff (OCMD, 2015). The stethoscope is to be held over the brachial artery pulse, slightly below and inwards of the bend of the elbow (cubital fossa) yet needs to be placed near the bottom of a BP cuff, if one is used (NHBPEP, 2005:5).

A digital and visual method of measuring BP in children is a method that makes use of oscillometric devices. The oscillometric device visually displays the amplitude of arterial pulse oscillations measured over time (OCMD, 2015). The oscillometric device is not generally prescribed to be used with children as the results differ between the different brands and manufacturers (NHBPEP, 2005:7). A second digital method for BP measurement is a standard sphygmomanometer in conjunction with a stethoscope, which is considered as the gold standard for BP measurement within an office (NHBPEP, 2005:5). The sphygmomanometer is a non-automated or automated device which is connected to an inflatable cuff and a scale gauge which measures in millimetres of mercury (mmHg) (OCMD, 2015). The manometers using mercury are being phased out due to the toxicity of mercury and are replaced with aneroid manometer devices (NHBPEP, 2005:6). Auscultation, a manual method which is recommended for children, is a reliable method to determine the mean arterial BP, the SBP and the DBP values (NHBPEP, 2005:6). The NHBPEP (2005:38) have determined regression coefficients from BP regression models for 10-year-old boys (SBP $p = 1.824$ and DBP $p = 0.683$) and girls (SBP $p = 1.943$ and DBP $p = 1.013$). A third digital method, which is considered the least invasive, is the Doppler ultrasound method (OCMD, 2015). This method relies on the frequency of sound from the blood flow in the vessels to indicate the movement of blood within the vessels (OCMD, 2015). Now that the measurement techniques for HTN have been reviewed, the possible causes of HTN will be discussed next.

2.5.5 Possible causes of childhood hypertension

According to the Oxford Concise Medical Dictionary (OCMD) (Martin, 2015), HTN is classified into two samples, primary hypertension and secondary hypertension. Primary hypertension is named when the cause of HTN is not a result of another known condition or results from an unknown cause (Felman, 2019; OCMD, 2015). When the HTN is caused by another fundamental condition it will be classified as secondary hypertension (Felman, 2019; OCMD, 2015). In general, HTN in children younger than six is a secondary symptom of a primary cause (Gidding, 2017; Mayo Clinic, 2019). Children older than six years develop HTN from similar primary causes as adults; causes such as excessive weight gain, inadequate exercise or excessive salt intake, which will be described in the following paragraphs (Gidding 2017; Mayo Clinic, 2019; OCMD, 2015).

Lifestyle habits

Weight gain

Several researchers support the argument that weight gain, increase in BF%, WC or BMI, places a child at a higher risk for HTN (Chungag *et al.*, 2019:260; Kemp *et al.*, 2011:120; Pazin *et al.*, 2017:510; Roldão da Silva *et al.*, 2020:164; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis, 2019:117). Sinaiko *et al.* (1999:1473) observed that the rate of childhood weight gains significantly affected the SBP of the participant later during young adulthood and that current weight gain had a significant influence on current SBP. Chungag *et al.* (2019:260) and Kemp *et al.* (2011:120) associated the high prevalence of HTN with increased body weight amongst South

African children and adolescents in cross-sectional research. Pazin *et al.* (2017:510–512) confirmed that the amount of adipose tissue, instead of weight gain itself, was the identified factor that caused BP to increase regardless of other influencing factors (age, sex or ethnicity) amongst children classified with a normal BMI value.

Lack of physical activity and poor cardiorespiratory fitness

The Mayo Clinic (2019) explains that as one lacks exercise, the CRF levels decrease; one's heart becomes weaker and the effort to pump blood becomes more difficult resulting in higher BP values. Roldão da Silva *et al.* (2020:164) and Nqweniso *et al.* (2020:8) found cross-sectional and longitudinal inverse associations between CRF and HTN, where children and adolescents who reported higher levels of sport participation were less likely to have HTN. Physical activities that increase the heart rate will have a positive impact on lowering BP; the activities may include, but are not limited to, walking, swimming, dancing, household chores, hiking or climbing, or jogging (Mayo Clinic, 2019). Weight training has long-term health benefits on BP by strengthening the CV system, if the techniques are executed correctly and breathing is consistent (Mayo Clinic, 2019). To have a healthy effect on BP values, one needs to exercise regularly for about three months and the results last only on condition that exercising continues (Mayo Clinic, 2019).

Excessive dietary sodium

Even a small amount of sodium or salt has a negative effect on the body by increasing body water retention which increases the high arterial flow in the vessels and causes natriuresis pressure (increased renal sodium excretion and decreased sodium absorption) , resulting in increased BP values (Gidding 2017; Mayo Clinic, 2019; NHBPEP, 2005:25). The NHBPEP (2005:25) suggest that children between four and eight years should have no more than 1 200mg sodium per day, where as children older than eight years should adhere to 1 500mg sodium per day. By adding one level teaspoon of salt (2 300mg sodium) to food, the maximum limit of daily sodium surpasses the healthy recommended guideline of sodium intake for children nine to 13 years old (<2 200mg) (Webb, 2017). To monitor sodium content, guardians should compare food labels to find lower sodium content foods; children should eat fresh, home cooked meals instead of processed foods or eating out regularly; and guardians should strive to make home meals from whole foods (Gidding 2017; Webb, 2017).

Various causes of HTN lead to harmful effects that are detrimental to young people (NHBPEP, 2005:17; Nqweniso *et al.*, 2020:8; Pazin *et al.*, 2017:512; Roldão da Silva *et al.*, 2020:164; Webb, 2017).

2.5.6 Negative effects of hypertension

The negative effects of HTN are numerous and fatal, often affecting several vital organs of the human body or possibly resulting in pre-mature mortality (Cifu & Davis, 2017:2133; NHBPEP, 2005:17; Moselakgomo *et al.*, 2012:566). Some of the effects are CV disruptions, nervous system interferences, pulmonary illnesses,

digestive related diseases and other bodily changes; which will be elaborated on in the following paragraphs (NHBPEP, 2005:18; Moselakgomo *et al.*, 2012:566; Sinaiko *et al.*, 1999:1473).

Cardiovascular disorders

Hypertension has been found to have pathologic effects on the CV system resulting in CVD, heart dysfunctions and heart failures (Adil *et al.*, 2016:27; Cifu & Davis, 2017:2133; NHBPEP, 2005:18; Goon *et al.*, 2013:492; Moselakgomo *et al.*, 2012:566). When performing paediatric HTN exams, the NHBPEP (2005:18) took notice of heart murmurs and observed that coarctation of the aorta caused an upper and lower extremity difference in pulse and BP. The onset of HTN affects the heart when damage is caused by heart attack or cardiac arrest (Goon *et al.*, 2013:492; Moselakgomo *et al.*, 2012:566). Adil *et al.* (2016:27) identified that the prevalence of children diagnosed with arterial ischemic stroke, HTN and an additional comorbid CV condition was 8.7% for congestive heart failure, 6% for valvular heart disease and 9.5% for deficiency anaemia. Adil *et al.* (2016:27) further identified the prevalence of secondary diagnoses in children with HTN, and arterial ischemic stroke was 2.8% for cardiomyopathy, 9.6% for sickle cell disease and 1.8% for deep venous thrombosis.

Pulmonary illnesses

An association has been established between HTN and pulmonary illnesses, like sleep apnoea, chronic lung disease and pneumonia (Adil *et al.*, 2016:27; DelRosso *et al.*, 2018:104; Enright *et al.*, 2003:901; NHBPEP, 2005:17). Enright *et al.* (2003:901) and NHBPEP (2005:17) observed that about 15% of the children were reported to snore loudly while sleeping, while a significant association was found between the increases in BP and sleep disturbances due to breathing problems found among one to three percent of participants. DelRosso *et al.* (2018:104–105) explained that children who were diagnosed with obstructive sleep apnoea had higher levels of BP, and that positive airway pressure intervention programs decreased their BP levels. Children diagnosed with arterial ischemic stroke and HTN had a prevalence of 3.2% for obstructive sleep apnoea as compared to children without HTN (0.5%) (Adil *et al.*, 2016:27). Adil *et al.* (2016:27) noticed that pneumonia, as a secondary diagnosis, is higher amongst children with HTN (4.3%) than amongst children without HTN (2.1%).

Nervous system disturbances

Researchers have found that HTN negatively affects children's nervous systems, namely the brain and its functioning, resulting in disturbances in the nervous system (Adil *et al.*, 2016:27; Cifu & Davis, 2017:2133; NHBPEP, 2005:18). Mayo Clinic (2019) indicated that two symptoms of HTN's influence on the nervous system are headaches and seizures, while Cifu and Davis (2017:2133) identified stroke as symptom with a strong association. Adil *et al.* (2016:27) noted that the prevalence for paralysis among children with HTN was 11.3%, compared to 2.9% among children not diagnosed with HTN. Lande and Kupferman (2019:537–538)

noted an association between HTN and decreased neurocognitive test performances in children, that HTN early in life can have a negative effect on a child's memory, verbal ability learning, vocabulary and fine motor skills.

Premature Mortality

Hypertension is a preliminary risk for disability and death affecting about two to four percent of children worldwide (Adil *et al.*, 2016:26; Cifu & Davis, 2017:2133; Pazin *et al.*, 2017:509). Adil *et al.* (2016:26), Pazin *et al.* (2017:509) as well as Cifu and Davis (2017:2133) described that as HTN steadily increases among children, the mortality risk among children also increases. Adil *et al.* (2016:26) specifically found that for children who have HTN after an ischemic stroke have a 7.4% higher associated risk for mortality than for children without HTN (2.8%). An influence in the increased risk for mortality was that 10% of the participants who were diagnosed with HTN after an ischemic stroke had renal failure (Adil *et al.* 2016:26). The renal failure hampered the effective excretion or reabsorption of sodium, allowing for higher water retention levels; more pressure on the arterial flow; and increased natriuresis pressure (Adil *et al.* 2016:27; NHBPEP, 2005:18).

2.6 CHAPTER SUMMARY

In closing of Chapter Two, the international CRF prevalence amongst children and adolescents showed a longitudinal range in $\dot{V}O_2$ max between 28 mL/kg/min and 43 mL/kg/min, which was below and within health criterion referenced CRF standards (35–47 mL/kg/min) (Agostinis-Sobrinho *et al.*, 2018:132; He *et al.*, 2011:111; Kallerman, 2019:36; Roldão da Silva *et al.*, 2020:165; Ruiz, *et al.*, 2014:769; Stratton *et al.*, 2007:1175). South African literature from specific provinces identified a cross-sectional prevalence range of CRF from between 26.66 mL/kg/min and 33.67 mL/kg/min for OW and inactive participants, and between 31.58 mL/kg/min and 34.12 mL/kg/min for normal weight active participants, which was well below health criterion referenced CRF standards (35–47 mL/kg/min) (Awotidebe *et al.*, 2016:247; Monyeke, M.A. *et al.*, 2017:119; Ruiz, *et al.*, 2014:769). According to sex, the CRF ranged between 22.29 mL/kg/min and 41.01 mL/kg/min amongst South African boys and between 25.43 mL/kg/min and 29.25 mL/kg/min amongst South African girls (Awotidebe *et al.*, 2016:247; Monyeke, M.A. *et al.*, 2017:119).

Satisfactory CRF levels have many benefits which include reduced risk for CVD clusters and all-cause mortality; as well as improved blood circulation, BC and psychological well-being (Kallerman, 2019:36; Palomäki *et al.*, 2015:591; Roldão da Silva *et al.*, 2020:166; Rhodes *et al.*, 2017:948). Yet poor CRF levels have strong associations with high risk to become or stay hypertensive and obese as negative effects, independent of age, sex and origin (Agostinis-Sobrinho *et al.*, 2018:132; Katzmarzyk & Staiano, 2017:782; Monyeke, M.A. *et al.*, 2017:118; Palomäki *et al.*, 2015:591).

Cardiovascular disease consists of four key components; HTN, diabetes, dyslipidaemia and OW (Gao *et al.*, 2013:2). An individual has a cluster of CVD risk factors if a medical professional diagnosed at least two major

CVD risk factors in this individual (Gao *et al.*, 2013:2). We identified HTN and obesity as primary components of discussion.

The international OW (4%–18%) and obesity (0.4%–18%) prevalence ranges have increased longitudinally amongst children and adolescents (He *et al.*, 2011:110; Roldão da Silva *et al.*, 2020:164). According to sex, the OW and obesity prevalence ranged between 16%–26% for boys and between 20%–31% for girls (Palomäki *et al.*, 2015:591; Stratton *et al.*, 2007:1174). South African longitudinal literature from selected provinces has identified increasing ranges of OW (9.9%–12.7%) and obesity (3.3%–18.8%) in children and adolescents (Monyeki, K.D. *et al.*, 2017:424; Nqweniso *et al.*, 2020:11; Pienaar, 2015:9; Van Staden *et al.*, 2019:98). The longitudinal sex related OW and obesity prevalence for boys ranged from 3.3% to 12.7% and was at 5% for girls (Monyeki, K.D. *et al.*, 2017:424; Van Staden *et al.*, 2019:98).

The various causes of OW or obesity among youth were grouped within categories of society, education, environment, the role of family, menarche, physical inactivity and dietary choices, which have negative consequences (Kruger *et al.*, 2006:355; Monyeki, K.D. *et al.*, 2017:419; Nqweniso *et al.*, 2020:8; Pazin *et al.*, 2017:510; Roldão da Silva *et al.*, 2020:166; Stratton *et al.*, 2007:1174). Literature has shown the negative effects of OW and obesity, such as CV illnesses, digestive conditions, emotional and social disorders, pulmonary diseases, and premature mortality (He *et al.*, 2011:110; Kemp *et al.*, 2011:120; Laghi & Rengo, 2017; Monyeki, M.A. *et al.*, 2017:118).

International literature showed that the prevalence of HTN amongst children and adolescents to range between 8.7%–24%, with the prevalence for sex ranging between 14.6%–65.5% for boys and between 16.1%–35.3% for girls (Castro-Piñero *et al.*, 2017:1755; Liu *et al.*, 2017:811; Musa & Williams, 2012:1981; Pazin *et al.*, 2017:510). Longitudinal literature noted a general increasing trend in HTN (Castro-Pinero *et al.*, 2017:1755; Roldão da Silva *et al.*, 2020:164). Most literature available on HTN amongst South African children and adolescents is partially representative of the full population, have cross-sectional results and from either low SES areas or a mix of SES areas, which indicated a HTN prevalence range that varied from 3.5% to 24.9% (Chungag *et al.*, 2019:259; Goon *et al.*, 2013:489–490; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7). Nqweniso *et al.* (2020:7) identified a longitudinal decrease in HTN within the sample. The South African literature also indicated a vast cross-sectional prevalence range of HTN amongst boys (between 0.4%–48%) and girls (between 0.2%–52%) (Chungag *et al.*, 2019:259; Goon *et al.*, 2013:489–490; Kemp *et al.*, 2011:120; Moselakgomo *et al.*, 2012:567; Nqweniso *et al.*, 2020:7).

Various HTN causes, such as excessive weight gain, lack of exercise or poor CRF and too much dietary sodium, lead to many negative effects that are harmful to young people (Gidding 2017; Mayo Clinic, 2019; Nqweniso *et al.*, 2020:8; Roldão da Silva *et al.*, 2020:164; Sinaiko *et al.*, 1999:1473; Stabouli & Kotsis,

2019:117). Several negative effects were identified, namely CV disruptions, nervous system interferences, pulmonary illnesses, digestive related diseases and other bodily changes; possibly resulting in pre-mature mortality (Cifu & Davis, 2017:2133; Moselakgomo *et al.*, 2012:566; Sinaiko *et al.*, 1999:1473).

These CV risk factors are modifiable and preventable with various lifestyle changes that include chronic stress reduction; dietary changes and exercise or CRF improvements (Cifu & Davis, 2017:2133; Pazin *et al.*, 2017:509). With children's health deteriorating at an alarming rate, based on conditions such as lower CRF levels, rising obesity and HTN rates, it's important to implement research and large-scale awareness unique to the characteristics of South African children (Kemp *et al.*, 2011:121; Monyeki, M.A. *et al.*, 2017:118).

2.7 REFERENCES

- Adil, M.M., Beslow, L.A., Qureshi, A.I., Malik, A.A. & Jordan, L.C. 2016. Pediatric neurology hypertension is associated with increased mortality in children hospitalized with arterial ischemic stroke. *Pediatric Neurology Elsevier*, 56:25–29.
- Agarwal, A. 2016. *Paediatric Obesity*. <https://www.slideshare.net/AbhinavAgarwal62/pediatric-obesity-60405183> Date of access: 19 Nov. 2019.
- Agostinis-Sobrinho, C., Ruiz, J.R., Moreira, C., Abreu, S., Lopes, L., Oliveira-Santos, J., ... Santos, R. 2018. Cardiorespiratory fitness and blood pressure: a longitudinal analysis. *Journal of Paediatrics*, 192(January):130–135.
- Anderssen, S.A., Cooper, A.R., Riddoch, C., Sardinha, L.B., Harro, M., Brage, S. & Andersen, L.B. 2007. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *European Society of Cardiology*, 14:526–531.
- Awotidebe, A., Monyeki, M.A., Moss, S.J., Strydom, G.L., Armstrong, M. & Kemper, H.C.G. 2016. Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of South African adolescents: the PAHL Study. *Journal of Human Hypertension*, 30:245–251.
- Balentine, J.R. 2019. *Obesity*. https://www.medicinenet.com/obesity_weight_loss/article.htm Date of access: 22 Nov. 2019.
- Beets, M. W. & Pitetti, K. H. 2006. Criterion-referenced reliability and equivalence between the PACER and 1-mile run/walk for high school students. *Journal of Physical Activity and Health*, 3(2):s21–s33, doi: <https://doi.org/10.1123/jpah.3.s2.s21>
- Cameron, N. & Getz, B. 1997. Sex differences in the prevalence of obesity in rural African adolescents. *International Journal of Obesity*, 21:775–782.
- Castro-Piñero, J., Perez-Bey, A., Segura-Jiménez, V., Aparicio, V.A., Gómez-Martínez, S., Izquierdo-Gomez, R.A., ... Ruiz, J.R. 2017. Cardiorespiratory fitness cut-off points for early detection of present and future cardiovascular risk in children: a 2-year follow-up study. *Mayo Clinic Proceedings*, 92(12):1753–1762.

Centers for Disease Control and Prevention. 2018. *BMI for Children and Teens*.
<https://www.cdc.gov/obesity/childhood/defining.html> Date of access: 25 Sept. 2019.

Chu, L. & Timmons, W. 2015. Nutritional considerations for the overweight young athletes. *Pediatric Exercise Science*, 2015(27):463–476.

Chungag, A., Tata, C.M., Sewani-Rusike, C.R., Nel, W. & Nkeh-Chungag, B.N. 2019. Ellirras longitudinal study 2017: association of hypertension with increasing levels of adiposity in 10- to 14-year-old boys and girls in the Eastern Cape (ELS 31). *Cardiovascular Journal of Africa*, 30(5):258–261.

Cifu, A.S. & Davis, A.M. 2017. Prevention, detection, evaluation, and management of high blood pressure in adults. *Journal of American Medical Association*, 318(21):2132–2134.

Cole, T.J., Bellizzi, M.C., Flegal, K.M. & Dietz, W.H. 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal*, 320(7244):1–6.

Dietz, W. H. & Robinson, T. N. 2005. Overweight children and adolescents. *The New England Journal of Medicine*, 352:2100–2109.

DelRosso, L.M., King, J. & Ferri, R. 2018. Systolic blood pressure elevation in children with obstructive sleep apnoea is improved with positive airway pressure use. *Journal of Paediatrics Elsevier*, 195:102–107.

De Onis, M., Onyango, A.W., Borgi, E., Siyami, A., Nishida, C. & Siekmann, J. 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organisation*, 85(February):660–667.

Enright, P.L., Goodwin, J.L., Sherrill, D.L., Quan, J.R. & Quan, S.F. 2003. Blood pressure elevation associated with sleep-related breathing disorder in a community sample of White and Hispanic children: The Tucson Children's Assessment of Sleep Apnea study. *Archives of Paediatric and Adolescent Medicine*, 2003(157):901–904.

Felman, A. 2019. *Everything you need to know about hypertension*.
<https://www.medicalnewstoday.com/articles/150109.php> Date of access: 4 Sept. 2019.

Gao, B., Zhang, L. & Wang, H. 2013. Clustering of major cardiovascular risk factors and the association with unhealthy lifestyles in the Chinese adult population. *Public Library of Science One*, 8(6):1–6.

Gidding, S. 2017. *Hypertension (High Blood Pressure)*.

<https://kidshealth.org/en/parents/hypertension.html?ref=search#catglandshormones> Date of access: 10 Oct. 2019.

Goon, D., Amusa, L., Mhlomo, D., Khoza, L. & Any-Anwu, F. 2013. Elevated blood pressure among rural South African children in Thohoyandou, South Africa. *Iranian Journal of Public Health*, 42(5):489–496.

Grace, J., Biggs, C., Naicker, A. & Moss, S. 2021. Effect of physical activity and nutrition education on body mass index, blood pressure and biochemical variables in overweight and obese adolescents. *Annals of Global Health*, 87(1):1–13.

He, Q., Wong, T., Du, L., Jiang, Z., Yu, T.I., Qiu, H., ... & Wu, J. 2011. Physical activity, cardiorespiratory fitness, and obesity among Chinese children. *Preventative Medicine*, 52(2011):109–113.

Healthy Active Kids South Africa (HAKSA). 2018. *Healthy active kids South Africa report card*. Retrieved from <https://www.westerncape.gov.za/westerncape-on-wellness/files/atoms/files/HAKSA-2018-Report-Card-FINAL.pdf> Date of access: 8 June 2019.

Kallerman, P.H. 2019. *Cardiovascular health in children and adolescents with obesity: Prevalence, prediction and supervised exercise*. Stockholm: Karolinska Institute. (Thesis – PhD).

Katzmarzyk, P.T. & Staiano, A.E. 2017. Relationship between meeting 24-hour guidelines and cardiometabolic risk factors in children. *Journal of Physical Activity and Health*, 14(10):779–784.

Kemp, C., Pienaar, A.E. & Schutte, A. 2011. The prevalence of hypertension and the relationship with body composition in Grade 1 learners in the North West Province of South Africa. *South African Journal of Sports Medicine*, 23(4):117–122.

Kent, M. 2006. *The Oxford dictionary of sports science & medicine*.

<http://www.oxfordreference.com.nwulib.nwu.ac.za/view/10.1093/acref/9780198568506.001.0001/acref-9780198568506> Date of access: 12 Mar. 2019.

Kruger R., Kruger H.S. & MacIntyre U.E. 2006. The determinants of overweight and obesity among 10- to 15-year-old schoolchildren in the North West Province, South Africa – the THUSA BANA study. *Public Health Nutrition*, 2006;9(3):351–358.

Kuczmarski, R.J. & Flegal, K.M. 2000. Criteria for definition of overweight in transition: background and recommendations for the United States. *American Society for Clinical Nutrition*, 2000(72):1074–1081.

Laghi, A. & Rengo, M. 2017. *Imaging in bariatric surgery*. Switzerland: Springer Nature.
<https://link.springer.com/content/pdf/10.1007/978-3-319-49299-5.pdf> Date of access: 9 Mar. 2018.

Lande, M.B. & Kupferman, J.C. 2019. Blood pressure and cognitive function in children and Adolescents. *Hypertension*, 2019(73):532–540.

Liu, W.J., Xiong, L.H., Guo, C.S., Pallan, M., Griffin, T., Cheng, K.K. & Adab, P. 2017. Weight status, cardiorespiratory fitness and high blood pressure relationship among 5-12-year-old Chinese primary schoolchildren. *Journal of Human Hypertension*, 31:808–814.

Mahar, M.T., Guerieri, A.M., Hanna, M.S. & Kemble, C.D. 2011. Estimation of aerobic fitness from 20-m multistage shuttle run test performance. *American Journal of Preventive Medicine*, 41(4S2):117–123.

Martin, E. 2015. *Concise Medical Dictionary*.
<https://www.oxfordreference.com/view/10.1093/acref/9780199557141.001.0001/acref-9780199557141>
Date of access: 5 Sept. 2019.

Mayo Clinic. 2018. *Childhood obesity*. <https://www.mayoclinic.org/diseases-conditions/childhood-obesity/symptoms-causes/syc-20354827> Date of access: 19 Nov. 2019.

Mayo Clinic. 2019. *High blood pressure in children*. <https://www.mayoclinic.org/diseases-conditions/high-blood-pressure-in-children/symptoms-causes/syc-20373440> Date of access: 10 Oct. 2019.

