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EFFECT OF A SCHOOL-BASED HEALTH INTERVENTION ON THE NON-COMMUNICABLE DISEASE RISK STATUS OF SCHOOLCHILDREN FROM DISADVANTAGED COMMUNITIES

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Effect of a School-Based Health Intervention on the Non-Communicable Disease Risk Status of Schoolchildren from Disadvantaged Communities

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BF%	Body Fat Percentage
BMI	Body Mass Index
BP	Blood Pressure
CAPS	South African Curriculum and Assessment Policy Statement
CRF	Cardiorespiratory Fitness
CVD	Cardiovascular Disease
CRS	Clustered Risk Score
DASH:	Disease, Activity and Schoolchildren's Health
DBE	South African Department of Basic Education
D-BP	Diastolic Blood Pressure
ECDoE	Eastern Cape Department of Education
EKNZ	Ethics Committee Northwest and Central Switzerland
FGD	Focus Group Discussion
FET	Further Education Training
GET	General Education and Training
HAKSA	Healthy Active Kids South Africa
HbA1c	Glycated haemoglobin
HDL-C	High-Density Lipoprotein
HIC	High-Income Country
HMS	Human Movement Science
HRQoL	Health Related Quality of Life
IDF	International Diabetes Federation
LDL-C	Low-Density Lipoprotein
LMIC	Low- to Middle-Income Country
MVPA:	Moderate-to-Vigorous Physical Activity
NCD	Non-Communicable Disease
OBE	Outcomes-Based Education
PA	Physical Activity
PE:	Physical Education
SAUPEA	South African University Physical Education Association
SDG	Sustainable Development Goal

List of Abbreviations

SES:	Socioeconomic Status
SSA	sub-Saharan Africa
S-BP	Systolic Blood Pressure
STH	Soil-transmitted Helminths
PA	Physical Activity
PE	Physical Education
RCT	Randomised Control Trial
T1	Baseline Assessment
T2	Post-Intervention Assessment
T2D	Type 2 Diabetes
Total-C	Total Cholesterol
TG	Triglycerides
T+C+W	*KaziKidz* toolkit + PE coach + workshop
T+C	*KaziKidz* toolkit + PE coach
T+W	*KaziKidz* toolkit + workshop
T	*KaziKidz* toolkit
UNICEF	United Nations Children's Fund
WC	Waist circumference
WHO	World Health Organisation

Publications Associated with this Study

Chapter 3: Publication 1

Müller, I., **Smith, D.**, Adams, L., Aerts, A., Damons, B. P., Degen, J., et al. 2019. Effects of a School-based Health Intervention Program in Marginalized Communities of Port Elizabeth, South Africa (the KaziBantu Study): Protocol for a Randomized Controlled Trial. *JMIR Res Protoc*.8(7):e14097. DOI: 10.2196/14097.

Chapter 4: Publication 2

Dolley, D., Walter, C., du Randt, R., Pühse, U., Bosma, J., Aerts, A., et al. (2022). Clustered cardiovascular disease risk among 8–13-year-old children from lower socio-economic schools in Gqeberha, South Africa. *BMJ Open Sport & Exercise Medicine.* 8:e001336. DOI: 10.1136/bmjsem-2022-001336.

Chapter 5: Publication 3

Dolley, D., du Randt, R., Pühse, U., Gerber, M., Bosma, J., Aerts, A., et al. 2023. Relationship between Body Mass Index and Physical Activity among Children from Low-Income Communities in Gqeberha, South Africa: A Cross-Sectional Study. Int.J. Environ. Res. Public Health 2023, 20, 1428. DOI.org/10.3390/ijerph20021428.

Chapter 6: Manuscript 4

Dolley D., Walter C, du Randt R, Pühse U, Bosma J, Arnaiz P, Adams L, Aerts A, Joubert N, Müller I, Nqweniso S, Seelig H, Steinmann P, Utzinger J, Gerber M. Effect of the *Kazibantu* School-Based Physical Activity Intervention on Non-Communicable Disease Risk Factors of Children from Lower Socioeconomic Schools in Gqeberha, South Africa: Randomized Controlled Trial.

Permission to include the published manuscripts and the manuscript under review was requested and granted for inclusion in this PhD thesis at the time of submission for examination (See Appendix A).

Conference Proceedings Associated with this Study

International

Smith, D. & Müller, I. A school-based toolkit contribution to enhance children's overall health. Presented at BRICS (Brazil, Russia, India, China and South Africa) Council of Exercise and Sports Science (BRICSCESS) Conference, 10-13 October 2019, Cape Town: South Africa.

Smith, D., Aerts, A. Adams, L., Bosma, J., du Randt, R., Gall, S., et al. Prevalence of non-communicable disease risk factors among primary schoolchildren in disadvantaged communities in Nelson Mandela bay, South Africa. International Society of Behavioral Nutrition and Physical Activity (ISBNPA) Online Conference. 15-24 June 2020. Auckland: New Zealand.

Dolley, D., Walter, C., du Randt, R., Pühse, U., Bosma, J., Aerts, A., et al. Clustered cardiovascular disease risk among 8–13-year-old children from lower socio-economic schools in Gqeberha, South Africa. Presented at the International Festival of Sports, Exercise & Medicine Conference (IFSEMC). 29 September - 2 October 2022, Pretoria: South Africa.

National

Smith, D., 2019. *KaziKidz:* A School-Based Toolkit Enhancing Children's Overall Health. Presented at the Medical Research Council Symposium: Advancing Research in the Eastern Cape Province, 29-30 August 2019, East London: South Africa.

Dolley, D., & Arnaiz, P., 2021. Prevalence of hypertension among 8–13-year-old children in Gqeberha, South Africa. Presented at the 1st SAHS NextGen Spring School Research Webinar, 11 November 2021, Online.

Dolley, D., & Zeller, D., 2022. Promoting Quality Physical Education through Short Learning Programmes for Teachers at Public Schools, Presented at the Western Cape Education Department Physical Education Conference, 29-30 March 2022. Cape Town: South Africa.

Abstract

Background: Non-communicable diseases (NCDs) such as cardiovascular diseases (CVDs) and dyslipidaemia are a global public health concern, but more so in low-income countries where the underprivileged are exposed to unhealthy lifestyle practices with limited access to primary health care. Poor dietary habits and physical inactivity have also led to the unprecedented rise of NCD risk factors among school-aged children, which places them at greater risk of disease later in life. These NCDs are largely driven by obesity which has continued to rise in sub-Saharan Africa. However, high levels of undernutrition (such as stunting, underweight and wasting) among children are also present, thereby translating to a dual burden of malnutrition. Promoting regular physical activity (PA) among children is crucial for the health of future generations as it assists in weight reduction, improves insulin sensitivity, reduces blood pressure and is associated with good health and wellbeing. However, physical education (PE), the most obvious vehicle to develop the motor abilities of children, creating opportunities for their sports skills development and educating learners about the importance of PA as a lifestyle, has long been overlooked since the transformation of the South African school curriculum. Furthermore, many in-service PE teachers were not trained to teach the new multi-disciplinary Life Skills and Life Orientation subjects, of which PE forms a small part. Evidence shows that many PE teachers lack the content knowledge and practical skills to implement the subject, which raises the question of how many children, especially those in low-income communities, are participating in quality PE needed to foster healthy lifestyles and prevent the risk of NCDs. Therefore, this study aimed to investigate the effect of a 20-week school-based health intervention on NCD risk factors of primary schoolchildren from low-income schools in Gqeberha, South Africa.

Methods: A cluster randomised control trial was used to test a 20-week intervention, which included three components, namely [1] the *KaziKidz* toolkit (comprised of pre-prepared PE, health, hygiene and nutrition lessons, equipment for PE, and painted games) [2] a PE coach (human movement science graduate to assist teachers) and [3] two 90-min training workshops. Eight schools were randomly selected to participate in the study: four intervention schools received the *KaziKidz* toolkit, while the external support components were staggered across three intervention schools, and the

remaining four schools served as the control group. Altogether 961 children (491 boys and 511 girls) from grades 4 to 6 (8 - 13 years old, M=10.88±1.19 yrs) participated In the study. Demographic information and socio-economic status were captured with a questionnaire. Further measures included height, weight, waist circumference, blood pressure, glycated haemoglobin, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, accelerometer-based PA and cardiorespiratory fitness (CRF).