Monyeki, M.A., Awotidebe, A., Moss, S.J., Sparks, M., Wushe, S., Coetzee, B., ... Twisk, J.W.R. 2017. Relationship between physical activity, body fatness and cardiorespiratory fitness in South African

- adolescents: The PAHL Study. *African Journal for Physical Activity and Health Sciences*, 23(1.2):111–128.
- Monyeki, M.A., Koppes, L.L.J., Monyeki, K.D., Kemper, H.C.G. & Twisk, J.W.R. 2007. Longitudinal relationships between nutritional status, body composition, and physical fitness in rural children of South Africa: The Ellisras Longitudinal Study. *American Journal of Human Biology*, 19:551–558.
- Monyeki, K.D., Matshipi, M. & Monyeki, M.S. 2017. Prevalence of abdominal obesity among rural South African children over time: Ellisras Longitudinal Study. *African Journal for Physical Activity and Health Sciences*, 23(3):416–430.
- Moselakgomo, V.K., Toriola, A.L., Shaw, B.S., Goon, D.T. & Akinyemi, O. 2012. Body mass index, overweight, and blood pressure among adolescent schoolchildren in Limpopo province, South Africa. *Revista Paulista de Pediatria*, 30(4):562–569.
- Moselakgomo, V.K. & Van Staden, M. 2017. Predictors of obesity and cardiometabolic disease risk in South African children. *South African Journal of Child Health*, 11(4):186–191.
- Musa, D.I. & Williams, C.A. 2012. Cardiorespiratory fitness, fatness, and blood pressure associations in Nigerian Youths. *American College of Sports Medicine*, 44(10):1978–1985.
- National High Blood Pressure Education Program (NHBPEP). 2005. *The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents*. (4th ed.), Philadelphia, PA: U.S. United States Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, National High Blood Pressure Education Program.
- Nqweniso, S., Walter, C., du Randt, R., Aerts, A., Adams, L., Degen, J., ... Gerber, M. 2020. Prevention of overweight and hypertension through cardiorespiratory fitness and extracurricular sport participation among South African schoolchildren. *Sustainability*, 12(16):1–16.
- Palomäki, S., Heikinaro-Johansson, P. & Huotari, P. 2015. Cardiorespiratory performance and physical activity in normal weight and overweight Finnish adolescents from 2003 to 2010. *Journal of Sports Sciences*, 33(6):588–596.
- Pazin, D.C., Rosaneli, C.F., Olandoski, M., Netto de Oliveira, E.R., Pellegrino Baena, C., Figueredo, A.S., ... Faria-Neto, J.R. 2017. Waist circumference is associated with blood pressure in children with

normal body mass index: a cross-sectional analysis of 3,417 schoolchildren. *Brazilian Archives of Cardiology*, 109(6):509–515.

Pienaar, A.E. 2015. Prevalence of overweight and obesity among primary schoolchildren in a developing country: NW-CHILD longitudinal data of 6-9-yr-old children in South Africa. *Biomedical Central Obesity*, 2(2):1–10.

Plowman, S.A. & Meredith, M.D. 2013. Fitnessgram/Activitygram Reference guide. 4th ed. Dallas, TX: The Cooper Institute.

Roldão da Silva, P., Castilho dos Santos, G., Marcio da Silva, J., Ferreira de Faria, W., Gonçalves de Oliveira, R. & Stabelini Neto, A. 2020. Health-related physical fitness indicators and clustered cardiometabolic risk factors in adolescents: A longitudinal study. *Journal of Exercise Science and Fitness*, 18(3):162–167.

Rhodes, R.E., Janssen, I., Bredin, S.S.D., Warburton, D.E.R. & Bauman, A. 2017. Physical activity: Health impact, prevalence, correlates and interventions. *Psychology & Health*, 32(8):942–975.

Rossouw, H.A., Grant, C.C. & Viljoen, M. 2012. Overweight and obesity in children and adolescents: The South African problem. *South African Journal of Science*, 108(5–6):1–7.

Ruiz, J.R., Huybrechts, I., Cuenca-Garcia, M., Artero, E.G., Labayen, I., Meirhaeghe, A., ... Ortega, F.B. 2015. Cardiorespiratory fitness and ideal cardiovascular health in European adolescents. *Heart Cardiac Risk Factors and Prevention*, 101(10):766–773.

Shokeen, D. & Aeri, B.T. 2017. Rising Incidence of Overweight and Obesity among Children and Adolescents in India. *International Journal for Life Sciences Scientific Research*, 3(5):1392–1399.

Sinaiko, A.R., Donahue, R.P., Jacobs, D.R. & Prineas, R.J. 1999. Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults the Minneapolis children's blood pressure study. *Circulation*, 1999(99):1471–1476.

Stabouli, S. & Kotsis, V. 2019. Diagnosis of hypertension in children and adolescents: 2019 update. *Hellenic Journal of Atherosclerosis*, 9(4):111–120.

- Stratton, G., Canoy, D., Boddy, L.M., Taylor, S.R., Hackett, A.F. & Buchan, I.E. 2007. Cardiorespiratory fitness and body mass index of 9-11-year-old English children: A serial cross-sectional study from 1998 to 2004. *International Journal of Obesity*, 31(7):1172–1178.
- Taylor, R.W., Jones, I.E., Williams, S.M. & Goulding, A. 2000. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y13. *American Journal of Clinical Nutrition*, 72(2):490–495.
- Van Staden, D., Coetzee, D. & du Plessis, W. 2019. *A longitudinal study on the effect of overweight, obesity, stunting and wasting on academic performance of primary school boys: the NW-CHILD study*. Potchefstroom: North-West University. (Dissertation: M.A.).
- Webb, D. 2017. *Kid's & sodium intake*. <https://www.todaysdietitian.com/newarchives/0217p22.shtml> Date of access: 10 Oct. 2019.
- Himmelfarb, J. & Alp Ikizler, T. 2010. *Chronic kidney disease, dialysis and transplantation*. 4th ed. USA: Saunders.
- World Health Organisation. 2020a. *Obesity and overweight*. <https://www.who.int/news-room/factsheets/detail/obesity-and-overweight> Date of access: 4 Dec. 2020.
- World Health Organisation. 2020b. *Physical activity and young people*. https://www.who.int/dietphysicalactivity/factsheet_young_people/eng/ Date of access: 13 Jul. 2020.

CHAPTER THREE

CHAPTER 3: THREE-YEAR CHANGES IN CARDIORESPIRATORY FITNESS AND CARDIOVASCULAR RISK (OBESITY AND HYPERTENSION) IN 10–13-YEAR-OLD ADOLESCENTS: THE NW-CHILD STUDY

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ABSTRACT

This manuscript aimed to determine longitudinal changes in cardiorespiratory fitness and two components of cardiovascular risk factors (obesity and hypertension) among North West Province residing South African adolescents. Participants were measured in 2013 (N = 864, mean age = 9.88 years, boys = 455 and girls = 409) and 2016 (N = 558, mean age = 12.89 years, boys = 290 and girls = 268). Standard anthropometric techniques and age-sex-adjusted body mass index cut-off points were used to categorised overweight and obesity. The 20m PACER shuttle run indicated cardiorespiratory fitness estimations and resting blood pressure was measured applying standard procedures. Descriptive statistics, paired t-tests, Pearson Product Moment and Spearman Rank correlations coefficient were used during data analysis. The results revealed significant ($p \leq 0.05$) increases in thinness grade one (5.4%–23.3%), standard weight (18.4%–34.4%), and overweight and obesity (4.5%–10.6%). Cardiorespiratory fitness changed insignificantly ($p > 0.05$) (42.45 mL/kg/min–42.04 mL/kg/min). High significant ($p \leq 0.05$) developmental correlation coefficient changes were noted in body composition variables, while blood pressure and cardiorespiratory fitness had moderate and low coefficients. The plateau observed in cardiorespiratory fitness, along with growth or other positive life-style changes, may have contributed to the decrease in pre-hypertension (15%–7.7%) and hypertension (13%–6.3%).

Key words: Adolescents; Blood pressure; Cardiorespiratory fitness; Clustered cardiovascular risk factors; Obesity.

Three-year changes in cardiorespiratory fitness and cardiovascular risk (obesity and hypertension) in 10–13-year-old adolescents: the NW-CHILD study

3.1 INTRODUCTION

Of the current poor health concerns that young people need to deal with, several longitudinal studies have identified three main concerns. These three poor health concerns are widespread decreasing cardiorespiratory fitness (CRF) levels, an increasing prevalence of obesity and hypertension (HTN) (Pienaar, 2015; Castro-Piñero *et al.*, 2017; Kallerman, 2019; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020).

Increased risk for excessive fat gain has been noted because of poor CRF levels, whereas sufficient CRF levels have numerous benefits for adolescents, such as improved BC, prevention of diabetes, enhanced well-being, and decreased risk for high BP (Palomäki *et al.*, 2015; Kallerman, 2019; Roldão da Silva *et al.*, 2020).

Hypertension and obesity are two major cardiovascular disease (CVD) risk factors and may develop in childhood but may merely present its harshest effects during adulthood (Anderssen *et al.*, 2007). Numerous causes of childhood obesity were identified and have destructive negative effects. These negative effects expose adolescents to a higher risk for conditions like pulmonary diseases, digestive associated conditions, and CV disorders, especially HTN (Sinaiko *et al.*, 1999; Pazin *et al.*, 2017). Hypertension is mainly caused by lifestyle factors, such as excessive body fat deposits, sedentary behaviour, stress and dietary habits, which result in damaging negative effects (National High Blood Pressure Education Program Working Group [NHBPEP], 2005). Several repercussions of HTN in adolescents are CVD, nervous system disruptions, pulmonary illnesses and increased risk for premature mortality (NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018; Roldão da Silva *et al.*, 2020).

A few longitudinal South African studies have identified the prevalence of obesity, HTN and CRF levels amongst either younger participants, boys only or participants from different provinces (Pienaar, 2015; Van Staden *et al.*, 2019; Nqweniso *et al.*, 2020). There are limited studies, which identified longitudinal changes in CRF, HTN, and obesity amongst South African adolescent boys and girls, yet no research has specifically observed these changes in young adolescents from the North West Province (NWP).

Therefore, this study aimed to determine the longitudinal changes in cardiorespiratory fitness and in two CV risk factor components (obesity and hypertension) among school attending adolescents 10–13 years old living in the NWP, SA. It is hypothesised that significant changes will be found in CRF to decrease, obesity to increase and HTN to increase over a three-year period.

3.2 MATERIALS AND METHODS

3.2.1 Research Design

The present study formed part of the Child Health, Integrated with Learning and Development Study (NW-CHILD study). The NW-CHILD study followed a longitudinal study design from 2010 to 2016, originally aimed to observe health, learning and development in children and adolescents. The baseline measurement in 2010 and two follow-up measurements in 2013 (Follow-up measurement point 1 [MP1]) and 2016 (Follow-up measurement point 2 [MP2]) rendered data analysed according to a repeated cross-sectional design. This study used a longitudinal design, only including data from MP1 and MP2 measurements.

3.2.2 Participants

The NW-CHILD study included 816 participants six to 13 years old from four of eight school districts across the NWP, SA. The sampling used stratified random selection techniques with the assistance of Statistical Consultation of the North-West University. The North West Provincial Department of Education provided a list of NWP school names from which the research sample was determined. This list was grouped into eight educational districts according to quintile status, each representing 12–22 regions with approximately 20 schools (minimum 12, maximum 47) per region. The quintile status was determined by the National Treasury according to the South African National Poverty Table. Regions and schools were randomly selected acknowledging population density and school status (Quintile 1: schools from poorest socio-economic status (SES) to Quintile 5: schools from highest SES). We included schools from quintiles 1–5 in the sample, to insure a relatively good representative of children and adolescents throughout the province. The data of the second and third follow-up measurements were used for this study. In 2013, the first follow-up or MP1 measurements included 574 participants, presenting a drop-out of 30.1% of the original number of 816 participants. The observed drop-out rate was a result of participants being absent during measurement days, school drop-out or transferral to a new school. The drop-out reasons were beyond the researcher's control and did not have a significant effect on the current study's objectives. New randomly selected participants were added to the sample allowing for a new total of 864. This sample had a mean age of 9.88 years, with 455 boys and 409 girls, and a race distribution of 215 participants classified as White and 649 participants classified as Black. The sample category grouped as Black was a combination of participants classified as Black, Coloured and Indian as there were too few participants classified as Coloured and Indian to form a sample group, according to a qualified statistician's advice. In 2016, the second follow-up or MP2 measurements were taken from 661 Grade 7 participants, of which 77 refused consent, resulting in 584 participants being measured. The data of 558 participants met the inclusion criteria that the participant was to be present at both follow-up measurements. This sample had a mean age of 12.89 years, with 290 boys and 268 girls.

3.2.3 Measuring Instruments

The following measurements and equations have relevance to this study: mass, stature, body mass index (BMI), waist circumference (WC), subscapular skinfold, triceps skinfold, fat percentage, blood pressure (BP) and CRF. Additional relevant data was also collected such as sex, age and race. The measurements were taken during school time, in private, sex-separated, cordoned-off indoor areas, such as the school hall, sickbay or office. These measurements were taken by postgraduate students and researchers in Kinderkinetics. Participants were required to wear minimal clothing during measurements. For the ethical safety of the participants, two researchers or postgraduate students needed to be present during measurements.

Body Mass Index

Mass and stature were used to determine BMI value. Mass was measured to the nearest 0.1 kg with an electronic scale (Omron, BF 511, Omron Corporation, Japan) following the International Society for the Advancement of Kinanthropometry (ISAK) protocol (Stewart *et al.*, 2011). Stature was measured to the nearest 0.1 cm using a portable stadiometer with the participant's head in Frankfort position and after inhaling deeply, following ISAK protocol (Stewart *et al.*, 2011). The formula for determining BMI value was mass divided by stature squared (kg)/m². The age and sex-specific cut-off points for overweight (OW) and obesity between the ages of 10–13.5 years are shown in **Table 3.1**, which were used in this study (Cole *et al.*, 2000). Body mass index was categorised and used as a basic marker for CVD risk. The categories were defined as thinness grade three (with BMI < 16 (kg)/m² or – 3 standard deviation points), two (with BMI 16 to <17 (kg)/m² or – 2 standard deviation points), and one (with BMI 17 to < 18.5 (kg)/m² or – 1 standard deviation points), standard weight (with BMI between 18.5 and < 25 (kg)/m²), OW (with BMI between 25 and < 30 (kg)/m²), and obesity (with BMI > 30 (kg)/m²). Body mass index has been identified as not being the best indicator of adiposity, therefore, WC and fat percentage were used as additional indicators.

Table 3.1: BODY MASS INDEX INDICATOR OF OVERWEIGHT AND OBESITY: INTERNATIONAL AGE AND SEX-SPECIFIC CUT-OFF POINTS FOR OVERWEIGHT AND OBESITY BY COLE ET AL. (2000)

Age (years)	Body Mass Index 25 kg/m ²		Body Mass Index 30 kg/m ²	
	Males	Females	Males	Females
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20

kg = kilogram; m = meter

Waist Circumference

The WC measurement was measured at the narrowest aspect between the lower costal rib (10th rib) and the most superior aspect of the Crista Iliaca with a participant in a standing position according to ISAK protocol (Stewart *et al.*, 2011). The measurement was taken twice using a standard metal measuring tape and the mean value of the two measurements was used. Waist circumference was additionally used as a basic measurement for abdominal OW and obesity as it is known to be a strong indicator for CVD risk (Pazin *et al.*, 2017).

Subscapular and Triceps Skinfolds

The subscapular skinfold measurement was taken at an oblique downwards angle at the subscapular landmark with a participant in a standing position according to ISAK protocol (Stewart *et al.*, 2011). The triceps skinfold was the measurement taken perpendicular to the long axis of the arm at the triceps skinfold landmark with a participant in standing position and arm relaxed according to ISAK protocol (Stewart *et al.*, 2011). Each measurement was taken twice in millimetres (mm) using a Harpenden skinfold calliper (Baty International, manufactured in England) and the mean value of the two measurements was used.

Body Fat Percentage

The body fat percentages (BF%) were calculated using Slaughter *et al.* (1988) equations for the triceps and subscapular skinfolds, the equations were corrected for maturation and race. The sum of skinfold ($\sum SF$) was calculated by adding the mean of the triceps skinfold with the mean of the subscapular skinfold. The intercepts (I) were substituted into the equations below for the participant's maturation level, only for boys with BF% less than 35. Calculating the BF% through Slaughter equations (Slaughter *et al.*, 1988) was based on several factors.

If $\sum SF$ was **greater than 35**, then the following equations were used for participants classified as Black or White:

- All boys; $BF\% = 0.783 (\sum SF) + 1.6$
- All girls; $BF\% = 0.546 (\sum SF) + 9.7$

If $\sum SF$ was **less than 35**, then the following equations for participants classified as Black or White are used:

- Boys; $BF\% = 1.21 (\sum SKF) - 0.008(\sum SKF)^2 + I^*$
- All girls; $BF\% = 1.33 (\sum SKF) - 0.013(\sum SF)^2 - 2.5$

Whenever an intercept was used, the substitute value of Slaughter *et al.* (1988) applied as indicated in **Table 3.2**.

Table 3.2: SKINFOLD EQUATION INTERCEPT (I*) SUBSTITUTION RECOMMENDED FOR PREDICTING BODY FAT IN BOYS WITH A SUM OF FATNESS LESS THAN 35, BASED ON MATURATION AND ETHNICITY

Stage	Black Category	White Category
Pre-pubescent	-3.2	-1.7
Pubescent	-5.2	-3.4
Post-pubescent	-6.8	-5.5

The number of participants classified as Indian and Coloured were too few to form their own categories, therefore based on the statistician's advice these two races were combined with the category of participants classified as Black. These specific skinfold measurements were used because they give the highest correlation and overall BF% of adolescents, which is a good indicator of CVD risk (Castro-Piñero *et al.*, 2017; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020).

Blood Pressure

Blood pressure was measured by a clinically validated oscillometric automatic device (Omron 705CP-II, Omron Corporation, Japan). The widths of the sleeve cover (small 17-22 cm, medium 22-32 cm, large 32-42 cm wide) were adjusted for the arm circumference. Blood pressure was taken while the subject was sitting with the right arm resting on a table and the palm facing upwards after the subject rested for 5 minutes. Three readings were obtained with 5-minute intervals between measurements and the average of the last two readings was used for the BP value. Average BP was termed when the systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) values were less than the 90th percentile for age, sex and stature according to the cut-off points of the NHBPEP on high BP in children and adolescents (NHBPEP, 2005). Prehypertension was for participants whose SBP and/or DBP values were greater than the 90th percentile but less than the 95th percentile, while paediatric HTN was when SBP and/or DBP values were greater than or equal to the 95th BP percentile for age, sex and stature (NHBPEP, 2005). **Table 3.3** and **Table 3.4** were used as BP standards to determine the child's BP percentile, and whether the child was hypertensive or not (NHBPEP, 2005).

Table 3.3: BLOOD PRESSURE STANDARDS FOR BOYS BY AGE AND STATURE BY NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM WORKING GROUP (NHBPEP, 2005)

Age (years)	BP Percentile	Systolic BP (mmHg)							Diastolic BP (mmHg)						
		Percentile of Stature							Percentile of Stature						
		5 th	10 th	25 th	50 th	75 th	90 th	95 th	5 th	10 th	25 th	50 th	75 th	90 th	95 th
10	50 th	97	98	100	102	103	105	106	58	59	60	61	61	62	63
	90 th	111	112	114	115	117	119	119	73	73	74	75	76	77	78
	95 th	115	116	117	119	121	122	123	77	78	79	80	81	81	82
	99 th	122	123	125	127	128	130	130	85	86	86	88	88	89	90
11	50 th	99	100	102	104	105	107	107	59	59	60	61	62	63	63
	90 th	113	114	115	117	118	120	121	74	74	75	76	77	78	78
	95 th	117	118	119	121	123	124	125	78	78	79	80	81	82	82
	99 th	124	125	127	129	130	132	132	86	86	87	88	89	90	90
12	50 th	101	102	104	106	108	109	110	59	60	61	62	63	63	64
	90 th	115	116	118	120	121	123	123	74	75	75	76	77	78	79
	95 th	119	120	122	123	125	127	127	78	79	80	81	82	82	83
	99 th	126	127	129	131	133	134	135	86	87	88	89	90	90	91
13	50 th	104	105	106	108	110	111	112	60	60	61	62	63	64	64
	90 th	117	118	120	122	124	125	126	75	75	76	77	78	79	79
	95 th	121	122	124	126	128	129	130	79	79	80	81	82	83	83
	99 th	128	130	131	133	135	136	137	87	87	88	89	90	91	91

yrs. = years; BP = blood pressure; mmHg = millimetre of mercury

Table 3.4: BLOOD PRESSURE STANDARDS FOR GIRLS BY AGE AND STATURE BY NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM WORKING GROUP (NHBPEP, 2005)

Age (years)	BP Percentile	Systolic BP (mmHg)							Diastolic BP (mmHg)						
		Percentile of Stature							Percentile of Stature						
		5 th	10 th	25 th	50 th	75 th	90 th	95 th	5 th	10 th	25 th	50 th	75 th	90 th	95 th
10	50 th	98	99	100	102	103	104	105	59	59	59	60	61	62	62
	90 th	112	112	114	115	116	118	118	73	73	73	74	75	76	76
	95 th	116	116	117	119	120	121	122	77	77	77	78	79	80	80
	99 th	123	123	125	126	127	129	129	84	84	85	86	86	87	88
11	50 th	100	101	102	103	105	106	107	60	60	60	61	62	63	63
	90 th	114	114	116	117	118	119	120	74	74	74	75	76	77	77
	95 th	118	118	119	121	122	123	124	78	78	78	79	80	81	81
	99 th	125	125	126	128	129	130	131	85	85	86	87	87	88	89
12	50 th	102	103	104	105	107	108	109	61	61	61	62	63	64	64
	90 th	116	116	117	119	120	121	122	75	75	75	76	77	78	78
	95 th	119	120	121	123	124	125	126	79	79	79	80	81	82	82
	99 th	127	127	128	130	131	132	133	86	86	87	88	88	89	90
13	50 th	104	105	106	107	109	110	110	62	62	62	63	64	65	65
	90 th	117	118	119	121	122	123	124	76	76	76	77	78	79	79
	95 th	121	122	123	124	126	127	128	80	80	80	81	82	83	83
	99 th	128	129	130	132	133	134	135	87	87	88	89	89	90	91

yrs. = years; BP = blood pressure; mmHg = millimetre of mercury

Cardiorespiratory Fitness

The PACER (Progressive Aerobic Cardiovascular Endurance Run) is a multi-stage progressive aerobic endurance test, based on the testing protocol of the FitnessGram reference guide (Plowman & Meredith, 2013). Participants had to run over a 20m distance back and forth, turning around on a beep sound. The test began with an easy pace and progressively became more difficult as the time between the beeps became shorter. Participants had to run until failure to reach the line twice before the beep sound. The score recorded was the total laps completed (Plowman & Meredith, 2013). The total laps were used to determine the estimates of maximal oxygen consumption ($\dot{V}O_2$ max), as recommended by Plowman and Meredith (2013), and indicated in **Table 3.5** (Mahar *et al.*, 2011).

Table 3.5: THE PROGRESSIVE AEROBIC CARDIOVASCULAR ENDURANCE RUN MAXIMAL OXYGEN UPTAKE CONVERSIONS FOR BOYS AND GIRLS AGED 10–16 YEARS BY MAHAR ET AL. (2011)

$\dot{V}O_2$ max Conversion - from 20-meter PACER Test											
Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max
4	25	26.8	6	45	34.3	8	65	41.1	10	85	47.4
4	26	27.2	6	46	34.0	8	66	41.5	10	86	47.7
4	27	27.6	6	47	35.0	8	67	41.8	10	87	48.0
4	28	28.0	6	48	35.4	8	68	42.1	10	88	48.4
4	29	28.3	6	49	35.7	8	69	42.4	10	89	48.7
4	30	28.7	6	50	36.1	8	70	42.7	10	90	49.0
4	31	29.1	7	51	36.4	9	71	43.0	10	91	49.3
4	32	29.5	7	52	36.8	9	72	43.3	10	92	49.6
5	33	29.9	7	53	37.1	9	73	43.6	11	93	49.9
5	34	30.2	7	54	37.5	9	74	43.9	11	94	50.2
5	35	30.6	7	55	37.8	9	75	44.2	11	95	50.5
5	36	31.0	7	56	38.2	9	76	44.5	11	96	50.8
5	37	31.4	7	57	38.5	9	77	44.9	11	97	51.1
5	38	31.8	7	58	38.9	9	78	45.2	11	98	51.4
5	39	32.2	7	59	39.2	9	79	45.5	11	99	51.7
5	40	32.6	7	60	39.6	9	80	45.8	11	100	51.9
5	41	32.9	8	61	39.9	9	81	46.2	11	101	52.2
6	42	33.3	8	62	40.2	10	82	46.5	11	102	52.5
6	43	33.6	8	63	40.5	10	83	46.8	11	103	52.8
6	44	34.0	8	64	40.8	10	84	47.1	11	104	53.1

$\dot{V}O_2$ max = maximal oxygen uptake

3.2.4 Procedure

Ethical Clearance and Research Procedure

Ethical clearance was obtained from the Ethics Committee of the North-West University Potchefstroom Campus (number: NWU-00070-09-A1-02) as well as from the Department of Basic Education of the North West Province. A list of schools from the NWP was used to determine the sample. We organised a meeting with each principle, where we explained objectives and format of the study, and requested to collect data in school hours. The randomly selected participants were given informed consent forms to be completed by the parents or legal guardians before each measurement period. The consent form thoroughly explained what participants had to do as well as any possible risks involved. Participants who returned parent or legal guardian approved consent forms were required to sign participant's indemnity forms as well as give informed assent and participate in the measurements. Re-consent and assent had to be given before MP1 and MP2 measurements. The study objectives and non-obligation to participate were verbally explained to all participants before each measurement period. The participants had a chance to inquire about the research procedures. The participants could withdraw from the research at any time. During the measurement periods,

if English or Afrikaans were not the participants' first language, instructions were given from the evaluators by external proficient interpreters to participants.