Results: Cross-sectional baseline data showed that 43.1% of the sample presented with at least one NCD risk factor, and 17% presented with an elevated clustered risk score (CRS). In addition, higher CRF and moderate to vigorous PA (MVPA) were associated with a lowered CRS whereby an elevated CRS was halved for every 49 min increase in MVPA (95% CI 27 - 224) or every 2.17 ml/kg/min increase in CRF, as determined via estimated VO2max (95% CI 1.66 - 3.12). Overall, 13% of the cohort were underweight, 12% overweight, 7% obese, and 64% engaged in an average of 60 min MVPA per day. The results also identified an inverse association between body mass index categories and the total duration of MVPA achieved per day as children categorised as underweight to normal-weight (boys: OR = 3.89, 95% CI: 2.18 - 6.93; girls: OR =1.78, 95% CI: 1.13 - 2.80) were more likely to engage in 60 min per day of MVPA than overweight to obese children. Finally, the school-based health intervention results revealed improvements in children's NCD risk factors and increased MVPA levels when the intervention conditions included the workshops and, in some cases, the PE coach. The *KaziKidz* toolkit (on its own) showed little to no improvements in NCD risk factors and MVPA levels.

Conclusion: School-based health interventions have the potential to improve the NCD risk factors of children attending low-income schools in South Africa. These findings also add to our understanding of implementing interventions in settings where teachers are not sufficiently trained to teach PE. Therefore, school-based health interventions, including a toolkit, should be accompanied by workshops to equip educators with the necessary tools to confidently facilitate PE lessons and integrate a range of PE activities into their classrooms. Future research is recommended to determine the long-term sustainability of school-based health interventions and the long-term post-intervention impact on NCD risk factors.

Chapter 1: Introduction

1.1 Introduction and problem statement

Many countries in the last three to four decades have experienced a nutritional transition, influenced by economic development with subsequent changes in dietary habits and declines in physical activity (PA), causing changes in body size and body composition (Popkin & Ng, 2022). The result of these dramatic changes is overweight and obesity which affects nearly 20% of adults in every country worldwide (Popkin, Corvalan & Grummer-Strawn, 2020). This has led to an exponential rise of nutrition-related non-communicable diseases (NCDs) like cardiovascular diseases (CVD), such as hypertension, type 2 diabetes (T2D), strokes and heart attacks (World Health Organisation, 2016).

NCDs are typical in adulthood as these are 'diseases of lifestyle'; however, evidence shows that much of the NCD burden in adulthood relates to modifiable risk factors that develop during childhood and adolescence (Biswas, Townsend, Huda, Maravilla, Begum, Pervin, Ghosh, Mahumud, Islam & Anwar, 2022). Literature shows that 70% of premature adult mortalities result from behaviours that develop during adolescence (Naik & Kaneda, 2014). The adolescent experience can be a period of increased susceptibility to adopting unhealthy lifestyle behaviours (Uddin, Lee, Khan, Tremblay & Khan, 2020). Unhealthy dietary habits and physical inactivity are established contributors to NCDs, which are associated with the risk of low self-esteem and psychiatric disorders during adolescence (Shorey & Ng, 2020). Being overweight or obese during childhood and adolescence also increases the risk for substance abuse, CVDs, and certain types of cancer, which represents a significant threat to poor mental health and overall quality of life (Shorey & Ng, 2020; Uddin et al., 2020).

Behavioural risk factors are unlikely to occur in isolation but rather cluster and interact, exponentially increasing the risk for NCDs (Patton, Sawyer, Santelli, Ross, Afifi, Allen, Arora, Azzopardi, Baldwin & Bonell, 2016; Uddin et al., 2020; Biswas et al., 2022). Thus, effective interventions are needed to address adverse behavioural risk factors such as overweight and obesity, physical inactivity, substance abuse, and poor nutrition (Patton et al., 2016). Furthermore, increased screening and monitoring of NCD risk factors (overweight and obesity as well as high levels of BP, cholesterol, and blood glucose) are needed to mitigate the clustering of risk factors that cause metabolic syndrome (MetS) (Akseer, Mehta, Wigle, Chera, Brickman, Al-Gashm, Sorichetti, Vandermorris, Hipgrave & Schwalbe, 2020; Mbogori, Kimmel, Zhang, Kandiah & Wang, 2020). MetS refers to the clustering of NCDs that relate to one another and are associated with increased CVD risk (Anderson & Durstine, 2019). The NCDs related to the diagnosis of MetS include high BP, elevated low-density lipoprotein cholesterol (LDL-C), total cholesterol (total-C), triglycerides (TG) and low high-density lipoprotein cholesterol (HDL-C), central obesity and elevated blood glucose (WHO, 2020). Global strategies have emerged to target NCD reduction and to promote mental health and wellbeing in the Sustainable Development Goal (SDG) (target 3.4) (Bennett, Kontis, Mathers, Guillot, Rehm, Chalkidou, Kengne, Carrillo-Larco, Bawah & Dain, 2020). However, concerted efforts are needed within schools to promote and encourage positive health behaviours (such as healthy eating and regular PA) as these are cost-effective strategies for combating NCD risk factors among children and adolescents (Naik & Kaneda, 2014; Biswas et al., 2022).