Statistical Analysis

Descriptive statistics (mean and SD) for the CRF levels, BC, and BP for MP1 and MP2 measurement points were analysed by SPSS Data Processing package version 27.0.0 (IBM Corporation 2019). Categorical variables were presented as proportions in percentages (%) with the number of subjects (n) for MP1 and MP2 measurements, and chi-square was used to determine the significant differences. Paired t-tests were used to evaluate the differences in CRF levels, obesity or BC, BP, and age between the baseline measurement variables and the follow-up measurement variables for the total sample, and by sex. Spearman's Rho correlation coefficients (r_s) were used to measure development changes at one measurement point for changes in CRF levels, obesity or BC, BP, and age between the baseline measurement variables and the follow-up measurement variables. Rho correlations are interpreted as follow $r \approx 0.1$ as low, $r \approx 0.3$ as medium, and $r \geq 0.5$ as high. Spearman's correlation coefficients rank was also used to determine practical significance, where the statistical significance level was set as at $p \leq 0.05$. To determine effect size (ES) when determining practical significance, we interpreted the r-values according to $r \approx 0.1$ as small, $r \approx 0.3$ as moderate, and $r \geq 0.5$ as large.

3.3 RESULTS

Table 3.6 presents the percentage scores for BMI categories (thinness grade three, two, and one, standard weight, OW, and obesity) according to sample and sex in MP1 and MP2. According to the sample percentage, thinness grade three decreased from 38.1% to 17.7% and thinness grade two decreased from 33.6% to 14%; whereas thinness grade one increased from 5.4% to 23.2%; standard weight increased from 18.4% to 34.4% and OW and obesity increased from 4.5% to 10.6%. According to sex amongst boys, thinness grade three decreased from 37.1% to 20.3% and thinness grade two decreased from 35.8% to 14.8%, while thinness grade one increased from 5.3% to 20.1%; standard weight increased from 17.1% to 28.3% and OW and obesity increased from 4.6% to 10.3% over the three-year period. A decrease in percentage was found amongst the girls in the categories of thinness grade three from 39.1% to 14.9% and thinness grade two from 31.1% to 13.1%, whereas an increase in thinness grade one from 5.6% to 20.1%; standard weight from 19.8% to 41% and OW and obesity from 4.4% to 10.8% has been noted.

Table 3.6: PRESENT PERCENTAGES FOR BODY MASS INDEX (kg/m²) CATEGORIES BY SAMPLE AND SEX FOR THE THREE-YEAR MEASUREMENT POINTS

	Total		Thinness G3 (BMI < 16) = -3 SD		Thinness G2 (BMI 16 to < 17) = -2 SD		Thinness G1 (BMI 17 to < 18.5) = -1 SD		Standard Weight (BMI between 18.5 to < 25)		Overweight (BMI 25 to < 30) and Obese (BMI > 30)	
	MP1 (n)	MP2 (n)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)
Sample	864	558	329 (38.1)	99 (17.7)	290 (33.6)	78 (14.0)	47 (5.4)	130 (23.3)	159 (18.4)	192 (34.4)	39 (4.5)	59 (10.6)
Boys	455	290	169 (37.1)	59 (20.3)	163 (35.8)	43 (14.8)	24 (5.3)	76 (26.2)	78 (17.1)	82 (28.3)	21 (4.6)	30 (10.3)
Girls	409	268	160 (39.1)	40 (14.9)	127 (31.1)	35 (13.1)	23 (5.6)	54 (20.1)	81 (19.8)	110 (41.0)	18 (4.4)	29 (10.8)

In **Table 3.7**, the percentages for HTN categories (standard, pre-hypertensive, and hypertensive) of the sample and sex from MP1 to MP2 are presented. The sample percentage for standard BP increased from 72% to 86%, where decreases in pre-hypertension from 15% to 7.7% and in HTN from 13% to 6.3% have been noted. According to sex the boys' group classified as standard BP increased from 73.3% to 88.3%, whereas pre-hypertension group decreased from 14.8% to 6.2% and the HTN group decreased from 11.9% to 5.5% in the three-year period. Amongst the girls, the standard BP category indicated an increase from 71.9% to 83.6% along with the decrease in pre-hypertension from 14.7% to 9.3% and HTN from 13.4% to 7.1%.

Table 3.7: PERCENTAGES FOR BLOOD PRESSURE CATEGORIES BY SAMPLE AND SEX FOR THE THREE-YEAR MEASUREMENT POINTS

	Total		Standard		Pre-hypertensive		Hypertensive	
	MP1 (n)	MP2 (n)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)	MP1, n (%)	MP2, n (%)
Sample	863	558	627 (72)	481 (86)	127 (15)	43 (7.7)	109 (13)	35 (6.3)
Boys	454	290	333 (73.3)	256 (88.3)	67 (14.8)	18 (6.2)	54 (11.9)	16 (5.5)
Girls	409	268	294 (71.9)	225 (83.6)	60 (14.7)	25 (9.3)	55 (13.4)	18 (7.1)

Table 3.8 illustrates the results on the changes and correlation coefficients for growth of the sample over the three-year period. Significant ($p < 0.001$) developmental increases were noted between MP1 and MP2 in participants' stature, mass, BMI, WC, $\sum$ SF, BF%, BP and PACER laps. No significant ($p > 0.05$) developmental change was noted for $\dot{V}O_2$ max between the two measurement points. High significant correlation coefficients for longitudinal changes were found in all anthropometric and BC measures that ranged between $r_s = 0.71$ and $r_s = 0.88$ over two years. A slightly lower correlation coefficient was noted in the BP measurements which ranged between $r_s = 0.36$ and $r_s = 0.43$. PACER shuttle run and $\dot{V}O_2$ max revealed a medium correlation coefficient between $r_s = 0.49$ and $r_s = 0.51$.

Table 3.8: PAIRED T-TEST AND CORRELATION COEFFICIENT FOR LONGITUDINAL CHANGES IN BODY COMPOSITION, BLOOD PRESSURE AND CARDIORESPIRATORY FITNESS FOR THE TOTAL SAMPLE

		MP1	MP2			
	N	Mean ± SD	Mean ± SD	Δ Mean change	p-value of differences	Developmental change correlation coefficient
Stature, cm	558	135.77 ± 7.26	152.85 ± 8.39	17.50	< 0.001	0.86*
Mass, kg	558	32.20 ± 9.16	45.71 ± 13.45	13.50	< 0.001	0.88*
Body Mass Index, (kg)/m ²	558	17.34 ± 3.87	19.36 ± 4.48	2.02	< 0.001	0.84*
Waist Circumference, cm	558	59.42 ± 7.92	65.22 ± 9.61	5.80	< 0.001	0.81*
Sum of Skinfolds, mm †	558	18.33 ± 10.08	21.65 ± 13.80	3.31	< 0.001	0.84*
Body Fat %	542	20.01 ± 8.17	21.75 ± 8.72	1.73	< 0.001	0.71*
Systolic Blood Pressure, mmHg	558	101.48 ± 11.59	104.96 ± 11.33	3.48	< 0.001	0.43*
Diastolic Blood Pressure, mmHg	558	63.79 ± 10.03	66.30 ± 8.05	2.51	< 0.001	0.36*
PACER Shuttle Run, laps	556	22.38 ± 12.48	30.97 ± 17.57	8.59	0.08	0.51*
$\dot{V}O_2$ max, mL/kg/min	540	42.45 ± 4.48	42.04 ± 6.20	-0.41	< 0.001	0.49*
† Sum of skinfolds, mm = subscapular skinfold + triceps skinfold						
Correlation coefficients rank: $r \approx 0.1$ is low, $r \approx 0.3$ is medium, $r \approx 0.5$ is high						
Significance level: $p \leq 0.05$.						

Table 3.9 indicates results of longitudinal changes and correlation coefficients for growth in boys at the first and second follow-up periods in MP1 and MP2. Significant ($p < 0.001$) developmental increase was found in the boys' stature, mass, BMI, WC, the $\sum$ SF, BF%, BP and PACER laps. No significant developmental change was found in $\dot{V}O_2$ max between MP1 and MP2. High significant correlation coefficients for longitudinal changes were recognised amongst the boys in all anthropometric and BC measures that ranged between $r_s = 0.71$ and $r_s = 0.91$. PACER shuttle runs, $\dot{V}O_2$ max, and SBP, as well as DBP, revealed a medium correlation coefficient between $r_s = 0.36$ and $r_s = 0.44$.

Table 3.9: PAIRED SAMPLE T-TEST AND CORRELATION COEFFICIENT FOR CHANGES BODY COMPOSITION, BLOOD PRESSURE AND CARDIORESPIRATORY ENDURANCE FOR BOYS

	MP1 n = 290	MP2 n = 290			
	Mean ± SD	Mean ± SD	Δ Mean change	p-value of the differences	Developmental change correlation coefficient
Stature, cm	135.79 ± 7.10	153.59 ± 7.39	17.89	< 0.001	0.79*
Mass, kg	32.22 ± 9.63	47.14 ± 13.45	14.92	< 0.001	0.91*
Body Mass Index, (kg)/m²	17.37 ± 4.32	19.76 ± 4.70	2.39	< 0.001	0.89*
Waist Circumference, cm	58.65 ± 7.98	65.11 ± 9.41	6.46	< 0.001	0.86*
Sum of Skinfolds, mm †	20.12 ± 10.14	24.34 ± 13.07	4.22	< 0.001	0.79*
Body Fat %	20.01 ± 8.17	21.75 ± 8.72	1.73	< 0.001	0.71*
Systolic Blood Pressure, mmHg	101.74 ± 11.79	105.15 ± 11.06	3.41	< 0.001	0.44*
Diastolic Blood Pressure, mmHg	64.27 ± 9.41	67.36 ± 8.00	3.09	< 0.001	0.36*
PACER Shuttle Run, laps	18.89 ± 9.30	22.62 ± 12.44	3.73	0.08	0.40*
VO₂ max, mL/kg/min	41.13 ± 3.23	39.16 ± 4.47	1.97	< 0.001	0.38*
† Sum of skinfolds, mm = subscapular skinfold + triceps skinfold					
Correlation coefficients rank: r ≈ 0.1 is low, r ≈ 0.3 is medium, r ≈ 0.5 is high					
Significance level: p ≤ 0.05.					

Table 3.10 shows the results of longitudinal changes and correlation coefficients for girls in MP1 and MP2. Significant ($p < 0.001$) developmental increases were noted in the girls' stature, mass, BMI, WC, the $\sum$ SF, BF%, BP and PACER laps over the three-year period. No significant ($p > 0.05$) developmental change was observed for $\dot{V}O_2$ max. All anthropometric and BC measures indicated high significant correlation coefficients for longitudinal changes that ranged between $r_s = 0.71$ and $r_s = 0.91$. Slightly lower, moderate correlation coefficients were observed in the BP measurements, the PACER laps, and $\dot{V}O_2$ max ranging between $r_s = 0.36$ and $r_s = 0.44$.

Table 3.10: PAIRED SAMPLE T-TEST AND CORRELATION COEFFICIENT FOR CHANGES BODY COMPOSITION, BLOOD PRESSURE AND CARDIORESPIRATORY ENDURANCE FOR GIRLS

	MP1 n = 268	MP2 n = 268			
	Mean ± SD	Mean ± SD	Δ Mean change	p-value of the differences	Developmental change correlation coefficient
Stature, cm	135.69 ± 7.44	153.59 ± 7.39	17.89	< 0.001	0.79*
Mass, kg	32.22 ± 9.63	47.14 ± 13.45	14.92	< 0.001	0.91 *
Body Mass Index, (kg)/m²	17.37 ± 4.32	19.76 ± 4.70	2.39	< 0.001	0.89*
Waist Circumference, cm	58.65 ± 7.98	65.11 ± 9.41	6.46	< 0.001	0.86*
Sum of Skinfolds, mm †	20.12 ± 10.14	24.34 ± 13.07	4.22	< 0.001	0.79*
Body Fat %	20.01 ± 8.17	21.75 ± 8.72	1.73	< 0.001	0.71*
Systolic Blood Pressure, mmHg	101.74 ± 11.79	105.15 ± 11.06	3.41	< 0.001	0.44*
Diastolic Blood Pressure, mmHg	64.27 ± 9.41	67.36 ± 8.00	3.09	< 0.001	0.36*
PACER Shuttle Run, laps	18.89 ± 9.30	22.62 ± 12.44	3.73	0.08	0.40*
VO₂ max, mL/kg/min	41.13 ± 3.23	39.16 ± 4.47	1.97	< 0.001	0.38*
† Sum of skinfolds, mm = subscapular skinfold + triceps skinfold					
Correlation coefficients rank: r ≈ 0.1 is low, r ≈ 0.3 is medium, r ≈ 0.5 is high					
Significance level: p ≤ 0.05.					

3.4 DISCUSSION

The objective of this study was to determine the longitudinal changes over three years in cardiorespiratory fitness levels and clustered cardiovascular (CV) risk factors (obesity and hypertension) among school attending adolescents 10–13 years old attending school in the North West Province.

The results show a decline in thinness grades three and two, whereas significant ($p \leq 0.05$) increases were noted in the prevalence of thinness grade one, standard weight, OW and obesity categories. A decline in pre-HTN and HTN was observed in the study over three years. From the results, significant ($p \leq 0.05$) developmental increase was observed in stature, mass, BMI, the $\sum$ SF, BF% and WC. An insignificant ($p > 0.05$) change was observed in CRF. Furthermore, high practical and statistically significant ($p \leq 0.05$) correlation coefficient for longitudinal changes were noted for BC variables, while medium and low correlation

coefficients were noted in BP and CRF over the three-year period amongst 10–13-year-old South African adolescents attending school in the NWP. The results regarding BC and CRF development change were similar according to sex compared to the sample's results.

From the results, the total sample in this study indicated a weight category decrease in thinness grades three and two, contributing to an increase in thinness grade one, standard weight, as well as the OW and obesity categories over the three-year period. Agostinis-Sobrinho *et al.* (2018) similarly found an increase in the standard weight category over a two-year period. In our study, the increase in OW and obesity during adolescence agreed with what literature presented (Sinaiko *et al.*, 1999; Stratton *et al.*, 2007; He *et al.*, 2011; Pienaar, 2015; Van Staden *et al.*, 2019; Nqweniso *et al.*, 2020). Yet on the contrary, two studies found a decrease in standard weight (Pienaar, 2015; Van Staden *et al.*, 2019). The growth rate diversity between two of the four-phase growth patterns during youth can clarify the variation in standard weight results (Malina *et al.*, 2004). During middle childhood, the growth rate of stature and mass is steady, followed by rapid growth rates during the adolescent growth spurts, between which BMI varies greatly (Sinaiko *et al.*, 1999; Malina *et al.*, 2004; He *et al.*, 2011). This can explain the difference in the standard weight group of younger participants (six to nine years old) from Pienaar (2015) compared to the current increase in standard weight of older participants, who are in the adolescent rapid growth spurt age phase (nine to 13 years old). Malina *et al.* (2004) explained that girls are briefly taller and heavier than what boys are during the early part of the adolescent growth spurt before boys catch up and become taller and heavier. The present participants (nine to 13 years old) and the participants from Van Staden *et al.* (2019) had overlapping ages (six to 13 years old). Yet, the current study included both sexes, whereas Van Staden *et al.* (2019) had boys only. This may explain why the standard weight increased with the present results of both sexes as compared with the decrease in boys' results of Van Staden *et al.* (2019) where the boys will soon enter the rapid adolescent growth spurt. Monyeki *et al.* (2017) observed a decreasing prevalence of abdominal obesity amongst South African children from Ellisras (newly named Lephalale), Limpopo Province (a rural classified area) between 1996 and 2003. A large mitigating reason for the difference in results could be that Monyeki *et al.* (2017) carried out the study with the focus on obesity prevalence amongst children from a low SES setting or rural South African setting, whereas the current study observed children from various SES settings. Socio-economic status has shown an association with OW and obesity prevalence amongst children, where children from higher SES have been noted to have higher OW and obesity risk (Pienaar, 2015; Van Staden *et al.*, 2019).

Regarding sex and weight categories, the boys and girls had an increase, like the total sample, in thinness grade one, standard weight and OW and obesity. Similarly, Stratton *et al.* (2007) and He *et al.* (2011) noted an increase in OW and obesity amongst both sexes. A comparable increase in obesity amongst girls was noted by Agostinis-Sobrinho *et al.* (2018) and Pienaar (2015). Pienaar (2015) noted a similar increase in OW in both sexes, whereas Agostinis-Sobrinho *et al.* (2018) further noted an increase in standard weight amongst boys

and girls. Van Staden *et al.* (2019) found a similar increase in OW and obesity amongst South African boys, but a contrasting decrease in standard weight prevalence. Yet on the contrary, literature found a decrease in OW and obesity amongst boys and a decrease in OW amongst girls (Agostinis-Sobrinho *et al.*, 2018). Monyeki *et al.* (2017) observed, amongst children from Ellisras (newly named Lephalale), Limpopo Province, SA, that girls had a decreasing prevalence in obesity, whereas boys had an increasing obesity prevalence. The proxy measure of fatness determined through BMI classification could be a reason that OW and obesity prevalence may change vastly between age groups, sex, SES and geographical areas (Sinaiko *et al.*, 1999; Pienaar, 2015; Monyeki *et al.*, 2017).

Within the total sample, the standard BP group increased, whereas the pre-hypertensive and hypertensive groups decreased. Nqweniso *et al.* (2020) similarly observed the total sample prevalence of standard BP increasing where HTN decreased amongst South African children. Yet in contrast, Kallerman (2019) noted an increase in HTN during childhood through to young adulthood. A possible explanation for the difference in results could be because the included participants were already considered obese, with a higher risk for HTN, and were required to partake in an obesity intervention (Kallerman, 2019). According to sex, the current study found that the standard BP group increased where the pre-hypertensive and hypertensive groups decreased amongst the boys and the girls. Likewise, Agostinis-Sobrinho *et al.* (2018) observed a decrease in HTN amongst the boys and girls over a two-year period. The decrease in HTN could be the result of lowered CVD risk (NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018). As participants improved their physical activity (PA) and CRF, weight loss occurred, heart rate improved, and the artery walls and heart had less pressure (NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018).

From the results, significant ($p \leq 0.05$) developmental increase was observed in stature, mass, BMI, the $\sum$ SF, BF% and WC. The anthropometric and BC results indicated a high correlation coefficient for developmental change from MP1 to MP2. These results agreed with other longitudinal studies, which found an increase in BMI, BF% and WC (Sinaiko *et al.*, 1999; Stratton *et al.*, 2007; He *et al.*, 2011; Palomäki *et al.*, 2015; Pienaar, 2015; Monyeki *et al.*, 2017; Agostinis-Sobrinho *et al.*, 2018; Roldão da Silva *et al.*, 2020). The developmental increase in BC variables indicated stable growth between MP1 and MP2. These results agree with Malina *et al.* (2004) that increases in stature, mass, BMI, $\sum$ SF and BF% are standard for growth from seven to 13 years of age. Significant ($p \leq 0.05$) increase, with lower developmental correlation coefficient changes, were noted in the total sample's SBP and DBP measurements. A child's BP is expected to increase gradually as he or she grows, once bradycardia has established (when an infant's heart rate decelerates) (Malina *et al.*, 2004). Roldão da Silva *et al.* (2020) noted a comparable increase in DBP, yet SBP remained equal over three years. While Agostinis-Sobrinho *et al.* (2018) contrarily noted a decrease in BP among their total sample over time, a mitigating reason for differing BP results could be that the CVD risk of participants from the literature was lowered through improved CRF levels, which encourages better heart rate, as well as less heart and arterial

wall pressure; while the current study showed contrasting results (NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018).

According to sex, the results were like the total sample, where both boys and girls had a significant developmental increase with a high correlation in BMI, WC, the $\sum$ SF and BF%. Literature similarly found a longitudinal increase in the $\sum$ SF, BMI and BF% amongst both sexes (Sinaiko *et al.*, 1999; Stratton *et al.*, 2007; Pienaar, 2015; Castro-Piñero *et al.*, 2017; Monyeki *et al.*, 2017). Malina *et al.* (2004) explained that as a part of standard growth, participants' stature, mass, BMI, $\sum$ SF and BF% increase should be expected in boys and girls from seven to 13 years of age. The increase in SBP and DBP was similar amongst the boys and girls alike, which agreed with previous literature regarding the findings of BP according to sex (Castro-Piñero *et al.*, 2017). Whereas Agostinis-Sobrinho *et al.* (2018) noted that both boys and girls had a longitudinal decline in DBP and SBP. Once again, a mitigating reason for the above difference may be due to the results from the literature showing improved CRF levels, which may positively influence the CV system reducing BP (NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018).

A moderate increase and insignificant correlation coefficient developmental change in $\dot{V}O_2$ max or CRF was noted. The total sample's CRF levels were within health criterion referenced CRF standards (35 to 47 mL/kg/min) (Ruiz *et al.*, 2014). Longitudinal literature similarly reported a significant decrease or insignificant change in CRF or $\dot{V}O_2$ max, of which all, except Stratton *et al.* (2007), were within the CRF health standards (Stratton *et al.*, 2007; He *et al.*, 2011; Ruiz *et al.*, 2014; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017; Kallerman, 2019; Roldão da Silva *et al.*, 2020). Malina *et al.* (2004) clarified that CRF is positively influenced by growth in fat free mass and should increase until the ages between 13–16-years-old and plateaus through adolescence. Yet, fat mass has a negative effect on CRF performance, as the child has excessive weight to carry (Malina *et al.*, 2004). This supports the current findings that as OW and obesity increased, CRF changed insignificantly. It also agrees with the findings of He *et al.* (2011) and Agostinis-Sobrinho *et al.* (2018). He *et al.* (2011) specifically noted the decrease in CRF amongst the group classified as OW and obese, whereas Agostinis-Sobrinho *et al.* (2018) noted an increase in CRF in the group classified as standard weight. A probable mitigating reason for the difference in CRF findings is that He *et al.* (2011) and Agostinis-Sobrinho *et al.* (2018) considered the changes of CRF relative to BMI categories, whereas the current study observed the BMI and CRF changes individually.

Regarding sex, the boys and girls had a comparable insignificant change in CRF. The girls met the CRF health standards from MP1 to MP2 (standards for girls between 35–42 mL/kg/min), yet the boys met the standards in MP1 but not in MP2 (standard for boys between 40–47 mL/kg/min) (Ruiz *et al.*, 2014). Further literature equally showed an insignificant decrease in $\dot{V}O_2$ max amongst boys and girls over a longitudinal period (Stratton *et al.*, 2007; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017). The CRF standards were not met by

boys and girls of literature that is available (Stratton *et al.*, 2007; Ruiz *et al.*, 2014; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017). Malina *et al.* (2004) explained that CRF should increase linearly in boys until age 16, whereas girls have an increase of CRF until 13-years-old and plateaus through adolescence. Yet the current results showed insignificant changes in CRF in both sexes. A mitigating reason for this could be explained by the increase in fat mass (OW and obesity) amongst boys and girls that negatively influenced their CRF levels to plateau (Malina *et al.*, 2004). Agostinis-Sobrinho *et al.* (2018) noted an increase in CRF in boys and girls alike. Possible reasons for the difference in findings between this study's outcomes and Agostinis-Sobrinho *et al.* (2018) were the participants' age, the measurement frequency and study duration. Agostinis-Sobrinho *et al.* (2018) participants' age range was older (12–18 years), time from the baseline to follow-ups was longer (annually) and the measurement frequencies were once every second year (Stratton *et al.*, 2007; Roldão da Silva *et al.*, 2020).

3.5 LIMITATIONS AND RECOMMENDATIONS

A combination of various accurate anthropometric measurements, instead of self-reported data, and the stratified, longitudinal study design, are the strengths of this study. The total sample consisted of regional data from four of the eight school districts in the NWP. The NWP is one of nine South African provinces. These current findings were a partial representation of South African adolescents, which we identified as a weakness. A recommendation is that future research should include participants from more school districts of each South African province. If the rates of obesity rise and passive CRF levels remain like that of literature findings, South African adolescents are at high risk for obesity and HTN. Firstly, additional studies regarding CRF, HTN and obesity prevalence and changes amongst South African adolescents are recommended to confirm or refute current findings. Secondly, health care providers, parents and educators should encourage young people to improve CRF levels by cultivating a lifelong habit of sufficient PA. Finally, health professionals should routinely monitor BMI, BP and CRF changes amongst youth. The monitoring should be aimed to intervene, improve or maintain health status according to scientifically approved dietary and PA guidelines.