While South Africa is classified as an upper-middle-income country, it has also been ranked as the most unequal country in the world with a Gini coefficient of 0.63 points (World Bank, 2022b): about half of the adult population and 65% of children live in poverty, whereas, the wealthiest 10% of the country hold the majority (71%) of the wealth (Hall K, 2019; Statistics South Africa, 2019; World Bank, 2022a). More than a decade ago, researchers reported that South Africa had undergone a health transition now characterised by infectious diseases like human immunodeficiency virus (HIV), acquired immunodeficiency syndrome (AIDS), tuberculosis (TB) and a rise of NCDs in a population conflicted with peri-natal and maternal disorders, violence, and injury (Mayosi, Flisher, Lalloo, Sitas, Tollman & Bradshaw, 2009; Kimani-Murage, Kahn, Pettifor, Tollman, Dunger, Gómez-Olivé & Norris, 2010). The impact of NCDs in low to middle-income countries (LMICs) that are already crippled with the burden of infectious diseases results in reduced quality of life, higher uses of healthcare services, unforeseen hospital admissions, disability, and premature death (Mudie, Jin, Kendall, Addo, dos-Santos-Silva, Quint, Smeeth, Cook, Nitsch & Natamba, 2019; Modjadji, 2021). The apparent inequality and poverty in South Africa further exacerbate the burden of NCDs; thus, it is critical to discern and address disease risk before the advanced stage of chronic disease onset.

Some low-and middle-income countries still face undernutrition which is akin to poverty and defined as being underweight, stunted (a low height for age) or severe thinness. Individuals who experience malnutrition during sensitive developmental periods (e.g., in utero and during the first post-natal years) are likely to have lifelong health problems with increased susceptibility to NCDs later in life (Barouki, Gluckman, Grandjean, Hanson & Heindel, 2012; Long, Beckmann, Lang, Seelig, Nqweniso, Probst-Hensch, Müller, Pühse, Steinmann & du Randt, 2021). Thus, there is emerging research on the role of maternal nutrition: a recent report highlighted that mothers who are stunted are more likely to have stunted and overweight babies (May, Witten & Lake, 2022). Countries with incidences of overweight, obesity, and undernutrition consequently suffer a double burden of malnutrition that may manifest at the community, household, or individual level (Tzioumis & Adair, 2014). A recent study by Mbogori et al. (2020) investigated the shifts in nutritional status among children and adults in four selected African countries (Kenya, Malawi, Ghana, and South Africa). This study reported that South African children (under five years old) had the highest prevalence of overweight/obesity (13%) and stunting (27%) (Mbogori et al., 2020). Global efforts to eliminate hunger (United Nations, 2022) have shown small decreases in wasting and stunting (Popkin & Ng, 2022). However, the increasing prevalence of overweight and obesity in LMICs is often much greater than the decline in undernutrition (WHO, 2016). For example, over an 8-year period (2008 - 2016), there was a decrease prevalence of wasting (-2.3%) and underweight (-2.9%) among South African children (under five years old); still, no change was observed in the prevalence of overweight/obesity (13%) (Mbogori et al., 2020). If appropriate interventions are not implemented, the consequences of the shifts in nutritional status and the coexistence of malnutrition are severe, as children are more likely to develop diet-related NCDs later in life (May et al., 2022).