3.6 CHAPTER CONCLUSION

The aim was to determine changes in obesity, HTN and CRF among South African adolescents attending school in the NWP over three years. Significantly more adolescents were classified as OW and obese over a three-year period. Pre-hypertension and HTN decreased considerably amongst the adolescents. The BC and BP of the adolescents increased as expected for average growth, but CRF decreased insignificantly over the three-year period. Numerous factors influence changes in BC, BP, excessive weight gain, HTN and CRF among adolescents. Physical inactivity may have contributed to the increase in OW and obesity, along with dietary, societal and other influencing factors. A contributory reason as to why CRF appeared to have plateaued, could have been an influence of the OW and obese group increasing (adolescents carrying excessive fat mass during exercise). We are not fully certain as to how the HTN groups decreased considering that the

OW and obese groups increased and there were no significant increases in CRF, yet the CRF plateau could have influenced that the HTN decreased. It is important to improve or maintain physical health, as today's children become tomorrow's adults. Therefore, the above recommendations should be applied during early childhood to stop lifelong chronic CVDs.

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3.7 REFERENCES

- AGOSTINIS-SOBRINHO, C.; RUIZ, J.R.; MOREIRA, C.; ABREU, S.; LOPES, L.; OLIVEIRA-SANTOS, J.; MOTA, J. & SANTOS, R. (2018). Cardiorespiratory fitness and blood pressure: a longitudinal analysis. *Journal of Paediatrics*, 192(January): 130–135.
- ANDERSSSEN, S.A.; COOPER, A.R.; RIDDOCH, C.; SARDINHA, L.B.; HARRO, M.; BRAGE, S. & ANDERSEN, L.B. (2007). Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *European Society of Cardiology*, 14(August): 526–531.
- CASTRO-PIÑERO, J.; PEREZ-BEY, A.; SEGURA-JIMÉNEZ, V.; APARICIO, V.A.; GÓMEZ-MARTÍNEZ, S.; IZQUIERDO-GOMEZ, R.; MARCOS, A. & RUIZ, J.R. (2017). Cardiorespiratory fitness cut-off points for early detection of present and future cardiovascular risk in children: a 2-year follow-up study. *Mayo Clinic Proceedings*, 92(12): 1753–1762.
- COLE, T.J.; BELLIZZI, M.C.; FLEGAL, K.M. & DIETZ, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal*, 320(7244): 1–6.
- HE, Q.; WONG, T.; DU, L.; JIANG, Z.; YU, T.I.; QIU, H.; GAO, Y.; LIU, W. & WU, J. (2011). Physical activity, cardiorespiratory fitness, and obesity among Chinese children. *Preventative Medicine*, 52(2011): 109–113.
- IBM CORPORATION. (2019). IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corporation.
- KALLERMAN, P.H. (2019). Cardiovascular health in children and adolescents with obesity: Prevalence, prediction and supervised exercise. Unpublished doctoral dissertation. Stockholm, Sweden: Karolinska Institute.
- MAHAR, M.T.; GUERIERI, A.M.; HANNA, M.S. & KEMBLE, C.D. (2011). Estimation of aerobic fitness from 20-m multistage shuttle run test performance. *American Journal of Preventive Medicine*, 41(4S2): 117–123.
- MALINA, R.M.; BOUCHARD, C. & BAR-OR, O. (2004). *Growth, maturation and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.
- MONYEKI, K.D.; MATSHIPI, M. & MONYEKI, M.S. (2017). Prevalence of abdominal obesity among rural South African children over time: Ellisras Longitudinal Study. *African Journal for Physical Activity and Health Sciences*, 23(3): 416–430.
- NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM (NHBPEP). (2005). *The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents*, (4th ed.), Philadelphia, PA: U.S. United States Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, National High Blood Pressure Education Program.

- NQWENISO, S.; WALTER, C.; DU RANDT, R.; AERTS, A.; ADAMS, L.; DEGEN, J.; GALL, S.; GANI, Z.; JOUBERT, N.; MÜLLER, I.; SMITH, D.; SEELIG, H.; STEINMANN, P.; PROBST-HENSH, N.; UTZINGER, J.; PÜHSE, U. & GERBER, M. (2020). Prevention of overweight and hypertension through cardiorespiratory fitness and extracurricular sport participation among South African schoolchildren. *Sustainability*, 12(16): 1–16.
- PAZIN, D.C.; ROSANELI, C.F.; OLANDOSKI, M.; NETTO DE OLIVEIRA, E.R.; PELLEGRINO BAENA, C.; FIGUEREDO, A.S.; DA LUZ KAESTNER, T.L.; GUAARITA-SOUZA, L. & FARIA-NETO, J.R. (2017). Waist circumference is associated with blood pressure in children with normal body mass index: a cross-sectional analysis of 3,417 schoolchildren. *Brazilian Archives of Cardiology*, 109(6): 509–515.
- PIENAAR, A.E. (2015). Prevalence of overweight and obesity among primary schoolchildren in a developing country: NW-CHILD longitudinal data of 6-9-yr-old children in South Africa. *Biomedical Central Obesity*, 2(2): 1–10.
- PALOMÄKI, S.; HEIKINARO-JOHANSSON, P. & HUOTARI, P. (2015). Cardiorespiratory performance and physical activity in normal weight and overweight Finnish adolescents from 2003 to 2010. *Journal of Sports Sciences*. 33(6): 588–596.
- PLOWMAN, S.A. & MEREDITH, M.D. (2013). *Fitnessgram/Activitygram reference guide*. (4th ed.). Dallas, TX: The Cooper Institute.
- ROLDÃO DA SILVA, P.; CASTILHO DOS SANTOS, G.; MARCIO DA SILVA, J.; FERREIRA DE FARIA, W.; GONÇALVES DE OLIVEIRA, R. & STABELINI NETO, A. (2020). Health-related physical fitness indicators and clustered cardiometabolic risk factors in adolescents: A longitudinal study. *Journal of Exercise Science and Fitness*, 18(3): 162–167.
- RUIZ, J.R.; HUYBRECHTS, I.; CUENCA-GARCIA, M.; ARTERO, E.G.; LABAYEN, I.; MEIRHAEGHE, A.; VICENTE-RODRIGUEZ, G.; POLITO, A.; MANIOS, Y.; GONZALEZ-GOSS, M.; MARCOS, A.; WIDHALM, K.; MOLNAR, D.; KAFATOR, A.; SJÖSTRÖM, M.; MORENO, L.A.; CASTILLO, M.J. & ORTEGA, F.B. (2015). Cardiorespiratory fitness and ideal cardiovascular health in European adolescents. *Heart Cardiac Risk Factors and Prevention*, 101(10): 766–773.
- SINAIKO, A.R.; DONAHUE, R.P.; JACOBS, D.R. & PRINEAS, R.J. (1999). Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults the Minneapolis children's blood pressure study. *Circulation*, 1999(99): 1471–1476.
- SLAUGHTER, M.H.; LOHMAN, T.G.; BOILEAU, R.A.; HORSWILL, C.A.; STILLMAN, R.J.; VAN LOAN, M.D. & BEMBEN, D.A. (1988). Skinfold equations for estimations of body fatness in children and youth. *Human Biology*, 60(5): 709–723.

- STRATTON, G.; CANOY, D.; BODDY, L.M.; TAYLOR, S.R.; HACKETT, A.F. & BUCHAN, I.E. (2007). Cardiorespiratory fitness and body mass index of 9-11-year-old English children: A serial cross-sectional study from 1998 to 2004. *International Journal of Obesity*, 31(7): 1172–1178.
- STEWART, A.; MARFELL-JONES, M.; OLDS, T. & DE RIDDER, H. (2011). *International Standards for anthropometric assessment*. (3rd ed). Lower Hutt: The international society for the advancement of Kinanthropometry.
- VAN STADEN, D.; COETZEE, D. & DU PLESSIS, W. (2019). A longitudinal study on the effect of overweight, obesity, stunting and wasting on academic performance of primary school boys: the NW-CHILD study. Unpublished master's dissertation. Potchefstroom, South Africa: North-West University.

CHAPTER FOUR

CHAPTER 4: ASSOCIATIONS BETWEEN CARDIORESPIRATORY FITNESS AND TWO COMPONENTS OF CARDIOVASCULAR RISK (OBESITY AND HYPERTENSION) FROM THE AGE OF 10–13: THE NW-CHILD STUDY

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ABSTRACT

This study aimed to determine longitudinal associations between cardiorespiratory fitness and two cardiovascular risk components (obesity and hypertension). Included were South African participants from the NW-CHILD study in 2013 (N = 864, mean age = 9.88 years, boys = 455 and girls = 409) and 2016 (N = 558, mean age = 12.89 years, boys = 290 and girls = 268). We collected data using measurements of body mass index, body fat percentage and blood pressure results, as well as cardiorespiratory fitness values from FitnessGram 20m Progressive Aerobic Cardiovascular Endurance Run. We utilised descriptive statistics, analysis of covariance, paired sample t-test, Spearman's rank order correlation and practical effect size to determine associations between cardiorespiratory fitness and two clustered cardiovascular disease risk factors. High tracking coefficients were found for body mass index, body fat percentage, and the total sample's $\dot{V}O_2$ max. Moderate tracking correlations were found for systolic blood pressure; diastolic blood pressure for the girls; and $\dot{V}O_2$ max among boys and girls, yet the total sample and diastolic blood pressure for the boys showed weak correlations. The body fat increase had a significant negative influence on cardiorespiratory fitness levels which decreased insignificantly. The insignificant decrease of cardiorespiratory fitness significantly influenced blood pressure; this being a blood pressure increase among adolescents when adjusted for age and sex.

Key words: Adolescents, Cardiorespiratory fitness, Clustered cardiovascular risk factors, Obesity, Blood pressure

Associations between cardiorespiratory fitness and two components of cardiovascular risk (obesity and hypertension) from the age of 10–13: the NW-CHILD study

4.1 INTRODUCTION

Several studies have observed inverse associations between low cardiorespiratory fitness (CRF) levels and increased risk for obesity and hypertension (HTN) in young people world-wide and in specific provinces of South Africa (SA) (Pienaar, 2015; Awotidebe *et al.*, 2016; Castro-Piñero *et al.*, 2017; Kallerman, 2019; Roldão da Silva *et al.*, 2020). Excessive fat gain determines HTN risk and acts as extra weight for a child to carry (Sinaiko *et al.*, 1999; Malina *et al.*, 2004). The extra weight makes partaking in physical activity (PA) hard for adolescents classified as overweight (OW) or obese, resulting in greater fat gain because of physical inactivity (Sinaiko *et al.*, 1999; Malina *et al.*, 2004; Nqweniso *et al.*, 2020).

Several main causes of physical inactivity, obesity and HTN in youths are lifestyle factors, such as society or environment, parental roles, growth and development, psychological elements and dietary choices (Malina *et al.*, 2004; Monyeki, M.A., *et al.*, 2017; Pazin *et al.*, 2017; Agostinis-Sobrinho *et al.*, 2018).

South African studies using a cross-sectional study design found various relationships between CRF, body composition (BC) and blood pressure (BP) among children and adolescents of various South African provinces (Kemp *et al.*, 2011; Awotidebe *et al.*, 2016; Chungag *et al.*, 2019; Nqweniso *et al.*, 2020). A study by Kemp *et al.* (2011) found significant positive associations between BP and BC among South African Grade one learners during the NW-CHILD study from the North West Province (NWP). Awotidebe *et al.* (2016) reported positive associations between BC and BP, and negative associations between CRF and BP, as well as CRF and BC among South African adolescents from the Tlokwe Local Municipality areas of the NWP. Chungag *et al.* (2019) observed the positive association of HTN and adiposity levels amongst South African adolescents living in the Eastern Cape Province. Nqweniso *et al.* (2020) observed a negative association between high CRF and body mass index (BMI).

The cited longitudinal South African studies found nearly similar findings regarding CRF, BC and BP (Monyeki, K.D., *et al.*, 2017; Nqweniso *et al.*, 2020; Grace *et al.*, 2021). In their longitudinal analysis, Nqweniso *et al.* (2020) initially found significant negative associations between changes in CRF and obesity. Furthermore, no significant negative associations between changes in BP and in CRF were found when regression analyses were adjusted for possible confounders; yet, participants with higher CRF levels were at lower risk for HTN (Nqweniso *et al.*, 2020). Grace *et al.* (2021) aimed to determine PA and the impact of nutrition on BMI and BP among South African adolescents from KwaZulu-Natal Province. Results indicated that BMI and BP significantly decreased after the PA 10-week intervention and BMI remained significantly lower even when controlling for pre-test variables (Grace *et al.*, 2021).

Nqweniso *et al.* (2020) identified the effect sizes for CRF, BC and BP among young participants. Large effect sizes for BMI and CRF in relation to BMI categories were noted, whereas BP, in relation to CRF levels, indicated a moderate effect size among participants initially classified as non-hypertensive at baseline (Nqweniso *et al.*, 2020). Tracking of CRF and BP changes over time was limited in the cited literature; however, Monyeki, K.D., *et al.* (2017), Sinaiko *et al.* (1999) and Pienaar (2015) noted tracking correlations for BC or abdominal obesity (based on waist-to-height ratio) when observing BC changes.

The longitudinal and cross-sectional studies from SA have contributed to and confirm the knowledge of prominent relationships between CRF, obesity and HTN. Firstly, adolescents who increased in or had high fitness levels had a decreased obesity risk (Awotidebe *et al.*, 2016; Nqweniso *et al.*, 2020; Grace *et al.*, 2021). Secondly, it was stated that youths with higher PA participation or CRF levels had lower risk for HTN (Awotidebe *et al.*, 2016; Nqweniso *et al.*, 2020; Grace *et al.*, 2021). Finally, adolescents with larger BMI, WC or body fat percentage (BF%) showed higher BP values (Kemp *et al.*, 2011; Awotidebe *et al.*, 2016; Chungag *et al.*, 2019).

Through increasing HTN and obesity prevalence among youth, various destructive negative effects develop, for example, pulmonary diseases, nervous system disruptions, digestive associated conditions and increased risk for premature mortality (Sinaiko *et al.*, 1999; National High Blood Pressure Education Program (NHBPEP), 2005; Monyeki, M.A., *et al.*, 2017; Pazin *et al.*, 2017). These negative effects may develop in childhood, yet only have the most severe consequences during adulthood (Sinaiko *et al.*, 1999; Pienaar, 2015; Roldão da Silva *et al.*, 2020).

The cross-sectional and longitudinal literature have recognised inverse associations between low CRF levels and increased risk of obesity and HTN in adolescents world-wide and in SA (Pienaar, 2015; Awotidebe *et al.*, 2016; Castro-Piñero *et al.*, 2017; Kallerman, 2019; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020; Grace *et al.*, 2021). Yet, the South African longitudinal literature included participants who were either older (aged 13-16 years); participants who were already obese or participants from provinces other than the NWP (Nqweniso *et al.*, 2020; Grace *et al.*, 2021). Thus, research about associations between changes in CRF, obesity and HTN is required amongst South African adolescents attending school in the NWP.

Therefore, we aim to determine the longitudinal association between changes in cardiorespiratory fitness with changes in obesity and HTN among school attending adolescents 10–13 years old, living in the NWP, SA. It is hypothesised that significant associations will be found between changes in CRF and changes in BC and BP, over a three-year period.

4.2 MATERIAL AND METHODS

4.2.1 Research Design

This manuscript is a sub-study of the Child-Health-Integrated with Learning and Development (NW-CHILD study). The NW-CHILD study followed a repeated cross-sectional and longitudinal research design, initially aimed to observe health, learning and development among children and adolescents. The larger study took place in 2010 (baseline measurement), 2013 (Follow-up measurement point 1 [MP1]) and 2016 (Follow-up measurement point 2 [MP2]). The current manuscript used a longitudinal study design and only included data from the follow-up measurements.

4.2.2 Participants

The NW-CHILD study involved 816 six- to 13-year-old participants. Participants were from four of the eight school regions in the NWP, SA. With Statistical Consultation of the North-West University, we selected the sample using stratified random selection. The North West Provincial Department of Education produced a list of NWP school names from which the research sample was determined. They categorised this list into eight educational districts according to quintile status, each representing 12–22 regions with 20 schools (minimum 12, maximum 47) per region. The National Treasury determined the quintile status according to the South African National Poverty Table. They randomly selected regions and schools, recognising population density and school status (Quintile 1: schools from socio-economic status (SES) classified as the lowest to Quintile 5: schools from SES classified as the highest). The total sample included schools from quintiles 1–5, which may be a good representative of young people across the province. We used the first (2013 or MP1) and second (2016 or MP2) follow-up measurements' data for this study. The MP1 initially included 574 participants, resulting in a participant drop-out that was 30.1% from baseline (N = 816) to MP1. Therefore, we included new randomly selected participants, allowing for a MP1 sample total of 864. The drop-out rate was an effect of absenteeism during measurement days, school drop-out or participants moving to a new school. The reasons for dropping out were not within our control, and it did not significantly affect this study's aims. The sample characteristics were mean age = 9.88 years, boys = 455, girls = 409, participants categorised as Black = 649, and participants categorised as White = 215. The qualified statistician advised that because the number of participants classified as Coloured and Indian were too few to form a sample group, their data had to be combined with the sample group of participants classified as Black. Originally, 661 participants from Grade 7 were available for MP2, of which 77 participants refused consent. Therefore, 584 were measured and 558 participants met the final inclusion criteria to be present at both follow-up measurements. The total sample characteristics were mean age = 12.89 years, boys = 290, girls = 268.

4.2.3 Measuring Instruments

The measurements and equations that were applicable for this study are mass, stature, BMI, waist circumference (WC), subscapular skinfold, triceps skinfold, BF%, BP and CRF. Additional relevant

information was gathered like sex, age and race. We carried out measurements during school time, in private, gender-separated, cordoned-off indoor areas, for example, the school hall, sickbay, or an office. Participants had to wear minimal clothing during measurements. Postgraduate Kinderkinetics students and researchers acquired the measurements. Two researchers or students had to be present during measurements for ethical participant safety.

Body Mass Index

Mass and stature were used to calculate BMI values. We measured mass to the nearest 0.1 kg with an electronic scale (Omron, BF 511, Omron Corporation, Japan), making use of the International Society for the Advancement of Kinanthropometry (ISAK) guidelines (Stewart *et al.*, 2011). Stature was measured to the nearest 0.1 cm using a portable stadiometer. The researcher positioned the participant's head in Frankfort position and told the participant to take one deep inhalation before recording the value, following ISAK procedure (Stewart *et al.*, 2011). Mass divided by stature squared (kg)/m² was the equation method used to calculate BMI. This study made use of age and gender-specific cut-off points for OW and obesity between 10–13.5 years of age, as indicated in **Table 4.1** (Cole *et al.*, 2000). The basic marker for OW or obesity, known as a main cardiovascular disease (CVD) risk, was BMI. We know BMI is not the best adiposity indicator, therefore, we used WC and fat percentage as added indicators.

Table 4.1: BODY MASS INDEX INDICATOR OF OVERWEIGHT AND OBESITY: INTERNATIONAL AGE AND GENDER-SPECIFIC CUT-OFF POINTS FOR OVERWEIGHT AND OBESITY BY COLE ET AL. (2000)

Age (years)	Body Mass Index 25 kg/m ²		Body Mass Index 30 kg/m ²	
	Males	Females	Males	Females
9.5	19.46	19.45	23.39	23.46
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20

kg = kilogram; m = meter

Waist Circumference

We measured the WC size according to ISAK procedure at the narrowest section between the lower costal rib (10th rib) and the most superior part of the Crista Iliaca while the participant stood (Stewart *et al.*, 2011). The

researcher or student took two measurements with a normal metal measuring tape and recorded the mean value. Waist circumference was an additional measurement for abdominal OW or obesity (Pazin *et al.*, 2017).

Subscapular and Triceps Skinfolts

We measured the subscapular skinfold value at an oblique downwards angle at the subscapular landmark while the participant stood, according to ISAK protocol (Stewart *et al.*, 2011). The triceps skinfold was the measurement taken perpendicular to the long axis of the arm, at the triceps skinfold landmark with a participant in standing position and arm relaxed according to ISAK protocol (Stewart *et al.*, 2011). The researcher or student measured the value twice in millimetres (mm) using a Harpenden skinfold calliper (Baty International, manufactured in England) and recorded the mean value of the two measurements.

Fat Percentage

We calculated the BF% using the triceps and subscapular skinfold values in the equations from Slaughter *et al.* (1988), equations were modified for maturation and race. By adding the mean of the triceps skinfold to the mean of the subscapular skinfold, we calculated the sum of skinfolds (ΣSF). For boys with BF% below 35, we replaced the intercepts (I) into the equations below to correct for the participant's maturation level. The calculations of BF% by Slaughter equations (Slaughter *et al.*, 1988) were influenced by several factors, for example:

If the skinfolds sum was **above 35**, the following equations were applicable for participants classified as Black or White:

- All boys; $BF\% = 0.783 (\Sigma SF) + 1.6$
- All girls; $BF\% = 0.546 (\Sigma SF) + 9.7$

If the skinfolds sum was **below 35**, the following equations for participants classified as Black or White are used:

- Boys; $BF\% = 1.21 (\Sigma SKF) - 0.008(\Sigma SKF)^2 + I^*$
- All girls; $BF\% = 1.33 (\Sigma SKF) - 0.013(\Sigma SF)^2 - 2.5$

Whenever an intercept was used, the following by Slaughter *et al.* (1988) applies:

Table 4.2: SKINFOLD EQUATION INTERCEPT (I*) SUBSTITUTION RECOMMENDED FOR PREDICTING BODY FAT IN BOYS WITH A SUM OF FATNESS LESS THAN 35, BASED ON MATURATION AND ETHNICITY

Stage	Black Category	White Category
Pre-pubescent	-3.2	-1.7
Pubescent	-5.2	-3.4
Post-pubescent	-6.8	-5.5

We chose the skinfold measurements mentioned above because they give the highest correlation of overall BF% amongst adolescents and are good indicators of CVD risk (Plowman & Meredith, 2013).

Blood Pressure

The researcher or student measured the BP with a clinically validated oscillometric automatic device (Omron 705CP-II, Omron Corporation, Japan). They would adjust the widths of the sleeve cover (small 17–22 cm, medium 22–32 cm, 32–42 cm wide) according to the participant's arm circumference. The participant had to sit, resting for 5 minutes, with his or her right arm relaxed on a table, palm faced upwards before researcher or student measured the BP. The researcher or a post-graduate student recorded the BP three times with 5-minute breaks in between and used the mean of the last two readings for the BP data. If a participant's SBP and/or diastolic blood pressure (DBP) values were less than the 90th percentile for age, sex and stature, according to the cut-off points of the NHBPEP on high BP in young people, then the participant has average BP (NHBPEP, 2005). Yet, participants with SBP and/or DBP values were greater than the 90th percentile but less than the 95th percentile are classified with prehypertension. Whereas paediatric HTN occurs when a participant's SBP and/or DBP values were greater than or equal to the 95th BP percentile (NHBPEP, 2005). Tables 4.3 and 4.4 indicate sex grouped BP standards, which show to the participant's BP percentile and whether the participant was hypertensive or not (NHBPEP, 2005).

Table 4.3: BLOOD PRESSURE STANDARDS FOR BOYS BY AGE AND STATURE BY NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM WORKING GROUP (NHBPEP, 2005)

Age (years)	BP Percentile	Systolic BP (mmHg)							Diastolic BP (mmHg)						
		Percentile of Stature							Percentile of Stature						
		5 th	10 th	25 th	50 th	75 th	90 th	95 th	5 th	10 th	25 th	50 th	75 th	90 th	95 th
10	50 th	97	98	100	102	103	105	106	58	59	60	61	61	62	63
	90 th	111	112	114	115	117	119	119	73	73	74	75	76	77	78
	95 th	115	116	117	119	121	122	123	77	78	79	80	81	81	82
	99 th	122	123	125	127	128	130	130	85	86	86	88	88	89	90
11	50 th	99	100	102	104	105	107	107	59	59	60	61	62	63	63
	90 th	113	114	115	117	118	120	121	74	74	75	76	77	78	78
	95 th	117	118	119	121	123	124	125	78	78	79	80	81	82	82
	99 th	124	125	127	129	130	132	132	86	86	87	88	89	90	90
12	50 th	101	102	104	106	108	109	110	59	60	61	62	63	63	64
	90 th	115	116	118	120	121	123	123	74	75	75	76	77	78	79
	95 th	119	120	122	123	125	127	127	78	79	80	81	82	82	83
	99 th	126	127	129	131	133	134	135	86	87	88	89	90	90	91
13	50 th	104	105	106	108	110	111	112	60	60	61	62	63	64	64
	90 th	117	118	120	122	124	125	126	75	75	76	77	78	79	79
	95 th	121	122	124	126	128	129	130	79	79	80	81	82	83	83
	99 th	128	130	131	133	135	136	137	87	87	88	89	90	91	91

yrs. = years; BP = blood pressure; mmHg = millimetre of mercury

Table 4.4: BLOOD PRESSURE STANDARDS FOR GIRLS BY AGE AND STATURE BY NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM WORKING GROUP (NHBPEP, 2005)

Age (years)	BP Percentile	Systolic BP (mmHg)							Diastolic BP (mmHg)						
		Percentile of Stature							Percentile of Stature						
		5 th	10 th	25 th	50 th	75 th	90 th	95 th	5 th	10 th	25 th	50 th	75 th	90 th	95 th
10	50 th	98	99	100	102	103	104	105	59	59	59	60	61	62	62
	90 th	112	112	114	115	116	118	118	73	73	73	74	75	76	76
	95 th	116	116	117	119	120	121	122	77	77	77	78	79	80	80
	99 th	123	123	125	126	127	129	129	84	84	85	86	86	87	88
11	50 th	100	101	102	103	105	106	107	60	60	60	61	62	63	63
	90 th	114	114	116	117	118	119	120	74	74	74	75	76	77	77
	95 th	118	118	119	121	122	123	124	78	78	78	79	80	81	81
	99 th	125	125	126	128	129	130	131	85	85	86	87	87	88	89
12	50 th	102	103	104	105	107	108	109	61	61	61	62	63	64	64
	90 th	116	116	117	119	120	121	122	75	75	75	76	77	78	78
	95 th	119	120	121	123	124	125	126	79	79	79	80	81	82	82
	99 th	127	127	128	130	131	132	133	86	86	87	88	88	89	90
13	50 th	104	105	106	107	109	110	110	62	62	62	63	64	65	65
	90 th	117	118	119	121	122	123	124	76	76	76	77	78	79	79
	95 th	121	122	123	124	126	127	128	80	80	80	81	82	83	83
	99 th	128	129	130	132	133	134	135	87	87	88	89	89	90	91

yrs. = years; BP = blood pressure; mmHg = millimetre of mercury

Cardiorespiratory Fitness (PACER)

The PACER (Progressive Aerobic Cardiovascular Endurance Run) is a multi-stage aerobic endurance test, based on the testing protocol of the Fitnessgram reference guide (Plowman & Meredith, 2013). The researcher or students measured out a 20m distance for participants in which to run back and forth, turning around at the end line before a beep sound. The time between the beep sounds progressively became shorter, making the easy pace more difficult over time. We stopped participants when they failed to reach the end line twice at the beep sound. The total laps completed formed the participants score and which we used to define the estimates of maximal oxygen uptake ($\dot{V}O_2$ max), as recommended by Plowman and Meredith (2013), and indicated in **Table 4.5** (Mahar *et al.*, 2011).

Table 4.5: THE PROGRESSIVE AEROBIC CARDIOVASCULAR ENDURANCE RUN MAXIMAL OXYGEN UPTAKE CONVERSIONS FOR BOYS AND GIRLS AGED 10–16 YEARS BY MAHAR ET AL. (2011)

$\dot{V}O_2$ max Conversion from 20-meter PACER Test											
Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max	Level	Lap	$\dot{V}O_2$ max
4	25	26.8	6	45	34.3	8	65	41.1	10	85	47.4
4	26	27.2	6	46	34.0	8	66	41.5	10	86	47.7
4	27	27.6	6	47	35.0	8	67	41.8	10	87	48.0
4	28	28.0	6	48	35.4	8	68	42.1	10	88	48.4
4	29	28.3	6	49	35.7	8	69	42.4	10	89	48.7
4	30	28.7	6	50	36.1	8	70	42.7	10	90	49.0
4	31	29.1	7	51	36.4	9	71	43.0	10	91	49.3
4	32	29.5	7	52	36.8	9	72	43.3	10	92	49.6
5	33	29.9	7	53	37.1	9	73	43.6	11	93	49.9
5	34	30.2	7	54	37.5	9	74	43.9	11	94	50.2
5	35	30.6	7	55	37.8	9	75	44.2	11	95	50.5
5	36	31.0	7	56	38.2	9	76	44.5	11	96	50.8
5	37	31.4	7	57	38.5	9	77	44.9	11	97	51.1
5	38	31.8	7	58	38.9	9	78	45.2	11	98	51.4
5	39	32.2	7	59	39.2	9	79	45.5	11	99	51.7
5	40	32.6	7	60	39.6	9	80	45.8	11	100	51.9
5	41	32.9	8	61	39.9	9	81	46.2	11	101	52.2
6	42	33.3	8	62	40.2	10	82	46.5	11	102	52.5
6	43	33.6	8	63	40.5	10	83	46.8	11	103	52.8
6	44	34.0	8	64	40.8	10	84	47.1	11	104	53.1

$\dot{V}O_2$ max = maximal oxygen uptake

4.2.4 Procedure

Ethical Clearance and Research procedure

The principal investigator attained ethical approval from the North-West University Potchefstroom Campus' Ethics Committee (number: NWU-00070-09-A1-02) and from the North West Province Basic Education Department. The researchers used a list of schools from the NWP to find the total sample. They met with each school principal to explain the study objectives and format and received consent to collect data during school time. The researchers gave the participants informed consent forms that the parents or legal guardians had to sign before each measurement period. The forms explained in detail what participants were to do and possible participation risks. Participants who returned approved consent forms could sign participant's indemnity forms, give informed assent, and could partake in the measurements. Re-consent and assent were necessary to be included in the MP1 and MP2 measurements. The researchers explained the study procedures and non-obligation to partake to participants before each measurement period. They gave the participants a chance to ask questions about the study. They allowed participants to leave the study at any time the participant chose to

withdraw. If English or Afrikaans was not the participants' first language, external trained interpreters relayed the instructions from the evaluators to participants.

4.2.5 Statistical Analysis

Descriptive statistics (mean and SD) were used to calculate changes in CRF levels, BC and BP for the MP1 and MP2, which were analysed by SPSS Data Processing package (IBM Corporation 2019, Version 27.0.0). To carry out the aim of the study, we analysed data through analysis of variance (ANOVA) for repeated measures of the changes in CRF, body fatness and BP. We used a paired sample t-test to determine the mean differences between the MP1 and MP2 measurement data for the total sample and by sex. Effect size partial eta square (η^2_p) was used to evaluate the magnitude of changes in two sets of measurement points. The values of effect size are interpreted according to three main classifications, where 0.2 or less indicates a small effect, around 0.5 indicates a moderate effect and 0.8 or more indicates a large effect size. Partial *Eta-squared* of ANOVA agrees with the rule of thumb of Cohen *et al.* (2015), whereby effects of η^2_p values interpret $\eta^2_p = 0.01$ as small, $\eta^2_p = 0.06$ as medium and $\eta^2_p = 0.14$ as large. We used Spearman's Rho correlation coefficients to find significance of the association to detect any changes that occurred between the baseline and follow-up measurements. The statistical significance level was set at $p \leq 0.05$.

4.3 RESULTS

Table 4.6 presents the BC, BP and CRF characteristics (mean, standard deviation [SD], mean change, partial *Eta-squared* and Rho values) for the total sample, according to sex between MP1 and MP2. Within the total sample BMI, BF%, SBP and DBP increased significantly ($p \leq 0.05$), whereas $\dot{V}O_2$ max decreased insignificantly. The results among the boys and girls indicated similar changes in BMI, SBP, DBP and $\dot{V}O_2$ max, yet the boys had a minor decrease in BF% and an increase in $\dot{V}O_2$ max over three years. Results showed significantly high tracking coefficients for BMI and BF% among the total sample, boys and girls. Blood pressure indicated low tracking coefficients (DBP total sample and boys Rho ≈ 0.21 – 0.28) and moderate tracking coefficients (SBP total sample, boys and girls and DBP girls Rho ≈ 0.36 – 0.44) over three years. The sample's $\dot{V}O_2$ max indicated a high tracking coefficient (0.51), whereas the boy's and girl's $\dot{V}O_2$ max tracking coefficients were moderate (Rho ≈ 0.40 – 0.46) between MP1 and MP2. Partial *Eta-squared* indicated a moderate practical effect size (η^2) in BMI of the total sample and among the boys and girls, as well as in BF% among girls. For BP and $\dot{V}O_2$ max, the practical effect sizes were small. The result analysis per sex indicated practical effect size variations in BC, BP and CRF.

Table 4.6: PARTICIPANT CHARACTERISTICS MEAN, STANDARD DEVIATION, P-VALUES AND EFFECT SIZE FOR THE TOTAL SAMPLE AND BY SEX

		MP1	MP2			
	N	Mean $\pm$ SD	Mean $\pm$ SD	Δ Mean	Rho	Effect size (Partial <i>Eta</i> -square)
Body Mass Index						
Sample	558	17.26 $\pm$ 3.87	19.36 $\pm$ 4.48	2.02*	0.88	0.5
Boys	290	17.3 $\pm$ 3.41	18.99 $\pm$ 4.23	1.69*	0.91	0.47
Girls	268	17.38 $\pm$ 4.31	19.77 $\pm$ 4.7	2.39*	0.87	0.54
Body Fat %						
Sample	558	20.02 $\pm$ 8.17	21.74 $\pm$ 8.72	1.74*	0.77	0.08
Boys	290	19.71 $\pm$ 7.87	19.22 $\pm$ 7.44	-0.49	0.77	0.008
Girls	268	20.34 $\pm$ 8.49	24.45 $\pm$ 8.19	4.11*	0.82	0.4
Systolic Blood Pressure (mmHg)						
Sample	558	101.48 $\pm$ 11.59	104.96 $\pm$ 11.33	3.48*	0.44	0.07
Boys	290	101.24 $\pm$ 11.42	104.78 $\pm$ 11.59	3.54*	0.44	0.08
Girls	268	101.74 $\pm$ 11.79	105.15 $\pm$ 11.07	3.41*	0.43	0.07
Diastolic Blood Pressure (mmHg)						
Sample	558	63.79 $\pm$ 10.06	66.3 $\pm$ 8.05	2.51*	0.28	0.05
Boys	290	63.34 $\pm$ 10.63	65.32 $\pm$ 7.98	1.98*	0.21	0.03
Girls	268	64.27 $\pm$ 9.41	67.36 $\pm$ 8	3.09*	0.36	0.09
$\dot{V}O_2$ max (mL/kg/min)						
Sample	558	42.45 $\pm$ 4.48	42.04 $\pm$ 6.2	-0.41	0.51	0.01
Boys	290	43.68 $\pm$ 5.09	44.71 $\pm$ 6.40	1.03*	0.46	0.03
Girls	268	41.14 $\pm$ 3.24	39.16 $\pm$ 4.47	1.98*	0.40	0.17
*p < 0.001; significant difference between boys and girls						
SD = standard deviation						
Rho Correlations: r $\approx$ 0.1 as low, r $\approx$ 0.3 as medium, and r $\geq$ 0.5 as high						
Partial <i>Eta</i> -square was used in SPSS to calculate practical effect size						
$\leq$ 0.2 = small effect; $\approx$ 0.5 = medium effect; $\geq$ 0.8 = large effect						

Table 4.7 shows the total sample's correlations between longitudinal changes in BC, BP and CRF of 10–13-year-old adolescents over three years. In MP1, the total sample showed associations of SBP with BMI ($r_s = 0.29$); Σ SF ($r_s = 0.26$) and BF% ($r_s = 0.24$); as well as DBP with BMI ($r_s = 0.16$); Σ SF ($r_s = 0.2$) and BF% ($r_s = 0.16$) which indicated low significant correlations. The total sample's $\dot{V}O_2$ max and BC components of Σ SF

($r_s = -0.44$) and BF% ($r_s = -0.37$) had medium significant ($p \leq 0.05$) inverse relationships. Whereas BMI and $\dot{V}O_2$ max had a low significant inverse correlation ($r_s = -0.3$).

In 2016 (MP2), SBP with BMI ($r_s = 0.38$) and with $\sum SF$ ($r_s = 0.3$); as well as DBP with $\sum SF$ ($r_s = 0.31$) showed medium significant ($p \leq 0.05$) correlations. Low associations were found between DBP with BMI ($r_s = 0.26$); and with BF% ($r_s = 0.25$); as well as BF% with SBP ($r_s = 0.23$) in MP2. $\dot{V}O_2$ max had high significant ($p \leq 0.05$) inverse correlations with $\sum SF$ ($r_s = -0.6$) and with BF% ($r_s = -0.58$), while BMI had a medium, inverse correlation with $\dot{V}O_2$ max ($r_s = -0.41$).

From 2013 (MP1) to 2016 (MP2), low tracking coefficients were noted between SBP 2013 with BMI 2016 ($r_s = 0.27$); $\sum SF$ 2016 ($r_s = 0.25$), and with BF% 2016 ($r_s = 0.24$); between SBP 2016 with BMI 2013 ($r_s = 0.29$), with $\sum SF$ 2013 ($r_s = 0.26$), and with BF% 2013 ($r_s = 0.26$). Further results showed low tracking coefficients between DBP 2013 with BMI 2016 ($r_s = 0.26$), with $\sum SF$ 2016 ($r_s = 0.2$), and with BF% 2016 ($r_s = 0.19$), including between DBP 2016 with BMI 2013 ($r_s = 0.21$), with $\sum SF$ 2013 ($r_s = 0.3$), and with BF% 2013 ($r_s = 0.2$). Medium significant ($p \leq 0.05$) inverse correlations were noted between $\dot{V}O_2$ max 2013 with BMI 2016 ($r_s = -0.35$), with $\sum SF$ 2016 ($r_s = -0.43$), and with BF% 2016 ($r_s = -0.41$); as well as medium correlations between $\dot{V}O_2$ max 2016 with $\sum SF$ 2013 ($r_s = -0.46$), and with BF% 2013 ($r_s = -0.34$). Body mass index 2013 and $\dot{V}O_2$ max 2016 indicated a low inverse association ($r_s = -0.29$).

Table 4.7: CORRELATIONS BETWEEN LONGITUDINAL CHANGES IN BODY COMPOSITION, BLOOD PRESSURE AND CARDIORESPIRATORY FITNESS

	Year	Systolic Blood Pressure				Diastolic Blood Pressure				VO ₂ max			
		2013		2016		2013		2016		2013		2016	
		N	r _s	N	r _s	N	r _s	N	r _s	N	r _s	N	r _s
Body Mass Index													
Sample	2013	864	0.285**	558	0.285**	864	0.162**	558	0.210**	849	-0.295**	553	-0.287**
	2016	558	0.271**	558	0.375**	558	0.164**	558	0.258**	545	-0.345**	550	-0.406**
Boys	2013	455	0.315**	290	0.340**	455	0.140**	290	0.228**	446	-0.252**	287	-0.315**
	2016	290	0.304**	290	0.413**	290	0.155**	290	0.255**	283	-0.268**	286	-0.373**
Girls	2013	409	0.254**	268	0.229**	409	0.186**	268	0.204**	403	-0.386**	266	-0.355**
	2016	268	0.249**	268	0.331**	268	0.164**	268	0.221**	262	-0.428**	264	-0.395**
Sum of Skinfolds, mm†													
Sample	2013	845	0.261**	558	0.261**	864	0.198**	558	0.295**	849	-0.444**	553	-0.457**
	2016	558	0.246**	558	0.300**	558	0.197**	558	0.311**	545	-0.434**	550	-0.602**
Boys	2013	455	0.325**	290	0.343**	455	0.204**	290	0.307**	446	-0.375**	287	-0.383**
	2016	290	0.248**	290	0.344**	290	0.151**	290	0.306**	283	-0.349**	286	-0.527**
Girls	2013	409	0.200**	268	0.178**	409	0.177**	268	0.219**	403	-0.457**	266	-0.357**
	2016	268	0.278**	268	0.275**	268	0.229**	268	0.241**	262	-0.443**	264	-0.457**
Body Fat %													
Sample	2013	845	0.243**	547	0.256**	845	0.163**	547	0.202**	832	-0.374**	542	-0.341**
	2016	553	0.235**	553	0.233**	553	0.192**	553	0.249**	541	-0.411**	545	-0.582**
Boys	2013	442	0.250**	284	0.308**	442	0.143**	284	0.199**	435	-0.328**	281	-0.352**
	2016	286	0.222**	286	0.194**	286	0.159**	286	0.186**	279	-0.318**	282	-0.508**
Girls	2013	403	0.237**	263	0.197**	403	0.183**	263	0.194**	397	-0.448**	261	-0.361**
	2016	267	0.282**	267	0.278**	267	0.216**	267	0.226**	262	-0.428**	263	-0.471**
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													
† Sum of skinfolds = subscapular skinfold + triceps skinfold													
r ≈ 0.1 as <u>low</u> ; r ≈ 0.3 as <u>medium</u> ; r ≥ 0.5 as <u>high</u>													

Table 4.7 further displays the correlations according to sex between longitudinal changes in BC, BP and CRF for the boys over the three-year period. In MP1, medium significant ($p \leq 0.05$) associations were found between SBP with BMI ($r_s = 0.32$); and with $\sum SF$ ($r_s = 0.33$) among the boys. Low significant ($p \leq 0.01$) correlations were noted between SBP with BF% ($r_s = 0.25$); as well as the associations between DBP with BMI ($r_s = 0.14$), with $\sum SF$ ($r_s = 0.2$) and with BF% ($r_s = 0.14$). Whereas $\dot{V}O_2$ max indicated medium inverse correlations with $\sum SF$ ($r_s = -0.38$) and BF% ($r_s = -0.33$), while BMI and $\dot{V}O_2$ max ($r_s = -0.25$) had a low inverse correlation in MP1.

In MP2, SBP with BMI ($r_s = 0.41$); and with $\sum SF$ ($r_s = 0.34$); as well as DBP with $\sum SF$ ($r_s = 0.31$) all indicated medium associations. Low significant ($p \leq 0.05$) correlations were found between DBP with BMI ($r_s = 0.25$); and with BF% ($r_s = 0.19$); in addition to SBP with BF% ($r_s = 0.19$) among the boys in MP2. $\dot{V}O_2$ max with $\sum SF$ ($r_s = -0.53$); and with BF% ($r_s = -0.51$) indicated high significant ($p \leq 0.05$) inverse correlations among the boys. Whereas $\dot{V}O_2$ max and BMI ($r_s = -0.37$) showed a medium inverse association.

From 2013 (MP1) to 2016 (MP2), medium significant ($p \leq 0.05$) correlations were noted in the boys between BMI 2016 ($r_s = 0.34$) with SBP 2013; between SBP 2016 with BMI 2013 ($r_s = 0.3$), with $\sum SF$ 2013 ($r_s = 0.34$), and with BF% 2013 ($r_s = 0.3$); as well as between DBP 2016 with $\sum SF$ 2013 ($r_s = 0.31$). Low significant ($p \leq 0.05$) correlations were found among boys between SBP 2013 with $\sum SF$ 2016 ($r_s = 0.25$), and with BF% 2016 ($r_s = 0.22$); correlations between DBP 2013 with BMI 2016 ($r_s = 0.16$), with $\sum SF$ 2016 ($r_s = 0.15$), and with BF% 2016 ($r_s = 0.16$); in addition to correlations between DBP 2016 with BMI 2013 ($r_s = 0.23$), and with BF% 2013 ($r_s = 0.19$). Medium inverse associations were found among the boys between $\dot{V}O_2$ max 2013 with $\sum SF$ 2016 ($r_s = -0.35$), and with BF% 2016 ($r_s = -0.32$); including associations between $\dot{V}O_2$ max 2016 with BMI 2013 ($r_s = -0.31$), with $\sum SF$ 2013 ($r_s = -0.38$), and with BF% 2013 ($r_s = -0.35$). Body mass index 2016 and $\dot{V}O_2$ max 2013 indicated a low inverse association ($r_s = -0.27$).

Table 4.7 displays the correlations for longitudinal changes in BC, BP and CRF amongst the girls from MP1 to MP2. The associations between SBP with BMI ($r_s = 0.25$); with $\sum SF$ ($r_s = 0.2$); and with BF% ($r_s = 0.24$); including the associations between DBP with BMI ($r_s = 0.19$); with $\sum SF$ ($r_s = 0.18$); and with BF% ($r_s = 0.18$) indicated low correlations in MP1. Medium significant ($p \leq 0.05$) inverse correlations between $\dot{V}O_2$ max with BMI ($r_s = -0.39$); with $\sum SF$ ($r_s = -0.46$); and with BF% ($r_s = -0.45$) were noted in MP1.

A medium significant ($p \leq 0.05$) association between BMI with SBP ($r_s = 0.331$) was observed among girls in MP2. Low significant ($p \leq 0.05$) associations were noted between SBP with $\sum SF$ ($r_s = 0.28$); and with BF% ($r_s = 0.28$); as well as DBP with $\sum SF$ ($r_s = 0.24$); with BF% ($r_s = 0.23$); and with BMI ($r_s = 0.22$). An inverse association was found between $\dot{V}O_2$ max with BMI ($r_s = -0.4$); with $\sum SF$ ($r_s = -0.46$); and with BF% ($r_s = -0.47$).

From 2013 (MP1) to 2016 (MP2), low associations were noted amongst the girls between SBP 2013 with BMI 2016 ($r_s = 0.25$), with $\sum SF$ 2016 ($r_s = 0.28$), and with BF% 2016 ($r_s = 0.28$); including between SBP 2016 with BMI 2013 ($r_s = 0.23$), with $\sum SF$ 2013 ($r_s = 0.18$), and with BF% 2013 ($r_s = 0.2$). Similarly, low associations were noted between DBP 2013 with BMI 2016 ($r_s = 0.16$), with $\sum SF$ 2016 ($r_s = 0.23$), and with BF% 2016 ($r_s = 0.22$); and including correlations between DBP 2016 with BMI 2013 ($r_s = 0.2$), with $\sum SF$ 2013 ($r_s = 0.22$), and with BF% 2013 ($r_s = 0.19$). Whereas medium significant ($p \leq 0.05$) inverse correlations among girls were found between $\dot{V}O_2$ max 2013 with BMI 2016 ($r_s = -0.43$), with $\sum SF$ 2016 ($r_s = -0.44$), and with BF% 2016 (r_s

= -0.43); as well as correlations between $\dot{V}O_2$ max 2016 with BMI 2013 ($r_s = -0.36$), with $\sum SF$ 2013 ($r_s = -0.37$), and with BF% 2013 ($r_s = -0.36$).

Table 4.8 presents the total sample's longitudinal correlations between changes in BC, BP and CRF adjusted for age and sex. Change (Δ) in BMI was significantly correlated with changes in BF% ($r = 0.56$) and in SBP ($r = 0.19$). The change in $\dot{V}O_2$ max was negative and significantly associated with changes in BMI ($r = -0.18$) and BF% ($r = -0.3$). Systolic BP change and DBP change was significantly correlated ($r = 0.73$). Additionally, insignificant associations were found between changes in DBP and BMI ($r = 0.09$), BP and BF% (SBP $r = -0.04$ and DBP $r = 0.02$), as well as BP and $\dot{V}O_2$ max (SBP $r = -0.004$ and DBP $r = -0.01$).

Table 4.8: CORRELATION MATRIX (R) BETWEEN CHANGES (Δ) IN BODY FATNESS, BLOOD PRESSURE AND CARDIORESPIRATORY FITNESS CONTROLLED FOR AGE AND SEX

		Δ Body Mass Index	Δ Body Fat %	Δ Systolic Blood Pressure	Δ Diastolic Blood Pressure	$\Delta \dot{V}O_2$ max
Δ Body Mass Index	r	-	0.56	0.19	0.09	-0.18
	p	-	< 0.001	< 0.001	0.04	< 0.001
Δ Body fat %	r	0.56	-	-0.04	0.02	-0.3
	p	< 0.001	-	0.4	0.63	< 0.001
Δ Systolic Blood Pressure	r	0.19	-0.04	-	0.63	-0.004
	p	< 0.001	0.4	-	< 0.001	0.92
Δ Diastolic Blood Pressure	r	0.09	0.02	0.63	-	-0.01
	p	0.04	0.63	< 0.001	-	0.82
$\Delta \dot{V}O_2$ max	r	-0.18	-0.3	-0.004	-0.01	-
	p	< 0.001	< 0.001	0.92	0.82	-
$p \leq 0.05$: significance level						

Table 4.9 presents the age adjusted standardised regression coefficient (β), as well as the p-values for the relationships of changes in $\dot{V}O_2$ max with changes (Δ) in BC and in BP. Changes in BMI and BF% were inversely associated with changes in $\dot{V}O_2$ max among boys (BMI $\beta = -0.32$ and BF% $\beta = -0.41$) and girls (BMI $\beta = -0.35$ and BF% $\beta = -0.41$). Similarly, changes in BP had a negative and significant association with changes in CRF among boys (SBP $\beta = -0.06$ and DBP $\beta = -0.11$) and girls (SBP $\beta = -0.08$ and DBP $\beta = -0.09$).

Table 4.9: AGE ADJUSTED STANDARDISED REGRESSION COEFFICIENT (β) AND P-VALUES FOR THE RELATIONSHIP OF CHANGES IN BODY COMPOSITION AND BLOOD PRESSURE WITH $\dot{V}O_2$ MAX

	β	P	95% CI
Body Mass Index			
Boys	-0.32	< 0.001	-0.27; -0.18
Girls	-0.35	0.08	-0.42; -0.28
Body Fat %			
Boys	-0.41	< 0.001	-0.69; -0.50
Girls	-0.41	0.001	-0.38; -0.10
Systolic Blood Pressure			
Boys	-0.06	0.12	-0.26; 0.03
Girls	-0.08	0.04	-0.46; 0.01
Diastolic Blood Pressure			
Boys	-0.11	0.003	-0.31; -0.06
Girls	-0.09	0.02	-0.38; 0.04

4.4 DISCUSSION

The objective of this study was to determine longitudinal associations between CRF, obesity and HTN among school attending adolescents 10–13 years old, attending school in the NWP, South Africa.