PA, a modifiable risk factor, is associated with preventing and managing NCDs (WHO, 2017). Regular PA is associated with increased HDL-C, reduced LDL-C, total-C, TG, BP, and weight reductions (Boreham & Riddoch, 2001; Strong, Malina, Blimkie, Daniels, Dishman, Gutin, Hergenroeder, Must, Nixon & Pivarnik, 2005; Janssen & LeBlanc, 2010). Guidelines on PA for children and youth (5 - 17 years) recommend an “average of” 60 minutes (min) of moderate-to-vigorous PA (MVPA) per day, most of which should be an aerobic activity to build cardiorespiratory fitness (CRF) (Bull, Al-Ansari, Biddle, Borodulin, Buman, Cardon, Carty, Chaput, Chastin & Chou, 2020). Moreover, at least 30 min of the recommended daily 60 min MVPA should be achieved during school hours (Institute of Medicine, 2013). However, the world has seen dramatic declines in PA. The Global Matrix 4.0 reported that the PA of children and adolescents is still a serious public health concern worldwide. Global estimates showed that only one-third (27% - 33%) of children and adolescents achieve the recommended 60 min daily MVPA (Healthy Active Kids Global Alliance, 2022). While in South Africa, the level of PA is relatively high as the recently published 2022 HAKSA Report Card estimates that 60% to 73% of children and adolescents meet the 60 min MVPA per day recommendation (Naidoo, Christie, Lambert, Nyawose, Basset, Monyeki, Janse van Rensburg, Cozett, Naidoo & Gradidge, 2022). However, PA behaviour is also influenced by several factors that may challenge participation. The 2022 HAKSA Report Card showed that 60% - 66% of children and youth use active transportation to and from school. However, there are safety concerns due to high pedestrian fatalities, road traffic accidents and crime rates. Furthermore, the rapid increase in urbanisation is also driving the population to be more sedentary (Naik & Kaneda, 2014; Naidoo et al., 2022).

The 2022 HAKSA Report Card stated that no data exists, indicating that schools implement physical education (PE) as intended by the curriculum. The report card also identified a lack of PE specialists since only about 20% of children are taught by PE specialists (Naidoo et al., 2022). In a recent study on the ‘state and status of PE in South African primary schools’, teachers identified a ‘lack of training and professional development’ as some of the major challenges regarding the delivery of PE (Burnett, 2021). Nevertheless, teachers are still expected to teach PE with limited content knowledge and pedagogical concepts. Without a deeper understanding of this specialised subject, generalist PE teachers lack the didactical flexibility to deliver PE in a learner-centred approach (Burnett, 2020). Consequently, little attention is given to addressing the needs of the marginalised children (girls and overweight/obese children) who may be at risk of obesity-related NCDs (Telford, Telford, Olive, Cochrane & Davey, 2016). For example, research shows that overweight and obese children are less likely to be active compared to children with normal weight (Baran, Weres, Wyszyńska, Pitucha, Czenczek-Lewandowska, Rusek, Leszczak & Mazur, 2020), and girls are less likely to be active and have lower levels of perceived competence in PE than boys (Telford et al., 2016).

Children and adolescents spend most of their day at school, making it an ideal setting for them to learn about healthy lifestyles. Schools also offer an accessible environment to promote PA participation for all children, irrespective of their social background. In fact, PE is the only school subject that affects the physical, cognitive, social and affective domains (Van Deventer, 2002), yet it is not given the status it deserves. In a global study of 12 countries, South Africa had the highest percentage of learners (32%) who were not participating in PE (Silva, Chaput, Katzmarzyk, Fogelholm, Hu, Maher, Olds, Onywera, Sarmiento & Standage, 2018). PE is often perceived poorly by the principals, parents, teachers, and learners. In addition, barriers like short curriculum allocation time, insufficient physical resources, and poor in-service professional development make the delivery of PE challenging, especially in underserved schools (Van Deventer, 2009; Van Deventer & Van Niekerk, 2009; Burnett, 2020). Unfortunately, South Africa's economic inequalities are evident within the school system. Evidence has shown that children attending high-income schools were more likely to participate in PE and organised sports than those attending lower-income schools (McVeigh, Norris & De Wet, 2004; Micklesfield, Pedro, Kahn, Kinsman, Pettifor, Tollman & Norris, 2014; United Nations Children's Fund, 2022). The lack of PE delivery in low-income schools is likely due to delapidated infrastructure, insufficient physical resources and professional development, as well as hostile and unsupportive environments. Meanwhile, high-income schools have a financial resources to employ qualified coaches or specialised service providers to deliver extramural sports coaching and PE (Burnett, 2020).