The development of body composition, blood pressure and $\dot{V}O_2$ max

Generally, results show that BC and BP increased significantly from 2013 to 2016. According to Malina *et al.* (2004), the developmental increase of BMI and BF% shows average reliable growth for children from seven to 13 years of age. Similarly, from the time that an infant's heart rate begins to slow down, or when bradycardia is established, a child's BP gradually increases as he or she grows (Malina *et al.*, 2004). Several longitudinal studies have similarly found an increase in BMI and BF% in participants with ages ranging between six to 23 years of age (Sinaiko *et al.*, 1999; Stratton *et al.*, 2007; He *et al.*, 2011; Palomäki *et al.*, 2015; Pienaar, 2015; Monyeki, K.D., *et al.*, 2017; Agostinis-Sobrinho *et al.*, 2018; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020). Opposingly, Grace *et al.* (2021) noted a longitudinal decrease in BMI among 13–16-year-old South African adolescents from eThekweni. The difference in BMI results between the current study and Grace *et al.* (2021) may be due to the difference in research aims. The current study aimed to evaluate longitudinal variable changes and associations, whereas Grace *et al.* (2021) aimed to evaluate the role of PA and nutrition intervention on BMI and BP among participants already classified as OW at baseline. The cited literature reported on various findings regarding changes in BP values among young people (Agostinis-Sobrinho *et al.*, 2018; Kallerman, 2019; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020). Kallerman (2019) noted a longitudinal increase from childhood (10 years old) into young adulthood (23 years old) in BP among participants classified as obese from Switzerland. Roldão da Silva *et al.* (2020) found a similar increase in

DBP, yet SBP stayed the same among 13.5–16.5-year-old participants over the three-year measurement period. Agostinis-Sobrinho *et al.* (2018), Nqweniso *et al.* (2020) and Grace *et al.* (2021) contrarily found a longitudinal decrease in BP among participants with ages ranging between eight and 16 years old. A possible reason for BP results being different from the current study could be that the participants of Agostinis-Sobrinho *et al.* (2018) showed increasing CRF values. A significant inverse association between the decrease in SBP (SBP decreased among boys from 121.93 ± 14.5 mmHg to 121.38 ± 12.4 mmHg and among girls from 117.32 ± 12.0 mmHg to 113.9 ± 11.9 mmHg) and increase in CRF (number of shuttle runs for boys from 58.09 ± 25.1 at baseline to 71.25 ± 26.1 at follow-up and for girls from 31.05 ± 15.1 at baseline to 38.05 ± 16.8 at follow-up) was noted (Agostinis-Sobrinho *et al.*, 2018). The variation in SBP outcomes between Grace *et al.* (2021) (SBP decreased from 125.9 ± 15.7 mmHg to 115.2 ± 12.4 mmHg), and the current study may largely be attributed to the difference in research aims as explained previously. Whereas the findings of Nqweniso *et al.* (2020) could not explain why hypertensive participants ($n = 99$) became non-hypertensive ($n = 91$) while CRF and sports participation also decreased significantly from baseline (2015) to follow-up (2016). Improved CRF levels stimulates improved heart rate and less pressure on the heart and arterial walls, thus decreasing the risk of high BP, whereas the current study had contrasting BP and CRF results (Malina *et al.*, 2004; NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018; Nqweniso *et al.*, 2020).

The total sample's $\dot{V}O_2$ max values decreased minimally from 2013 to 2016. The total sample CRF levels met the healthy CRF foundational level (35 to 47 mL/kg/min) (Ruiz *et al.*, 2014:769). Likewise, longitudinal literature noted a decrease or insignificant change in $\dot{V}O_2$ max levels (Stratton *et al.*, 2007; He *et al.*, 2011; Ruiz *et al.*, 2014; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017; Kallerman, 2019; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020). All the cited literature, except Stratton *et al.* (2007), met the health CRF requirements. During childhood, CRF is anticipated to increase continuously and plateau from about 13–16 years of age (Malina *et al.*, 2004). The growth of fat free mass has a positive influence on CRF, whereas fat mass negatively influences CRF, because of excessive weight that needs to be supported (Malina *et al.*, 2004; Nqweniso *et al.*, 2020). The idea that fat mass negatively influences CRF supports the current results, where OW and obesity increased while CRF only just changed, and similarly supports findings from He *et al.* (2011), Agostinis-Sobrinho *et al.* (2018) and Nqweniso *et al.* (2020). The groups classified as OW and obese performed poorer in CRF, where the normal weight groups had better CRF results (He *et al.*, 2011; Agostinis-Sobrinho *et al.*, 2018; Nqweniso *et al.*, 2020).

According to sex, the longitudinal BC results showed that the girls' BMI and BF% values increased like the total sample, yet the boys' BMI values increased whereas BF% decreased insignificantly. Healthy, standard growth should be expected in boys and girls from seven to 13 years of age and includes an increase of BMI and BF% within specific age and sex cut-off guidelines (Malina *et al.*, 2004). Longitudinal literature has found

similar results, where BMI and BF% increased among boys and girls (Sinaiko *et al.*, 1999; Stratton *et al.*, 2007; Pienaar, 2015; Castro-Piñero *et al.*, 2017; Monyeki, K.D., *et al.*, 2017).

The SBP and DBP indicated an increase, regardless of sex, over the three-year period. According to Malina (2004) once bradycardia begins during infancy, boy's and girl's BP gradually rises along with growth. Variation of BP increase between boys and girls occurs around 10 years of age when boys show greater SBP increase than girls, yet DBP increase shows no sex difference (Malina *et al.*, 2004). The current sex-related BP findings agreed with previous longitudinal literature (Castro-Piñero *et al.*, 2017). However, Agostinis-Sobrinho *et al.* (2018) noted the longitudinal decline in SBP and DBP among boys and girls. The literature's reduction in BP may be a result of participants' improved CRF levels, where the outcome is beneficial for the cardiovascular (CV) system (Malina *et al.*, 2004; NHBPEP, 2005; Agostinis-Sobrinho *et al.*, 2018).

Results of the boys and girls showed insignificant increase of $\dot{V}O_2$ max from 10–13-years-old. The girls $\dot{V}O_2$ max values were within the CRF health standards in 2013 and 2016 (standards for girls between 35–42 mL/kg/min), yet the boys met the standards in 2013 but not in 2016 (standard for boys between 40–47 mL/kg/min) (Ruiz *et al.*, 2014). According to Malina *et al.* (2004), CRF is expected to increase linearly in boys until 16 years, while girls' CRF should increase until 13 years then plateau thereafter. However, the current results indicated that boys and girls barely improved their CRF levels over three years. A reason that may explain this insignificant increase can be the increase in fat mass (OW and obesity), adding to the total mass that the child must carry, which negatively influences CRF levels to plateau among boys and girls (Malina *et al.*, 2004). Longitudinal literature similarly noted insignificant changes in $\dot{V}O_2$ max amid boys and girls (Stratton *et al.*, 2007; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017). The CRF standards were not met by the boys and girls in the available literature (Stratton *et al.*, 2007; Ruiz *et al.*, 2014; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017). The longitudinal findings of Agostinis-Sobrinho *et al.* (2018) contrarily showed that the boys and girls increased their CRF levels. A likely mitigating explanation for the current CRF outcome and Agostinis-Sobrinho *et al.* (2018) results differing, could be the range of participants' age. Agostinis-Sobrinho *et al.* (2018) included participants with an older age range (12–18 years) who have developmentally higher CRF levels according to Malina *et al.* (2004).

The tracking coefficients for body composition, blood pressure and $\dot{V}O_2$ max (Eta)

The total sample's main results showed moderate effects for the longitudinal changes in BMI and BF% for the sample and among the boys and girls, as well as in BF% among girls. Literature similarly found a practical, yet large effect for BMI (Nqweniso *et al.*, 2020). Small practical effects for the changes in SBP and DBP were noted. Nqweniso *et al.* (2020) found an effect of $\eta^2 = 0.274$ for BP among initially non-hypertensive participants when considering CRF. A small effect for CRF changes was observed over the three-year period; whereas

Nqweniso *et al.* (2020) noted a significantly large effect for CRF when considering BMI categories of participants. The effect size results according to sex showed differences in BC, BP and CRF.

The current study showed significantly high tracking coefficients for the BC variables' BMI and BF% among the total sample, boys and girls. Sinaiko *et al.* (1999) and Pienaar (2015) likewise noted tracking correlation for BC, whereas Monyeki, K.D., *et al.* (2017) found significant tracking of abdominal obesity. Moderate tracking correlation was found for SBP among the total sample, boys and girls, as well as for girls DBP, whereas the total sample and boys DBP results showed a low correlation. The moderate to low tracking for BP can be explained through the influence that growth has on the CV system and more specifically on BP (Malina *et al.*, 2004). High and moderate tracking was noted in $\dot{V}O_2$ max for the total sample and among boys and girls, respectively, over the three-year period.

The relationship of changes in body composition, blood pressure and $\dot{V}O_2$ max

The total sample's results showed that BC components, namely BMI, Σ SF, and BF% are moderately and inversely related to $\dot{V}O_2$ max or CRF from 2013 to 2016. Several studies have similarly found long-term inverse associations between CRF and BC (Stratton *et al.*, 2007; He *et al.*, 2011; Palomäki *et al.*, 2015; Castro-Piñero *et al.*, 2017; Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020). These associations may be clarified by the negative influence that high fat mass and a larger total mass has on boys' and girls' CRF levels (Malina *et al.*, 2004; Palomäki *et al.*, 2015; Nqweniso *et al.*, 2020). Young people classified as OW and obese need to carry more weight during PA resulting in them fatiguing sooner than young people with lower total body mass (Malina *et al.*, 2004; He *et al.*, 2011; Palomäki *et al.*, 2015; Agostinis-Sobrinho *et al.*, 2018; Nqweniso *et al.*, 2020). The boys' BP results show moderate longitudinal relationships with BC variables of BMI, BF% and Σ SF.

The changes in BMI and BF% had high significant correlations. Literature supported the significant correlations of change in BMI (Stratton *et al.*, 2007; Nqweniso *et al.*, 2020). According to our results, SBP change has a medium correlation and DBP shows a low correlation. Nqweniso *et al.* (2020) found no longitudinal significant correlation for BP among the participants. The total sample's $\dot{V}O_2$ max values indicated a high significant correlation from 2013 to 2016. The significant correlation in CRF changes were similarly found in literature (Stratton *et al.*, 2007; Castro-Piñero *et al.*, 2017; Nqweniso *et al.*, 2020).

According to sex, the longitudinal changes in BMI and BF% had high significant correlations among boys and girls between the baseline and follow-up, which agrees with findings from Stratton *et al.* (2007). The change in SBP among boys and girls had medium significant correlations, whereas the change in DBP among boys had a low significant correlation in the three-year period. The boys' and girls' results showed medium significant correlations for $\dot{V}O_2$ max changes from 10–13-years-old. Stratton *et al.* (2007) and Castro-Piñero

et al. (2017) similarly noted a positive relationship between CRF level at baseline and at follow-up among boys and girls.

The age and sex adjusted regression analysis indicated negative and significant associations between change in $\dot{V}O_2$ max with changes in BMI and BF% among boys and girls from 2013 to 2016. The current findings are consistent with longitudinal literature (Stratton *et al.*, 2007; He *et al.*, 2011; Castro-Piñero *et al.*, 2017; Grace *et al.*, 2021).

The regression analysis adjusted for age and sex indicated that BMI change was significantly related to change in SBP among boys and among girls. These findings are consistent with longitudinal literature's findings, yet literature found the association of SBP and DBP with BC changes among both sexes (Sinaiko *et al.*, 1999; Agostinis-Sobrinho *et al.*, 2018; Roldão da Silva *et al.*, 2020). Agostinis-Sobrinho *et al.* (2018) observed how the association between SBP and CRF was influenced by BC; when the initial age and sex adjusted analysis was adjusted for WC as well, the association between SBP and CRF became non-significant.

When adjusted for age and sex, SBP change and DBP change was significantly correlated from 2013 to 2016. Additionally, non-significant associations were found between changes in DBP and BMI, BP and BF%, as well as BP and $\dot{V}O_2$ max. Several studies also found non-significant inverse association between changes in BP and CRF when regression analyses were corrected for likely confounders (Roldão da Silva *et al.*, 2020; Nqweniso *et al.*, 2020).

The age adjusted standardised regression coefficient results indicated that changes in BP (SBP and DBP) were significantly inversely associated with the change in $\dot{V}O_2$ max among boys and girls over three years. Agostinis-Sobrinho *et al.* (2018) likewise noted a significant inverse association between longitudinal changes in CRF and SBP when the regression analysis was adjusted for age, sex and WC among the total sample, yet the association was not observed according to sex.

4.5 LIMITATIONS AND RECOMMENDATIONS

Contributing strengths toward this study are the longitudinal design, the relatively large sample and that consistent data measurements were taken by trained post-graduate students and researchers rather than relying on participants' self-reported information.

Although all efforts were made to maximise the outcomes of this study, the following limitations were identified. Growth, development and maturation; environmental elements; parental roles; SES; psychological impact as well as dietary choices are examples of important life-style factors that were not included for discussion, yet that influence changes in obesity and HTN, as well as CRF levels among youth (Malina *et al.*,

2004; Monyeki, M.A., *et al.*, 2017; Pazin *et al.*, 2017; Agostinis-Sobrinho *et al.*, 2018). The current study aimed to find associations between changes in CRF and changes in obesity and HTN. Yet, to investigate additional variables will be beneficial, for example, SES, psychological impacts or dietary choices, especially among South African young people. For a clearer understanding of how CRF, obesity and HTN are associated, and which other life-style factors influence the current variables, we recommend future research to investigate additional variables.

As this study has shown that CRF, BC and BP are associated in 10–13-year-old South African school attending adolescents of the NWP, we also recommend that further similar research be done to confirm or counter our findings. Additionally, health professionals should observe the BC, CRF and BP changes regularly with the goal to maintain or improve health status of young people. If a child or adolescent's health status needs to be improved, health care providers should encourage long term habits of sufficient PA to improve the child or adolescent's CRF level and BC.

4.6 CHAPTER CONCLUSION

The aim was to determine associations between changes in obesity, HTN and CRF in South African adolescents from the NWP over three years. It was evident that increases in BC had negative and significant influences on changes in CRF, letting it decrease insignificantly, and significantly influenced changes in BP to increase among 10–13-year-old South African adolescents over three years. Adjusted for sex and age, change in CRF is inversely associated with changes in BC and with changes in BP among the boys and girls. Thus, with these findings in mind, it is important to implement health improvement recommendations for youth to maintain their BC and CRF levels, to avoid CV risks factors like obesity and HTN, and to prevent life-long chronic CVDs.

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4.7 REFERENCES

- AGOSTINIS-SOBRINHO, C.; RUIZ, J.R.; MOREIRA, C.; ABREU, S.; LOPES, L.; OLIVEIRA-SANTOS, J.; MOTA, J. & SANTOS, R. (2018). Cardiorespiratory fitness and blood pressure: a longitudinal analysis. *Journal of Paediatrics*, 192(January): 130–135.
- AWOTIDEBE, A.; MONYEKI, M.A.; MOSS, S.J.; STRYDOM, G.L.; ARMSTRONG, M. & KEMPER, H.C.G. (2016). Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of South African adolescents: the PAHL Study. *Journal of Human Hypertension*, 2016(30): 245–251.
- CASTRO-PIÑERO, J.; PEREZ-BEY, A.; SEGURA-JIMÉNEZ, V.; APARICIO, V.A.; GÓMEZ-MARTÍNEZ, S.; IZQUIERDO-GOMEZ, R.; MARCOS, A. & RUIZ, J.R. (2017). Cardiorespiratory fitness cut-off points for early detection of present and future cardiovascular risk in children: a 2-year follow-up study. *Mayo Clinic Proceedings*, 92(12): 1753–1762.
- CHUNGAG, A.; TATA, C. M.; SEWANI-RUSIKE, C. R.; NEL, W. & NKEH-CHUNGAG, B. N. (2019). Ellirras longitudinal study 2017: Association of hypertension with increasing levels of adiposity in 10- to 14-year-old boys and girls in the Eastern Cape (ELS 31). *Cardiovascular Journal of Africa*, 30(5): 258–261.
- COHEN, E.; BERNARD, J.Y.; PONTY, A.; NDAO, A.; AMOUGOU, N.; SAID-MOHAMED, R. & PASQUET, P. 2015. Development and validation of the body size scale for assessing body weight perception in African populations. *Public Library of Science*, 10(11): 1–14.
- COLE, T.J.; BELLIZZI, M.C.; FLEGAL, K.M. & DIETZ, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal*, 320(7244): 1–6.
- GRACE, J.; BIGGS, C.; NAICKER, A. & MOSS, S. 2021. Effect of physical activity and nutrition education on body mass index, blood pressure and biochemical variables in overweight and obese adolescents. *Annals of Global Health*, 87(1): 1–13.
- HE, Q.; WONG, T.; DU, L.; JIANG, Z.; YU, T.I.; QIU, H.; GAO, Y.; LIU, W. & WU, J. (2011). Physical activity, cardiorespiratory fitness, and obesity among Chinese children. *Preventative Medicine*, 52(2011): 109–113.
- IBM CORPORATION. (2019). IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corporation.
- KALLERMAN, P.H. (2019). Cardiovascular health in children and adolescents with obesity: prevalence, prediction and supervised exercise. Unpublished doctoral dissertation. Stockholm, Sweden: Karolinska Institute.
- KEMP, C.; PIENAAR, A.E. & SCHUTTE, A.E. (2017). The prevalence of hypertension and the relationship with body composition in Grade 1 learners in the North West Province of South Africa. *South African Journal of Sports Medicine*, 23(4): 117–123.

- MAHAR, M.T.; GUERIERI, A.M.; HANNA, M.S. & KEMBLE, C.D. (2011). Estimation of aerobic fitness from 20-m multistage shuttle run test performance. *American Journal of Preventive Medicine*, 41(4S2): 117–123.
- MALINA, R.M.; BOUCHARD, C. & BAR-OR, O. (2004). *Growth, maturation and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.
- MONYEKI, K.D.; MATSHIPI, M. & MONYEKI, M.S. (2017). Prevalence of abdominal obesity among rural South African children over time: Ellisras Longitudinal Study. *African Journal for Physical Activity and Health Sciences*, 23(3): 416–430.
- MONYEKI, M.A.; AWOTIDEBE, A.; MOSS, S.J.; SPARKS, M.; WUSHE, S.; COETZEE, B.; PIENAAR, C.; BRUWER, E.; DE RIDDER, H.J.; SWANEPOEL, M.; DU TOIT, D.; GLAPA, A.; KEMPER, H.C.G. & TWISK, J.W.R. (2017). Relationship between physical activity, body fatness and cardiorespiratory fitness in South African adolescents: The PAHL Study. *African Journal for Physical Activity and Health Sciences*, 23(1.2): 111–128.
- NATIONAL HIGH BLOOD PRESSURE EDUCATION PROGRAM (NHBPEP). (2005). *The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents*, (4th ed.). Philadelphia, PA: U.S. U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, National High Blood Pressure Education Program.
- NQWENISO, S.; WALTER, C.; DU RANDT, R.; AERTS, A.; ADAMS, L.; DEGEN, J.; GALL, S.; GANI, Z.; JOUBERT, N.; MÜLLER, I.; SMITH, D.; SEELIG, H.; STEINMANN, P.; PROBST-HENSH, N.; UTZINGER, J.; PÜHSE, U. & GERBER, M. (2020). Prevention of overweight and hypertension through cardiorespiratory fitness and extracurricular sport participation among South African schoolchildren. *Sustainability*, 12(16): 1–16.
- PAZIN, D.C.; ROSANELI, C.F.; OLANDOSKI, M.; NETTO DE OLIVEIRA, E.R.; PELLEGRINO BAENA, C.; FIGUEREDO, A.S.; DA LUZ KAESTNER, T.L.; GUAARITA-SOUZA, L. & FARIA-NETO, J.R. (2017). Waist circumference is associated with blood pressure in children with normal body mass index: a cross-sectional analysis of 3,417 schoolchildren. *Brazilian Archives of Cardiology*, 109(6): 509–515.
- PIENAAR, A.E. (2015). Prevalence of overweight and obesity among primary schoolchildren in a developing country: NW-CHILD longitudinal data of 6–9-yr-old children in South Africa. *Biomedical Central Obesity*, 2(2): 1–10.
- PALOMÄKI, S.; HEIKINARO-JOHANSSON, P. & HUOTARI, P. (2015). Cardiorespiratory performance and physical activity in normal weight and overweight Finnish adolescents from 2003 to 2010. *Journal of Sports Sciences*. 33(6): 588–596.
- PLOWMAN, S.A. & MEREDITH, M.D. (2013). *Fitnessgram/Activitygram reference guide*. (4th ed.). Dallas, TX: The Cooper Institute.

- ROLDÃO DA SILVA, P.; CASTILHO DOS SANTOS, G.; MARCIO DA SILVA, J.; FERREIRA DE FARIA, W.; GONÇALVES DE OLIVEIRA, R. & STABELINI NETO, A. (2020). Health-related physical fitness indicators and clustered cardiometabolic risk factors in adolescents: A longitudinal study. *Journal of Exercise Science and Fitness*, 18(3): 162–167.
- RUIZ, J.R.; HUYBRECHTS, I.; CUENCA-GARCIA, M.; ARTERO, E.G.; LABAYEN, I.; MEIRHAEGHE, A.; VICENTE-RODRIGUEZ, G.; POLITO, A.; MANIOS, Y.; GONZALEZ-GOSS, M.; MARCOS, A.; WIDHALM, K.; MOLNAR, D.; KAFATOR, A.; SJÖSTRÖM, M.; MORENO, L.A.; CASTILLO, M.J. & ORTEGA, F.B. (2015). Cardiorespiratory fitness and ideal cardiovascular health in European adolescents. *Heart Cardiac Risk Factors and Prevention*, 101(10): 766–773.
- SINAIKO, A.R.; DONAHUE, R.P.; JACOBS, D.R. & PRINEAS, R.J. (1999). Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults the Minneapolis children's blood pressure study. *Circulation*, 1999(99): 1471–1476.
- SLAUGHTER, M.H.; LOHMAN, T.G.; BOILEAU, R.A.; HORSWILL, C.A.; STILLMAN, R.J.; VAN LOAN, M.D. & BEMBEN, D.A. (1988). Skinfold equations for estimations of body fatness in children and youth. *Human Biology*, 60(5): 709–723.
- STRATTON, G.; CANOY, D.; BODDY, L.M.; TAYLOR, S.R.; HACKETT, A.F. & BUCHAN, I.E. (2007). Cardiorespiratory fitness and body mass index of 9–11-year-old English children: A serial cross-sectional study from 1998 to 2004. *International Journal of Obesity*, 31(7): 1172–1178.
- STEWART, A.; MARFELL-JONES, M.; OLDS, T. & DE RIDDER, H. (2011). *International Standards for anthropometric assessment*. (3rd ed). Lower Hutt: The international society for the advancement of Kinanthropometry.

CHAPTER FIVE

CHAPTER 5: SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 SUMMARY

The aim of this chapter was to summarise the dissertation as discussed in the preceding chapters, followed by the main conclusions, limitations and recommendations of this study.

Chapter One provided an outline of the identified problem being that children and adolescents' cardiorespiratory fitness (CRF) levels are decreasing while obesity and hypertension (HTN) are increasing across many countries and in SA. The cited literature indicated associations between poor CRF levels and increased risk for obesity and HTN. Children classified as obese are at three times higher risk for comorbidities like HTN than children classified as non-obese. There is limited research on the relationships between obesity, HTN and CRF levels regarding school attending adolescents living in the North West Province (NWP) of SA. Therefore, the research question for this study was: What are the changes in cardiorespiratory fitness, obesity and HTN in 10–13-year-old school attending adolescents living in the NWP of SA, and do the changes relate to each other? To answer this question accurately, related literature about CRF, obesity and HTN among children and adolescents needs to be discussed.

Chapter Two included a literature review related to the objectives of this study. The literature review discussed CRF, obesity and HTN as the primary topics. The topics were grouped according to international and national prevalence; their criteria or guidelines; measurement tests; causes and negative effects of HTN, obesity and CRF.

Firstly, this chapter discussed literature on CRF. Longitudinal international CRF levels ranged somewhat below and within the health criterion-referenced standards. However, longitudinal South African literature from the NWP tracking adolescent's CRF levels is scarce. The South African cross-sectional CRF level ranged below the international range and well below the health criterion-referenced standards. Regarding sex, South African boys indicated higher CRF levels, which ranged somewhat below and within the health criterion-referenced standards. Whereas South African girls showed lower levels, which did not meet the health standards. The outcomes of satisfactory CRF levels (35–47 mL/kg/min) are far more valuable than the negative effects of poor CRF levels. Poor CRF levels places a child at higher risk for cardiovascular disease (CVD), which often results in the child becoming or remaining hypertensive and obese.

Obesity, HTN, diabetes and dyslipidaemia are the four primary risk factors of CVD. If a medical professional diagnoses a child with two risk factors, the child is considered as having a cluster of CVD risk factors. The two risk factors discussed in Chapter Two were HTN and obesity.

Secondly, literature regarding obesity was discussed. International and South African literature found longitudinal increases in overweight (OW) and obesity prevalence amongst children and adolescents. Yet, South African youth from specific provinces have shown a higher prevalence of OW and obesity. Girls displayed a higher obesity prevalence than boys in South Africa (SA) and internationally. Society, education, the environment, the role of family, menarche, physical inactivity and dietary choices were all factors identified as causes of excessive weight gain among children and adolescents. Obesity often results in harsh negative effects, which were discussed according to grouped categories, such as pulmonary, emotional, social, digestive, and cardiovascular (CV) comorbidities like HTN.

Third, the literature review discussed studies regarding HTN in children and adolescents. The international, longitudinal HTN prevalence showed an increase among youth. The world-wide prevalence ranged higher amongst boys than amongst girls. South African cross-sectional literature from certain provinces, indicated a HTN prevalence lower than the international prevalence, likely due to South African participants living in lower SES areas of a developing country. One study found a longitudinal decrease of HTN prevalence amongst South African adolescents. South African girls had a higher range HTN prevalence than South African boys. Daily habits could be modified to avoid the most common HTN causes, which were poor CRF levels, dietary choices and extra weight gain. The negative effects of HTN were discussed according to CV disturbances, nervous system obstructions, pulmonary illnesses, digestive related diseases and other bodily changes. Hypertension, along with obesity are both known to put a child at higher risk for pre-mature mortality. As gathered from literature, youth's health conditions are deteriorating rapidly. New longitudinal research is necessary to observe whether the CRF, obesity and BP conditions of South African youth from the NWP are improving or worsening.

The NW-CHILD study was the main research project on which Chapters Three and Four were based. The two manuscripts used the research design, measurements and equations briefly described below. During the longitudinal data collection of the main NW-CHILD study, the body composition measurements (BC), CRF levels and blood pressure (BP) values were recorded along with various additional variables. The baseline measurements were taken in 2010, and the first and second follow-up measurements were taken in 2013 (Follow-up measurement point 1 [MP1]) and 2016 (Follow-up measurement point 2 [MP2]), respectively. This study used the data from MP1 and MP2. Body composition values of mass, stature, waist circumference (WC), subscapular and triceps skinfolds were measured, and BP measurements were obtained from participants. Body mass index (BMI) was calculated from an equation to estimate body mass through dividing body mass in

kilograms (kg) by stature in meters (m) squared or $BMI = kg/m^2$. Body fat percentage (BF%) was also calculated through equations that were corrected for maturation and sex. The CRF or maximal oxygen uptake ($\dot{V}O_2 \text{ max}$) estimates were determined using the participant's total laps and the Progressive Aerobic Cardiovascular Endurance Run (PACER) conversion table. From the data collected, this sub-study's objectives were addressed, and the hypotheses were tested. The results of the study have been presented through two research manuscripts, Chapters Three and Four.

Chapter Three was presented in article format, titled “Three-year changes in cardiorespiratory fitness and cardiovascular risk (obesity and hypertension) in 10–13-year-old adolescents: the NW-CHILD study”. This manuscript was submitted to the *South African Journal for Research in Sport, Physical Education and Recreation* for possible publication. This manuscript addressed the first objective, which was to determine the changes in obesity, HTN and CRF in South African adolescents attending school in the NWP over three years. The results showed that significantly more adolescents were classified as OW and obese. Similar increases in OW and obesity were noted in the cited literature (He *et al.*, 2011:111; Nqweniso *et al.*, 2020:11; Sinaiko *et al.*, 1999:1472). Pre-hypertension and HTN declined noticeably, which confirmed the findings of Nqweniso *et al.* (2020). The adolescents' BC and BP increased significantly, but CRF decreased insignificantly over the three-year period. According to Malina *et al.* (2004:186–591), developmental increases in BC, BP and CRF are expected for average growth. Excessive increase in fat mass negatively influences CRF, which may explain the insignificant fitness change (He *et al.*, 2011:110; Malina *et al.*, 2004:53186–591; Nqweniso *et al.*, 2020:7; Palomäki *et al.*, 2015:592; Roldão da Silva *et al.*, 2020:164). Reasons for the increase in obesity may be due to numerous factors (unsatisfactory CRF levels, poor dietary choices, or other life-style habits), yet the decrease in pre-hypertension and HTN is uncertain. For better certainty regarding HTN changes, further research is necessary to determine associations between HTN, CRF and obesity.

Chapter Four has similarly been presented in article format. The manuscript was titled “Associations between cardiorespiratory fitness and two components of cardiovascular risk (obesity and hypertension) from the age of 10–13: the NW-CHILD study”. This manuscript is intended for submission for potential publication in the *South African Journal for Research in Sport, Physical Education and Recreation*. This manuscript chapter addressed the second objective, which was to determine the associations between CRF with BC, and with BP among South African adolescents attending school in the NWP over a three-year period. High tracking coefficients were noted for increases in BMI and BF%. Moderate tracking correlation was found for systolic blood pressure (SBP) increase among the total sample, boys and girls, as well as for the girls' diastolic blood pressure (DBP) increase. The increases in DBP of the total sample and boys showed weak correlations. The insignificant decrease of the total sample's $\dot{V}O_2 \text{ max}$ indicated a high tracking coefficient. Whereas moderate tracking correlations were noted for the non-significant increases in $\dot{V}O_2 \text{ max}$ among boys and girls. Three main relationships were identified between CRF, BC and BP. Firstly, results showed CRF change had

significant negative associations with BMI and BF% changes when corrected for age and sex. These associations correspond with literature where excessive fat mass, that must be carried around during physical activity (PA), decreases one's CRF ability (He *et al.*, 2011:110; Malina *et al.*, 2004:539; Nqweniso *et al.*, 2020:7; Palomäki *et al.*, 2015:592; Roldão da Silva *et al.*, 2020:164). Secondly, significant inverse relationships between BP (SBP and DBP) changes and CRF change were noted during the age adjusted standardised regression analysis. Literature also explained when a child or adolescent exercises to improve their CRF levels, the heart and arterial walls become strengthened and allow for BP to decrease or stabilise, the opposite is similarly true regarding poor CRF levels and an increase in BP (Agostinis-Sobrinho *et al.*, 2018:134; Malina *et al.*, 2004:591). Thirdly, the results further showed significant correlations between BMI and SBP change, as well as between SBP and DBP changes. Literature confirmed the relationships between BMI and SBP change and between SBP and DBP changes (Agostinis-Sobrinho *et al.*, 2018:134; Roldão da Silva *et al.*, 2020:164; Sinaiko *et al.*, 1999:1473). The three main relationships were apparent in Chapter Four as increases in BC negatively influenced CRF to change insignificantly, which influenced BP to increase among adolescents when corrected for age and sex. With better certainty about the relationships between CRF and the two CVD risk factors, obesity and HTN, the study was brought to conclusion.

Chapter Five brings this dissertation to an end with conclusions, limitations and recommendations for future research. The conclusions were written in accordance with the hypotheses set in Chapter One.

5.2 CONCLUSIONS

The conclusions of this dissertation are presented based on the hypotheses testing and findings of this study.

Hypothesis 1 indicated that we will find significant changes in cardiorespiratory fitness to decrease and two CV risk factor components (obesity and hypertension both to increase) from the age of 10–13 years among school attending adolescents living in the North West Province over a three-year period. Overweight and obesity prevalence increased significantly by 6.1% from MP1 to MP2. Pre-hypertension and HTN prevalence, however, decreased considerably (by 7.3% and by 6.7%, respectively) amongst the adolescents. Significant increases ($p < 0.001$) were noted in BC and BP among the adolescents, whereas CRF changed non-significantly from MP1 to MP2. Hypothesis 1 is thus *accepted*.

Hypothesis 2 proposed that we will find statistically significant negative associations between cardiorespiratory fitness and the two CV risk factor components (obesity and hypertension) among South African school attending adolescents from the age of 10–13 years living in the North West Province. When adjusted for sex and age, longitudinal change in CRF was inversely associated with changes in BC among adolescent boys (BMI $\beta = -0.32$ and BF% $\beta = -0.41$) and girls (BMI $\beta = -0.35$ and BF% $\beta = -0.41$), as well as with changes in BP among adolescent boys (SBP $\beta = -0.06$ and DBP $\beta = -0.11$) and girls (SBP $\beta = -0.08$ and DBP $\beta = -0.09$). Therefore, hypothesis 2 was *accepted*.

Conclusion: General Findings

The findings of this study bring new longitudinal information regarding the changes of and associations between CRF and CV risk factors among South African adolescents from the NWP. The results confirm that adolescents' BC, weight classification, BP and HTN are increasing; that CRF decreased insignificantly; and that CRF change has inverse associations with BC and BP changes among boys and girls. This strengthens the awareness that sufficient CRF is important for weight and BP management during childhood to avoid the long-term negative effects of CV risks into adulthood. Literature has similar outcomes among youth indicating the relationship between participating in PA to improve fitness and combatting excessive adipose gain to relieve pressure off the CV system. A vital key for a healthier life is to keep optimal BC and BP values in addition to maintaining healthy CRF standards from as young as 10–13 years old.

Cardiorespiratory fitness should be maintained by allowing youth to have structured and unstructured PA opportunities individually and in groups. Formal and informal events to learn about maintaining BC and BP through positive lifestyle choices (dietary, emotional regulation or exercise) should also be presented to youth. These opportunities need to be available and accessible to all youth from various sources, namely from teachers, family and other practitioners like Kinderkineticists, personal coaches or health care providers. Positive exposure to these opportunities may cultivate an enjoyment for movement by increasing CRF levels, and to improve BC and BP management, allowing youth to practice healthier lifestyle habits. With the current findings of obesity and HTN increasing, as well as inverse associations between stagnant CRF levels with BC and BP increases, South African adolescents from the NWP need urgent PA intervention and intentional exposure to healthy lifestyle education. When a practitioner works with a youth who has poor CRF or can be classified as OW or obese, it is important to intervene and provide these learning opportunities as soon as possible to avoid further health decline. The intervention and learning opportunities will help the youth make better choices from which they may reap benefits of optimal CRF levels, BC and BP values.

Sufficient maintenance of CRF levels improves cognition; reduces depression and stress; and lowers the risk for obesity, CVD (by 33%), HTN (by 32%), type two diabetes (by 40%) and stroke (by 31%) (Roldão da Silva *et al.*, 2020:166). Youth benefit greatly by maintaining BC and BP. Several main benefits are that they may experience improved social and emotional well-being; lower risk for CV and pulmonary disease; improved digestion; better hormonal functioning; and better overall quality of life. The greatest benefit is the reduced risk of premature mortality.

The current findings are a stepping stone for childhood health related practitioners, informing readers that prompt CRF, BC and BP interventions during youth will benefit the physical growth and quality of life of an individual from childhood, throughout adulthood. The positive impact these benefits will have on youth may motivate youth to increase sports participation, which sets an example for their families to adopt a lifestyle to

better health. Additionally, society profits in the long-term to have healthier, happier individuals and families with less stress and physical diseases. A healthier population could reduce several societal problems we face today and avoid numerous future world-wide health complications. Practitioners or people knowledgeable in physical intervention for obesity and fitness should pay attention to these associations and adequately assess CRF, as well as monitor BC and BP frequently among youths. The assessment goal should be to maintain or improve youth's health status according to scientifically approved guidelines. More health practitioners should be employed or involved at schools to help the youth at school. Moreover, families, teachers and experts have the responsibility to provide youth with adequate opportunities to improve their fitness and physical health as well as to encourage the young ones to participate in those opportunities. In turn, this encouragement nurtures an enjoyment and for youth to strive towards better fitness, and weight management to reap the benefits of healthy life-long habits. Lastly, it is important to understand and act accordingly regarding the associations between changes in CRF, BC and BP among youth to help South African children and adolescents avoid adult illnesses and pre-mature mortality.

5.3 STRENGTHS, LIMITATIONS AND RECOMMENDATIONS

5.3.1 Strengths

Three main aspects were identified, which strengthen this study and three limitations were identified for which recommendations are advised.

- ✓ The longitudinal study design was identified as a strength. The design allowed for observations of changes in BC, BP, CRF and several other variables, as well as to observe whether there were significant associations between the variable changes over a three-year period.
- ✓ The study has a decent (not absolute) generalisability because of the large sample of 558 randomly selected adolescent participants, which was also considered as a contributing strength.
- ✓ Additionally, reliable CRF, BC and BP measurements were taken according to standard procedures by trained post-graduate students rather than relying on participants' self-reported information.

5.3.2 Limitations

All efforts were made during the planning and conducting of this study to maximise the outcomes of this study. However, three main limitations were identified that need to be considered during interpretation of this study's findings.

- ✓ The study was conducted in primary schools from four of the eight school districts in the NWP, one of SA's nine provinces. Therefore, the current findings are a limited reflection of adolescents participating in the NW-CHILD study. The findings cannot be a generalisation of the associations between changes in CRF, BC and BP of all learners in the NWP nor among all South African adolescents.

- ✓ The drop-out challenge of participants, being beyond our control, may have influenced significance and was mainly due to participants relocating to different schools, non-consent from parents, or absence from school during measurement days. In 2010, during the baseline measurements, 816 participants were involved. In 2013 during MP1 there were initially 574 participants, presenting a drop-out of 242 participants between 2010–2013. Therefore, new participants were randomly selected to make the new total sample of 864 participants for the first measurement period. In 2016, during MP2, the initial sample size was 661 (drop-out of 203 participants from 2013 to 2016), yet for reasons named above, a further 103 participants dropped out and the final total sample of the second measurement period included was 558 participants.
- ✓ It is well known that obesity and HTN are influenced by CRF as well as other risk factors. Our results of obesity and HTN may have been influenced by these other factors, namely growth, maturation, dietary choices, education, environmental factors and more.
- ✓ The 20m PACER may be considered as a limitation, as the participants are required to run as many laps as possible while the time to run the lap becomes shorter. The participants thus require a lot of motivation to keep running as far as possible and as fast as necessary.

5.3.3 Future Research

Based on the limitations discussed, we recommend future research to consider the subsequent points to confirm or counter the current findings.

- ✓ For better comprehensive generalisations of South Africa's youth and their health, we recommend future research to investigate what the longitudinal changes in and associations between CRF, obesity and HTN will be among children and adolescents from more regions and provinces within South Africa.
- ✓ Even though the drop-out challenge was corrected to include new participants and the total sample allowed for sufficient significance in the analysis, it is recommended that future longitudinal research recruit a larger sample size to investigate whether the changes and associative results are consistent among more participants.
- ✓ We further recommend future research to observe which other factors have strong influences on CRF, obesity and HTN and to investigate how these variables are influenced among South African adolescents.
- ✓ Researchers should provide consistent and plenty of external motivation for the participants, that the boys and girls may do their best to run at their best. For future research, the influence of motivation on total PACER laps could also be investigated.

Let us take the stand to help our youth avoid adult diseases by guiding them to make better choices for greater health and joyful growth.

5.4 REFERENCES

- Agostinis-Sobrinho, C., Ruiz, J.R., Moreira, C., Abreu, S., Lopes, L., Oliveira-Santos, J., ... Santos, R. 2018. Cardiorespiratory fitness and blood pressure: a longitudinal analysis. *Journal of Paediatrics*, 192(January):130–135.
- He, Q., Wong, T., Du, L., Jiang, Z., Yu, T.I., Qiu, H., ... & Wu, J. 2011. Physical activity, cardiorespiratory fitness, and obesity among Chinese children. *Preventative Medicine*, 52(2011):109–113.
- Malina, R.M., Bouchard, C. & Bar-Or, O. (2004). *Growth, maturation and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.
- Nqweniso, S., Walter, C., du Randt, R., Aerts, A., Adams, L., Degen, J., ... Gerber, M. 2020. Prevention of overweight and hypertension through cardiorespiratory fitness and extracurricular sport participation among South African schoolchildren. *Sustainability*, 12(16): 1–16.
- Palomäki, S., Heikinaro-Johansson, P. & Huotari, P. 2015. Cardiorespiratory performance and physical activity in normal weight and overweight Finnish adolescents from 2003 to 2010. *Journal of Sports Sciences*, 33(6):588–596.
- Roldão da Silva, P., Castilho dos Santos, G., Marcio da Silva, J., Ferreira de Farai, W., Gonçalves de Oliveira, R. & Stateline Neto, A. 2020. Health-related physical fitness indicators and clustered cardiometabolic risk factors in adolescents: A longitudinal study. *Journal of Exercise Science and Fitness*, 18(3):162–167.
- Sinaiko, A.R., Donahue, R.P., Jacobs, D.R. & Prineas, R.J. 1999. Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults the Minneapolis children's blood pressure study. *Circulation*, 1999(99):1471-1476.

ANNEXURES

Annexures

Annexure A:

ETHICS



NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT

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Institutional Research Ethics Regulatory Committee

Tel +27 18 299 4849
Email Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF PROJECT

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

Project title: A Longitudinal analysis of health risk factors, growth and development among 7-13-year-old children.

Project Leader: Prof AE Pienaar

Ethics number:

N W U - 0 0 0 7 0 - 0 9 - A 1

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

Approval date: 2015-10-12

Expiry date: 2017-12-15

Risk:

**Children
Category 3**

Special conditions of the approval (if any): None

General conditions:

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

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

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

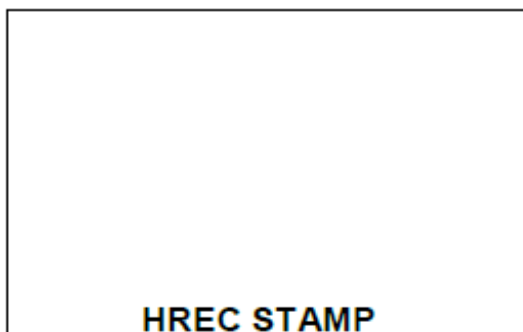
Yours sincerely

Linda du Plessis

Digitally signed by Linda du Plessis
DN: cn=Linda du Plessis, o=NWU,
ou=Vaal Triangle Campus,
email=Linda.duplessis@nwu.ac.za,
c=ZA
Date: 2015.10.16 10:03:26 +0200

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)



PARTICIPANT INFORMATION LEAFLET AND PARENTAL PERMISSION FORM FOR 12 TO 13-YEAR OLD PRIMARY SCHOOL CHILDREN IN THE NORTH-WEST PROVINCE

TITLE OF THE RESEARCH PROJECT:

A longitudinal analysis of health risk factors, growth and development among 7-13-year-old children: NW-CHILD study. ETHICS NUMBER: NWU-00070-09-A1

PRINCIPAL INVESTIGATOR:

Prof Anita Pienaar

ADDRESS:

North-West University
Faculty of Health Sciences
Private bag X6001
Potchefstroom
2520

CONTACT NUMBER:

(018) 299 1796

Your child is invited to take part in the final measurements of the on-going research project, namely the NW-CHILD Study, A longitudinal analysis of health risk factors, growth and development among 7-13-year-old children. You have already **consented** for your child to be part of this NW-CHILD longitudinal study that started in 2010 when he or she were in grade 1 but we need your on-going/re-consent due to the ongoing nature of the research. 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 your child will be involved. Also, your child's participation is entirely voluntary and he/she is free to decline to participate. If you say no, this will not affect your child's negatively in any way whatsoever.

Your child is also free to withdraw from the study at any point, even if he/she initially agrees 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-00070-09-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.

What is this research study all about?

- ☛ This final part of this study will be conducted again in the 20 primary schools that were selected randomly for the study in the North-West Province of South Africa in 2010 and will involve measurements that will determine the on-going effects of health risk factors over a period of 6 years in 7-13 year old children. It will be investigated *by experienced health researchers trained in Kinderkinetics*. 675 participants will be included in this final measurement of the study.
- ☛ The main objectives of this study were to determine the prevalence of and the relationship between health and developmental risk factors such as overweight and obesity, blood pressure, underweight, sport skills, motor proficiency and physical activity and fitness barriers identified among 7-year-old children, 3-years later at the age of 10-years, and again 7 years later at the age of 12-13-years.
- ☛ The long term effects that the above health risk factors will have on children's physical activity behaviour and scholastic success will be determined but more importantly strategies will be developed to improve identified health enhancing, sport promoting and academic restricting factors that influence the quality of life and optimal development of 6- to 13-year-old children. The following measurements will be taken to evaluate these risk factors: Growth measurements that will be taken in a private area will include weight, height, three skinfolds, one on the back of the arm, one on the back under the shoulder blade and one on the lower leg (calf), and upper arm and waist circumference. Blood pressure and physical activity and nutrition questionnaires will be completed in the school hall while motor proficiency and physical fitness testing will be done in a classroom or on the sports grounds of the school. Perceptual-motor proficiency and physical fitness status will be measured by using different field tests such as balancing on one leg, catching, kicking or dribbling a ball, or running a specified distance.

Why have your child been invited to participate?

- Your child has been invited to participate because he/she is attending a school in the North-West province where the research is going to be conducted and you have already consented for your child to be part of this NW-CHILD on-going study that started in 2010 when he or she were in grade 1 or grade 4 during the first follow up measurements.
- ***Your child have also complied with the following inclusion criteria:***

Your child was part of the study in 2010 and or in 2013 and because this study is based on follow-up measurements your child is now invited to participate again in the final measurements.

- Your child will be excluded from the study if he or she cannot move in a normal manner because of any physical problems which might be a barrier for him/her to do his/her best.
- He/she will also be withdrawn from the study in the instance of injury or illness.
- Your child will be excluded if you do not submit his/her informed consent form before the testing procedures commence.

What will your child's responsibilities be?

- It will be expected of your child to participate in all the measurements of the study. The measurements will be done during school hours on one morning and time as approved and arranged by the headmaster. The testing will start at 8:00 in the morning until all testing are completed which can take the whole morning but your child will be send back to his/her class as soon as he/she is finished. Your child will be allowed to have his/her lunch box from home during the official break times of the school.

Will your child benefit from taking part in this research?

- The direct benefits to the child will be that the school will receive feedback with regard to the testing of each of the children in the form of guidelines, which you will be able to obtain from the school.
- If you are interested, we can supply you with your child's testing information on request.

Are there risks involved in taking part in this research?

- The risks in this study are minimal, such as a short disruption of class time to measure the child's health and movement status. Teachers are aware of the measurements that will take place and they will make sure that your child receives the necessary learning materials that they have missed during the measurements.
- The measurements that the child will be involved in are not dangerous and are easy to perform and children normally enjoy taking part in this kind of testing.
- I am one of the Faculty of Health Sciences' established and skilled health researchers with significant experience in conducting research in the community.
- All the researchers that are involved in this research are also trained to work with children and will be able to adapt to the developmental needs of the children.

The benefits outweighs the risk

- We consider the benefits of becoming involved in this research, to outweigh the risks, which is minimal, such as a short disruption of class time, which justifies the research project. The direct benefits to a child are that his/her results can be made available to him/her that can be used to show them their strengths or to improve their shortcomings. The indirect benefits of this research are that it will provide researchers with knowledge to develop strategies to minimize health risks that can influence the health and well-being of children negatively.

What will happen in the unlikely event of some form of discomfort occurring as a direct result of your child taking part in this research study?

No risks or harm are anticipated as a result of this research. However, if your child brings it to the attention of the researchers' that he or she has some form of discomfort, such as tiredness we will immediately try to solve the problem or ask a teacher to assist us in solving the problem. If the language of your child presents a problem for him/her to understand the instructions, a translator or a teacher will assist the researcher to explain the instructions to your child.

- Should you have the need for further discussions after the data collection an opportunity will be arranged for you to speak to me about your child's results or to contact me in person at the included contact details.

Who will have access to the data?

We assure you that only the researchers will have access to the information that will be obtained from your child, and we assure you of the confidentiality of all the information that are obtained from your child who will only be identified by a subject number. Data 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.

What will happen with the data/samples?

This is an on-going study that will end in 2016 and the collected data will be transferred and stored on a computer at the Potchefstroom Campus of the North-West University from where it will be analysed by the researchers. The results will be published in the form of post graduate studies and in scientific articles. The hard copies of the data will be destroyed after seven years by means of a paper shredder. We request that we can use the data of your child in future studies that are planned for post graduate studies.

Will your child be paid to take part in this study and are there any costs involved? No remuneration or costs will be involved in the project. Children will receive a snack on the day of testing as a sign of gratitude for their participation.

Is there anything else that you should know or do?

- You can contact Prof Anita Pienaar at (018) 299 1796 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.
- You will receive a copy of this information and consent form for your own records.

How will you know about the findings?

The school will receive feedback with regard to the testing of each of the children in the form of guidelines, which you will be able to obtain from the school. You may also attend the testing, if you want to.

Declaration by parent/legal guardian

By signing below, I agree for my son/daughter
..... to take part in a research study
entitled: "A longitudinal analysis of health risk factors, growth and development among 7-13
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 to both 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 and that my child has not been
pressurised to take part.

My child may choose to leave the study at any time and will not be penalised or
prejudiced in any way.

My child may be asked to leave the study before it has finished, if the researcher
feels it is in his or her best interests, or if he or she does not follow the study plan,
as agreed to.