Schools have been recognised as an ideal environment for health initiatives as they have access to large heterogeneous samples of children. A handful of large-scale school-based health intervention studies have been conducted in South Africa. These are the HealthKick study (Draper, de Villiers, Lambert, Fourie, Hill, Dalais, Abrahams & Steyn, 2010), the DASH study (Yap, Müller, Walter, Seelig, Gerber, Steinmann, Damons, Smith, Gall & Bänninger, 2015), and the KaziAfya study (Gerber, Ayekoé, Beckmann, Bonfoh, Coulibaly, Daouda, du Randt, Finda, Gall & Mollel, 2020), to name a few. These studies implemented multi-component interventions and included components like PA promotion, nutrition education, nutrition supplements, health and hygiene education, deworming, and stakeholders like learners, parents, community members and government institutions. However, these interventions reported varying levels of success and subsequently require further investigation.

Given this background, it was considered necessary to identify NCD risks for the current and future health of the South African population. However, few studies in South Africa have investigated the prevalence of NCD risk factors in primary schoolchildren and the external support needed by generalist PE teachers to optimise the opportunity to directly and indirectly, promote increased PA among their learners. The shortage of specialised skills in low-income schools needed to deliver PE and improve the health and wellbeing of schoolchildren (especially vulnerable sub-groups such as girls and children with excess weight) should also be addressed as lifestyle and disease patterns are rapidly changing. School-based health interventions targeting nutrition and PA behaviours are necessary strategies to address NCD risk and, therefore, the focus of this study.

1.2 Aim and Objectives

1.2.1 Research Aim

This study aimed to investigate the effect of a school-based health intervention on the NCD risk status of grade (Gr) 4 - 6 school children from selected schools situated in disadvantaged communities in Gqeberha, South Africa.

1.2.2 Research Objectives

The following objectives were therefore addressed to achieve the primary aim of this study:

1. To describe baseline NCD risk factors (blood lipids, cholesterol, glycated haemoglobin glycated (HbA1c), BP, height, weight, body mass index (BMI), waist circumference and body fat percentage (BF%)), PA and CRF across Gr 4 - 6 children.

2. To determine the prevalence of a clustered risk score and its associations with PA and CRF.

3. To determine the prevalence of BMI categories (underweight, overweight and obesity) and the relationship between MVPA respective per gender across Gr 4 - 6.

4. To determine the effect of the *KaziKidz* intervention on NCD risk factors (WC, BP, blood lipids, cholesterol and HbA1c) and PA levels by comparing the four intervention conditions differing in level of support (experimental groups) with the control group.

1.3 Scope of this study within the KaziBantu Project

This study was embedded as a sub-study in the larger *KaziBantu* research project titled: *Effects of a school-based health intervention program in marginalised communities of Port Elizabeth, South Africa (the KaziBantu Study): Protocol for a Randomized Controlled Trial.* The *KaziBantu* study is an expansion from the former Disease Activity and Schoolchildren's Health (DASH) study (2014 - 2018) and was designed based on the findings of the DASH study. The researcher of this sub-study has assisted in numerous roles in her capacity as the South African *KaziBantu* project coordinator. The overarching aim of the *KaziBantu* project is to improve the health conditions of both teachers and learners, thereby creating 'Healthy Schools for Healthy communities' in under-resourced settings. *KaziBantu*, translated from Swahili and Xhosa into 'Active People', aims to contribute toward positive and sustainable changes in health by implementing a whole-school programme focused on healthy, active living within disadvantaged schools in LMICs. *KaziBantu* also aims to contribute to UNESCO's Sustainable Development Goals through SDG3: Good Health and Wellbeing and SDG4: Quality Education by implementing two toolkits, *KaziKidz and KaziHealth*. *KaziKidz* is an educational toolkit designed to contribute to learners' health by teaching them about PE, Health, and Hygiene, and *KaziHealth* is a workplace health promotion programme designed to empower teachers through an interprofessional wellness initiative. The *KaziBantu* study aimed to assess the effect of the *KaziKidz* and *KaziHealth* toolkits through two separate interventions at eight Quintile 3 primary schools from peri-urban areas of Gqeberha.