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

.....
Signature of parent/legal guardian

.....
Signature of witness

Declaration by person obtaining consent

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 an interpreter

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

.....
Signature of person containing consent

.....
Signature of witness

Declaration by researcher

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 an interpreter.

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

.....
Signature of researcher

.....
Signature of witness



PARTICIPANT INFORMATION LEAFLET AND ADOLESCENT ASSENT FORM FOR 12 TO 13-YEAR OLD PRIMARY SCHOOL CHILDREN IN THE NORTH-WEST PROVINCE

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REFERENCE NUMBERS:

NWU-00070-09-A1

PRINCIPAL INVESTIGATOR:

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CONTACT NUMBER:

(018) 299 1796

You are invited to take part in the final measurements of the on-going research project, namely the NW-CHILD Study, A longitudinal analysis of health risk factors, growth and development among 7-13-year-old children. You have already agreed through your parents to be part of this NW-CHILD longitudinal study that started in 2010 when you were in grade 1 and you also participated when you were in grade 4 but we need your on-going permission due to the nature of the research to participate in the final measurements that will take place today. Please ask your parent or the researcher any questions about any part of this project that you do not fully understand. It is very important that you are sure that you clearly understand what this research entails and how you will be involved.

Also, your participation is entirely your own decision 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 initially agree to take part.

This study has been looked at by a Committee at the North-West University (NWU-00070-09-A1) which made sure that the study will be conducted according to guidelines which will respect you as a child. This ethics committee can also inspect the research records to make sure that we adhere to these principles.

What is this research study all about?

^(f) This is the final part of this study and children of the same age as you in 20 primary schools in the North-West Province participated in the study since they were in grade 1. We are interested as researchers in factors that can have a negative influence on the health and well-being of children and we want to come up with solutions to improve the health of children. In order to be able to do so we need measurements of the same child at different ages. An example is to see how your length and body mass increased from grade 1 to grade 7 and in what kind of physical activities you choose to participate at different ages. All the measurements will be done by experienced health researchers trained in Kinderkinetics. 675 children from 20 different primary schools who were already part of the study in their grade 1 and or grade 4 years will be invited to take part in this final measurements of the study.

^(g) We as researchers know little about the health status of children in primary schools in South Africa, therefore the main reasons of this study are to get more knowledge about the status and prevalence of and the relationship between health and developmental risk factors such as overweight, blood pressure, sport skills, motor proficiency, physical activity and fitness barriers identified among 7-year-old children, 3 years later at the age of 10- years, and again 3-years later at the age of 12-13 years. You can help us to achieve these goals if you agree to participate in the measurements.

Once we have obtained the measurements we can use the results to see what we can do to improve children's health and sport readiness as we will have a better understanding of things that need to be changed, especially at different ages. We can then make plans to help children to become more active, while we can also give parents and teachers guidance on how to help children to be more active. The following measurements will be taken to evaluate the risk factors that we are interested in: Growth measurements that will be taken in a private area that will include, height, weight, three skinfolds, one on the back of the arm, one on the back under the shoulder blade and one on the lower leg (calf), and upper arm and waist circumferences. Blood pressure will be taken and physical activity and nutrition questionnaires will be completed in the school hall while motor proficiency and physical fitness testing will be done in a classroom or on the sports fields of the school. Perceptual-motor proficiency and physical fitness status will be measured in the school hall or on the sports field by using different field tests such as balancing on one leg, catching, kicking or dribbling a ball, or running a specified distance.

Why have you been invited to participate?

> You have been invited to participate in the measurements because you are attending one of the 20 primary schools in the North-West province where the research is going to be conducted.

You have also complied with the following inclusion criteria:

> You were part of the study in 2010 and or in 2013 and because this study is based on follow-up measurements that are taken on the same child as he or she gets older you are now invited to participate again in this final measurements that will take place today. Your parent gave parental permission for us to invite you to participate in the measurements today.

> You will be withdrawn from the study if you cannot move in a normal manner because of any physical problems which might be a barrier for you to do your best. You will also be withdrawn from the study in the instance of injury or illness.

> You will be excluded if you do not submit your parental permission consent form before the testing procedures commence.

What will your responsibilities be?

> It will be expected of you to participate in the measurements and activities that are appropriate for your age group on the day that the research team visits or school. The measurements will be done during school hours on one morning and time as approved and arranged by your headmaster. The testing will start at 8:00 in the morning until all testing are completed which can take the whole morning, but you will be send back to your class as soon as you are finished with all the measurements. You will be allowed to have your lunch box from home during the official break times of the school.

Will you benefit from taking part in this research?

> Your school will receive feedback with regard to the test results of each of the children in the form of guidelines, which they can use to help other children and your parent will also be able to obtain it from the school.

> If you are interested, we can supply you with your personal test information on request, which you can then use as you would like, for instance to improve your sport performance. Your parent is also free to contact us for more information on your test results.

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

> The risks in this study are minimal, such as a short disruption of your class time. Teachers are however aware of the measurements that will take place and they will make sure that you receive the necessary learning materials that you have missed during the measurements.

> The measurements that you will be involved in are not dangerous and are easy to perform and children normally enjoy taking part in this kind of testing. If you are injured in any way although the possibility is slight, the researchers are trained to assist you immediately with first aid procedures.

> I am a skilled health researcher with significant experience in conducting research in the community and especially with children.

> All the researchers that are involved in this research are also trained to work with children and will be able to adapt to the any of your needs on the testing day.

The benefits outweighs the risk

We consider that the benefits of becoming involved in this research are more than the risks, which is minimal, such as a short disruption of class time, which justifies the research project. The direct benefits to you are that these results can be made available to you which can be used to show

your strengths or to improve your shortcomings. The indirect benefits of this research are that it will provide researchers with knowledge to develop strategies to minimize health risks that can influence the health and well-being of children negatively.

What will happen in the unlikely event of some form of discomfort occurring as a direct result of you taking part in this research study?

No risks or harm are anticipated as a result of this research. However, if you brings it to the attention of the researchers' that you have some form of discomfort, such as tiredness or a slight injury we will immediately try to solve the problem or ask a teacher to assist you with solving the problem.

If the language presents a problem for you to understand the instructions, a translator or a teacher will assist the researcher to explain the instructions to you.

> Should you have the need for further discussions after the data collection an opportunity will be arranged for you to speak to me about your results or to contact me in person at the included contact details

Who will have access to the data?

We assure you that only the researchers will have access to the information that will be obtained from you, and we assure you of the confidentiality of all the information that are obtained from you. You will only be identified by a subject number. Data 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.

What will happen with the data/samples?

> This is an on-going study that will end in 2016 and the collected data will be transferred and stored on a computer at the Potchefstroom Campus of the North-West University from where it will be studied by the researchers. Your school will receive guidelines based on the results, and your parent may request an interpretation of your results. The results will be published in the form of post graduate studies of university students and as articles that are read by researchers. The hard copies of the data will be destroyed after seven years by means of a paper shredder. We want to request you that we may use your data in on-going studies of researchers.

Will you be paid to take part in this study and are there any costs involved?

You will not have to pay to be involved in the project or receive any payment for your participation but a snack and water will be given to you on the day of testing as a sign of our gratitude for your participation.

Is there anything else that you should know or do?

> Your parent can contact Prof Anita Pienaar at (018) 299 1796 if you have any further queries or encounter any problems.

> Your parent can also 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.

> You will receive a copy of this information and consent form for your own records.

How will you know about the findings?

The school will receive feedback with regard to the testing of each of the children in the form of guidelines, which your parent will be able to obtain from the school.

Declaration by the participant

By signing below, I agree to take part in a research study entitled: "A longitudinal analysis of health risk factors, growth and development among 7-13-year old children."

I declare that:

I have read this information and permission form and it is written 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 leave the study at any time and 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.

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

.....
Signature of children

.....
Signature of witness

Declaration by person obtaining consent

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 an interpreter.

I asked permission to take photos during the measurements.

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

.....
Signature of person containing consent

.....
Signature of witness

Declaration by researcher

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 an interpreter.

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

.....
Signature of researcher

.....
Signature of witness

NAVORSINGSPROJEK – Omgewingsinvloede en gesondheidsrisikofaktore se effek op die Gesondheid, Sport en Akademiese vordering van kinders woonagtig in die NW provinsie van SA ‘n 6-jaar opvolgondersoek

Hierdie navorsingsprojek is goedgekeur deur die Departement van Basiese Onderwys sowel as die Etiese komitee van die Noordwes-Universiteit, Potchefstroomkampus (NWU_00070-09-A1). Toestemming is ook by u skoolhoof verkry om voort te gaan met die navorsing.

U kind is deel van die groep wat geselekteer is om aan bogenoemde navorsingsprojek deel te neem, en het reeds die eerste metings in sy/haar graad 1 jaar in 2010 ondergaan. Die navorsingsprojek behels drie opvolgmetings op u kind oor die tydperkperk van sy/haar laerskooljare (Graad 1, 2010, 2013 en in 2016).

Die doel van hierdie navorsingsprojek is:

om inligting te bekom oor laerskoolkinders se groei en liggaamsamestelling, perseptueel-motoriese, fisieke, visuele vermoëns, basiese sportvaardighede en fiksheid ten einde ‘n profiel te kan daarstel van hierdie eienskappe van kinders woonagtig in die NW provinsie van SA, *maar meer* belangrik ook om strategieë te kan ontwikkel ter verbetering van geïdentifiseerde gesondheidsbevorderende, sportbevorderende en akademiese belemmerende faktore wat kinders tussen die ouderdom van 6 en 13 jaar se lewenskwaliteit en verdere ontwikkeling kan belemmer.

Alle toetsings en metings sal deur gekwalifiseerde navorsers uitgevoer word, is veilig om aan deel te neem, ouderdomgepas en verg min inspanning van die kind. Elke kind wat aan die studie deelneem word anoniem hanteer en kan sleg deur ‘n proefpersoonnommer geïdentifiseer word.

Deur u kind tydens hierdie opvolgmeting weer aan die bogenoemde navorsingsprojek te laat deelneem, kan dit nie net vir u kind tot voordeel wees nie, maar ook vir ouers, onderwysers en ander kundiges, inligting verleen wat gebruik kan word om belemmerende faktore in kinders se ontwikkeling vroegtydig te identifiseer, maar ook kinders van hierdie ouderdom se ontwikkeling te optimaliseer. Ons vra dus dat u dit sterk sal oorweeg om hom/haar weer te laat deelneem aan die navorsing. U is uiters geregtig om u kind op enige stadium, sonder enige verduideliking, te onttrek van die studie. Terugvoering sal aan u kind se skool gegee word nadat alle toetsings wat op een oggend tydens skoolure, soos gereël met die skoolhoof sal geskied, afgehandel en die inligting verwerk is. Vind asseblief aan die agterkant van hierdie brief ‘n vorm wat u asseblief moet teken en die volgende dag aan die skool moet terugbesorg. U kan enige tyd insae in die resultate van u kind vra. Vir enige verdere inligting oor die projek, is u welkom om my persoonlik te kontak by onderstaande kontakgegevens te kontak.

Prof. A.E. Pienaar
Projekleier
(Skool vir Biokinetika, Rekreasie en Sportwetenskap)
(018) 299 1796 (W)

NAVORSINGSPROJEK – Omgewingsinvloede en gesondheidsrisikofaktore se effek op die Gesondheid, Sport en Akademiese vordering van kinders woonagtig in die NW provinsie van SA ‘n 6-jaar opvolgondersoek

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U kind is deel van die groep wat geselekteer is om aan bogenoemde navorsingsprojek deel te neem, en het reeds die eerste metings in sy/haar graad 1 jaar in 2010 ondergaan. Die navorsingsprojek behels drie opvolgmetings op u kind oor die tydperkperk van sy/haar laerskooljare (Graad 1, 2010, 2013 en in 2016).

Die doel van hierdie navorsingsprojek is:

om inligting te bekom oor laerskoolkinders se groei en liggaamsamestelling, perseptueel-motoriese, fisieke, visuele vermoëns, basiese sportvaardighede en fiksheid ten einde ‘n profiel te kan daarstel van hierdie eienskappe van kinders woonagtig in die NW provinsie van SA, *maar meer* belangrik ook om strategieë te kan ontwikkel ter verbetering van geïdentifiseerde gesondheidsbevorderende, sportbevorderende en akademiese belemmerende faktore wat kinders tussen die ouderdom van 6 en 13 jaar se lewenskwaliteit en verdere ontwikkeling kan belemmer.

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**NAVORSINGSPROJEK – Omgewingsinvloede en gesondheidsrisikofaktore se effek op die
Gesondheid, Sport en Akademiese vordering van kinders woonagtig in die NW provinsie van
SA 'n 6-jaar opvolgonderzoek**

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Die doel van hierdie navorsingsprojek is:

om inligting te bekom oor laerskoolkinders se groei en liggaamsamestelling, perseptueel-motoriese, fisieke, visuele vermoëns, basiese sportvaardighede en fiksheid ten einde 'n profiel te kan daarstel van hierdie eienskappe van kinders woonagtig in die NW provinsie van SA, *maar meer* belangrik ook om strategieë te kan ontwikkel ter verbetering van geïdentifiseerde gesondheidsbevorderende, sportbevorderende en akademiese belemmerende faktore wat kinders tussen die ouderdom van 6 en 13 jaar se lewenskwaliteit en verdere ontwikkeling kan belemmer.

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NORTH-WEST UNIVERSITY
UNIBESITHI YA BOKONE BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS



NAVORSINGSPROJEK – Omgewingsinvloede en gesondheidsrisikofaktore se effek op die Gesondheid, Sport en Akademiese vordering van kinders woonagtig in die NW provinsie van SA 'n 6-jaar opvolgonderzoek

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Annexure B:
South African Journal for
Research in Sport, Physical
Education and Recreation
Author Information

INFORMATION FOR AUTHORS

The *South African Journal for Research in Sport, Physical Education and Recreation* is published by the North-West University, Potchefstroom. Contributions from the fields of Sport Science, Physical Education, Recreation/Leisure Studies, Exercise Science and Dance Studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

SUBMISSION

Manuscripts that do not comply with the following requirements regarding process, style and format will not be handled.

Manuscripts should be typed with **SINGLE spacing** in 10-point Times New Roman letter size for the text. All the text in *tables* and *figures* should be in 10-point Times New Roman font size and single spacing. Please do not use *Calibri*. The original manuscript can be submitted by Email. The length may not exceed 20 pages (tables, figures, references, etc. included). The **page setup** (cm) must be in the following format:

MARGINS	PAPER SIZE
Top: 3.56 cm	Width: 17.5 cm
Bottom: 1.78 cm	Height: 24.5 cm
Left: 2.11 cm	
Right: 2.11 cm	
Gutter: 0.00 cm	
Header: 2.03 cm	
Footer: 0.89 cm	

Original manuscripts may be submitted in English and should be sent to:

The Editor (Prof. Hanlie Moss)

Editorial Office

*South African Journal for Research in Sport,
Physical Education and Recreation*

Tel.: +27 (0)18-299 1821

Physical Activity, Sport and Recreation
Research Unit

E-mail: sajrsper@nwu.ac.za

North-West University, POTCHEFSTROOM
Republic of South Africa

CONDITIONS

Each manuscript must be accompanied by a **covering letter** in which the following is declared: (1) that the manuscript contains original research; (2) that the manuscript or parts of the manuscript has not been published elsewhere previously; (3) that the manuscript is not currently being presented elsewhere for publication; and (4) that all the authors have read and approved the manuscript. This signed declaration regarding the originality must accompany each manuscript. The cover letter must contain a rationale for how the manuscript is novel, why it is relevant to the journal, and how the research contributes to the field or advances the evidence base.

Authors are also requested to name three/3 potential referees, of which one/1 must be an *international* referee (the Journal is not bound to use these referees). These must be from a different institution to the first author and not have published with any member of the writing group in the previous 3 years. Complete information regarding the referees (name, surname, e-mail address and telephone numbers) must be provided in the cover letter.

We discourage the practice of parts of the same study submitted for other issues of this Journal. Authors who submit a manuscript from a study of which some data have been or will be published elsewhere, must provide a strong justification in the accompanying letter to the Editor. The justification for not publishing all the data together in one paper must also be motivated in the covering letter.

The author should also ensure that the **language** of the manuscript has been **edited** thoroughly (English [UK]) by the time of submission. The name, address and telephone number of the person who did the language editing must be provided. Any expenses incurred by the Journal dealing with language editing will be added to the

author's page fees.

The manuscript must have an **ethical clearance number** that was supplied by the authentic ethical committee of a specific institution. The process that was followed to obtain ethical clearance must be described in the manuscript under the heading, 'Ethical clearance'. No manuscript can be published without this declaration. Review, theoretic or philosophical articles do not require ethical clearance.

Any uncertainty regarding the **statistical procedures** that arise during the assessment of the manuscript will be referred to a local statistician. Any expenses incurred by the Journal dealing with statistical procedures will be added to the author's page fees.

All studies testing the effect of an intervention have to be registered with a trials registry to be eligible for peer review. We STRONGLY recommend prospective registration but will consider retrospectively registered trials with appropriate justification.

For completed randomised controlled trials, *SAJRSPER* requires the submission of a populated CONSORT checklist and flow diagram. The flow diagram should be included in the main body of the text and the checklist should be provided as an additional file. Both the flow diagram and the checklist should be referenced in the text. Submissions received without these elements will be returned to the authors as incomplete. A Word file of the checklist and flow diagram can be downloaded [here](#).

For all intervention components, authors are required to use the TIDieR Checklist, which should be provided as an additional file. The TIDieR Checklist is available to download as a [PDF](#) and a [Word file](#).

For observational studies, *SAJRSPER* requires the submission of a populated STROBE checklist (<http://strobe-statement.org/index.php?id=available-checklists>) along with the manuscript. For observational studies that focus on nutrition, the checklist should be modified to reflect the revised STROBE-nut guidelines (<http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1002036>). The completed checklist should be provided as an [additional file](#).

For systematic reviews and Meta-analyses, the PRISMA checklist and flow diagram (<http://www.equator-network.org/reporting-guidelines/prisma/>) should be completed. The Checklist should be uploaded as an additional file and the flow diagram included in the manuscript. The PRISMA Checklist as a [Word file](#) and flow diagram [word file](#) as can be downloaded [here](#).

For the reporting of therapeutic exercise interventions in rehabilitation, the [CERT](#) guidelines should be followed and the [checklist](#) uploaded as an additional file

PREPARATION OF MANUSCRIPT

Manuscripts must be presented in a format that is compatible with *Microsoft Word for Windows* (PC). Tables, all figures (illustrations, diagrams, etc.) and graphs are regarded as text and must be presented in a format that is compatible with **Word** and figures should be **accessible** to make any text corrections. Photographs must be presented in *jpg* format.

Original manuscripts must contain the following sections in the following sequence: Title page, Abstract, Introduction, Purpose of Research, Methodology, Results, Discussion, Practical application/Recommendations, Conclusions, Acknowledgements (if applicable) and References (not all applicable to review/theoretical/philosophical articles). Appendices are acceptable but must be succinct.

Title page

The first page of each manuscript should indicate the *title* in English, the *names* (title, first name in full and other initials, surname) of the author(s), the *telephone* numbers (work & home [& *mobile* for local authors]), *facsimile* number, *Email* address and the *field of study*. The **complete mailing address** and **telephone numbers** of the corresponding author and the institution (department, faculty, university, city, country) where the work was conducted should be provided in full. When more than one author and/or authors from various departments and institutions are involved, the ¹**author(s)** must be numbered according to their ¹**department(s)**. If any of the above-mentioned information should change during the review process, please inform the Subject Editor. A **short title** of not more than **45 characters** (including spaces), should be provided for use as a running heading.

Abstract

Each manuscript must be accompanied by an abstract of approximately 150-200 words in *English* and should be set on a *separate page* as a SINGLE paragraph (single spacing). A list of three to seven **keywords** in *English* is required for indexing purposes and should be typed below the abstract in alphabetical order.

Text

Start the text on a new page with the title of the article (centred and *without* the names of the authors). Follow

the style of the most recent issue of the Journal regarding the use of headings and subheadings. Use only **one line space** after a paragraph. Only make use of **section breaks** and not **page breaks**. The text, as well as the tables and figures, may not be in any other format than **normal**. Thus, **no style sheets** may be used, also in the case of the list of references.

Tables and figures

Tables and figures should be numbered with *Arabic* numerals (1, 2, etc.). Tables require the heading at the *top*, while figures have the legend *below* and both must **not** be included in the cells of the table/figure. **Note:** Use the decimal POINT (**not** the decimal comma). The site where the table or figure should be placed in the text must be indicated clearly in the manuscript. All tables and figures are to be placed *after the reference list* with each on a **separate page**, always ending with a **section break**. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

It is essential that tables/figures should be *contained/fit within the page setup* described earlier for this Journal. Portrait layout is preferred for all tables/figures. Tables must use separate rows/columns (do not merge cells) for each item. Figures must be in **Word** and *accessible to make corrections* or changes within the figure where deemed necessary. Please ensure that especially the figures are of high quality for printing purposes. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

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Only the references cited in the text should be listed alphabetically according to surname (last name) of authors (uppercase) after the body of text under the heading, **REFERENCES** (uppercase) starting on a new page. In the case where the TITLE of an article, book, etc., is in any other language than English, the author must also provide an **English translation** of the title in parentheses (this applies to Afrikaans titles as well).

In the case of articles published in **JOURNALS**, references listed should include the surnames and initials (upper case and with full-stop and without spaces between initials) of **all** authors, the date of the publication in parentheses, the full title of the article, the full title of the journal (italics and no abbreviations), the volume number, the series/issue number in parentheses (if the said journal does not use issue numbers, the month of publication should be used), followed by a colon and a space with the first and last page numbers separated by a hyphen. In the case of online journals, use "online" if page numbers are not provided. The use of the correct punctuation is of importance.

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In the case of a paper presented in conference **PROCEEDINGS**, the editors and the title of the proceedings, the page numbers of the article being referred to and the details of the congress (when and where it was held) and by whom (city, state, publisher) the proceedings was published should be provided.

Examples of style of formulations for different references

Journal

ZHENG, N.; BARRENTINE, S.W.; FLEISIG, G.S. & ANDREWS, J.R. (2008). Kinematic analysis of swing in pro and amateur golfer. *International Journal of Sports Medicine*, 29(6): 487-493.

Book

WEINBERG, R.S. & GOULD, D. (2011). *Foundations of sport and exercise psychology* (5th ed.). Champaign, IL: Human Kinetics.

Chapter in book

SCHNECK, C.M. (2010). Visual perception. In J. Case-Smith & J.C. O'Brian (Eds.), *Occupational therapy for children* (6th ed.) (pp. 373-403). Maryland Heights, MO: Mosby.

Thesis/Dissertation

SURUJLAL, J. (2004). Human resources management of professional sports coaches in South Africa. Unpublished doctoral dissertation. Johannesburg, South Africa: Rand Afrikaans University.

Proceedings of a conference

HARDMAN, K. & MARSHALL, J. (2001). Worldwide survey on the state and status of physical education in schools. In G. Doll-Tepner & D. Scoretz (Eds.), *World summit on physical education* (pp. 15-37). Proceedings of the "World Summit on Physical Education", 3-5 November 1999. Berlin, Germany: International Council of Sport Science and Physical Education (ICSSPE).

Personal communication/correspondence/interview

BOUKES, P.B. (2015). Personal communication from the Acting Director of Sport at the Nelson Mandela Metropolitan University, Port Elizabeth on 27 February 2015.

JACOBS, L. (2015). Personal interview with the Spokesperson of UNICEF, 25 August, Pretoria.

Newspaper

CAPE ARGUS (*The*) (1997). 25 March, p. 5.

Electronic source

DINOFFER, J. (2011). “Activities to build balance”. *Prevent child obesity 101*. Hyperlink: [http://www.preventchildobesity101.com/Activities/BalanceActivities.php]. Retrieved on 20 November 2012.

ADMINISTRATION

If authors honour the rules and specifications for the submission of manuscripts, unnecessary delays would be avoided. Requesting ‘copyright’, concerning figures or photographs, is the responsibility of the authors and should be indicated. A manuscript that does not meet the requirements, as set out above, will be returned to the author without being evaluated. A subject specialist Editor administers and coordinates the assessment of the referees and provides the final recommendation.

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Annexure C:
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Education and Recreation
Submission

>>> SAJRSPER 2021/12/07 06:45 >>>

Dear Mrs Du Plessis

Thank you for the submission. The manuscript has been received and sent for editorial review. You will soon receive a reference number.

Kind regards

SJ (Hanlie) Moss (PhD, MBA)

Professor

Editor: South African Journal for Research in Sport, Physical Education and Recreation

Physical Activity, Sport and Recreation Research Focus Area

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South Africa

Tel: +27182991821

Web: sajrsper.com



Annexure D:
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*This is to certify that the degree,
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Kinderkinetics*

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Lisa Claasen

has been edited by

Valerie Viljoen

of

Editing Excellence

*This Masters dissertation has been edited, including chapters 1, 2, 3,
4 and 5*

Date: 29 November 2021



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MEMBER NO. 1003396

Annexure E: Turnitin Report Summary

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