The present study pertains to the implementation of the *KaziKidz* intervention. The *KaziKidz* intervention consisted of three components: [1] the ***KaziKidz* toolkit (T),** comprising ready-to-use PE, health, hygiene and nutrition lessons, basic equipment for the teaching of PE, and painted games; [2] a **PE coach (C),** a graduate in the field of human movement science (HMS) to support teachers, and [3] two 90-min *KaziKidz* training **workshops (W).** All intervention schools received the *KaziKidz* toolkit, while the PE coach and the two training workshops served as external support components, which were staggered across the intervention schools. The role of the PE coach was to assist the non-specialist PE teachers while they presented their PE lessons. The two 90-minute onsite *KaziKidz* training workshops informed non-specialist PE teachers on practically implementing the *KaziKidz* lessons.

Two identical data assessments were conducted to assess the impact of the four *KaziKidz* intervention conditions. The study included a baseline assessment (T1) from January to February 2019, a 20-week intervention period and a post-intervention assessment (T2) from August to September 2019. Altogether 1020 children from Gr 4 – 6 (8 – 13 years, mean age: 10.4±1.2 years) were recruited, and 975 were enrolled in the *KaziBantu* study. The overarching *KaziBantu* study aimed to determine the effect of the *KaziKidz* intervention on different health outcomes and measured several health markers, such as NCD risk factors, health behaviours, psychosocial health, and cognitive performance among primary school children. The test battery comprised:

1. Questionnaire: Demographic information, health-related quality of life, food frequency and socio-economic status (SES). In addition, the children's end-of-year academic performance was captured to assess cognitive performance.
2. Clinical measures: BP, blood glucose (HbA1c), blood lipid profile (total-C), HDL-C, LDL-C and body composition (height, weight, waist circumference, BMI and BF%).
3. PA: Device-based accelerometry.
4. Physical fitness (PF): CRF was measured using the 20 m shuttle run test, and muscular strength was assessed with a grip strength dynamometer.

Meanwhile, the aim of the present study (*KaziBantu* sub-study) was to determine the effect of the four intervention conditions (differentiated by level of implementation support) on PA and NCD risk factors with the test battery only comprising of the following:

1. Questionnaires: Demographic information and SES
2. Clinical measures: BP, HbA1c, full blood lipid profile and body composition
3. PA: Device-based accelerometry
4. PF: 20 m shuttle run test

Ethical considerations for the larger *KaziBantu* study and the current PhD sub-study were reviewed and approved by the relevant ethics committees (See Appendix B for ethics approvals). Furthermore, the project information sheet and written informed consent form are presented in Appendix C.

1.4 Significance of the Study

A paucity of research focuses on implementing school-based health interventions targeting nutrition, PA and PE among primary schoolchildren attending low-income schools in South Africa. Few studies have also determined the level of external support needed by non-specialist PE teachers, given the lack of content knowledge and understanding to teach PE and the shortage of trained educators to teach the subject (Stroebel, Hay & Bloemhoff, 2016a; Burnett, 2021; UNICEF, 2022). The present study's unique contribution pertains to the study design being a randomised control trial (RCT) and the fact that the intervention differs by the level of intervention support to establish the assistance needed by non-specialist PE teachers to implement a school-based health intervention. This study's findings add to our understanding of implementing school-based health interventions in resource-scarce schools, where teachers are not sufficiently skilled to teach PE and will, therefore, further our knowledge about the potential of school-based health interventions to improve children's health and wellbeing.

1.5 Overview of Chapters

This PhD thesis follows a publication format and is arranged into seven chapters, including four publications (three have been published, and one manuscript is under review at the time of thesis submission for examination). Each publication is presented as a separate chapter (Chapters 3 to 6) in its original form as published in its respective journals. Each publication conforms to the guidelines of its relevant journal and, therefore, differs in formatting style.

This thesis begins with **Chapter 1**, which provides the introduction and background to the study. In light of current trends, this chapter has justified the need to investigate the NCD risk status of children in under-resourced schools and to identify means to support PE non-specialist teachers in delivering PE. This chapter also identifies the aim, objectives and significance of the study.

Chapter 2 focuses on the literature pertaining to NCDs in children, PA and CRF in children, PE in the South African context and school-based health interventions.

Chapter 3 presents the Methodology of the *KaziBantu* study of which this PhD thesis forms part. The study protocol, "*Effects of a school-based health intervention program in marginalised communities of Port Elizabeth, South Africa (the KaziBantu Study): Protocol for a Randomized Controlled Trial*", has been published in JMIR Research Protocols with an impact factor of 7.08. The researcher (D.D.) was not the first author but was involved in the study protocol's design, development and review process.

Chapter 4 presents the first publication where the researcher (D.D.) is the first author. This publication, "*Clustered cardiovascular disease risk among children aged 8–13 years from lower socioeconomic schools in Gqeberha, South Africa*", addressed objectives 1 and 2 and was published in *BMJ Open Sport & Exercise Medicine* with an impact factor of 3.14. The journal guidelines can be found at the following link BMJ submission guidelines. This paper determined the prevalence of individual CVD risk factors and clustered CVD risk and investigated the independent association between the clustered CVD risk, MVPA, and CRF.

Chapter 5 presents the second publication, where D.D. is the first author. This publication, "*Relationship between body mass index and physical activity among children from low-income communities in Gqeberha, South Africa: a* *cross-sectional study*" addressed objective 3 and was published in the International Journal of Environmental Research and Public Health (click the link for the submission guidelines); impact factor: 4.61. This paper aimed to establish the prevalence of underweight, overweight and obesity and the level of MVPA among primary school-aged children from selected low-income communities in Gqeberha, South Africa. In addition, this paper also sought to determine the association between children's BMI classification and PA behaviour.

Chapter 6 presents the final paper, "*Effect of the KaziBantu school-based health intervention on non-communicable disease risk factors of children from low-income schools in Gqeberha, South Africa*", where D.D. is the first author. This publication addressed objective 4 and is under review with the African Journal for Physical Activity and Health Sciences (AJPHES) (click the link for the submission guidelines). This paper aimed to assess the effect of the school-based health intervention conditions (differing by the level of teacher support) targeting PA behaviour and NCD risk factors among children in low-income communities.

Chapter 7, the final chapter, provides an overview of the significant findings, which are discussed according to the objectives of this study. This chapter also synthesizes the key findings of the publications presented in Chapters 4 to 6. Subsequently, this chapter presents the methodological strengths and limitations, followed by a conclusion, recommendations for future research, and practical implications that will be made available to policymakers and government authorities.

The following chapter builds on the introduction to the study presented in Chapter 1 by providing a literature review on selected lifestyle-related NCDs among children and adolescents as well as focusing on factors PA, CRF and PE, which are means to promote children's health and wellbeing. This chapter goes on to investigate school-based interventions which are aimed at improving the health conditions of primary schoolchildren in low-income settings.

Chapter 2: Literature Review

2.1 Introduction

Changes across social, economic and demographic structures of society are often accompanied by epidemiological transitions of disease, as described by Omran (2005). The worldwide disease burden has shifted from infectious diseases to NCDs, which have dramatically increased in high and low-income countries. The coexistence of infectious diseases and NCDs was documented in middle-income countries (Frenk, Bobadilla, Sepuúlveda & Cervantes, 1989) and is the current scenario in South Africa (Stats SA, 2018). South Africa also experiences a dual burden of malnutrition, with an increased incidence of overweight and obesity amidst various forms of undernutrition such as stunted growth, wasting and being underweight (Mbogori et al., 2020). A strategy to combat the rising prevalence of overweight, obesity and NCDs is to foster healthy and active lifestyles while children are young and impressionable. However, many children and adolescents are inactive and may not be aware of the physical (Roman-Viñas, Chaput, Katzmarzyk, Fogelholm, Lambert, Maher, Maia, Olds, Onywera & Sarmiento, 2016; van Niekerk, Du Toit D & Pienaar, 2016; Bull et al., 2020) and physiological health benefits of PA and CRF (Strong et al., 2005; Rossouw, Grant & Viljoen, 2012; Lubans, Smith, Morgan, Beauchamp, Miller, Lonsdale, Parker & Dally, 2016).

The school environment provides a sustainable opportunity (Milton, Cavill, Chalkley, Foster, Gomersall, Hagstromer, Kelly, Kolbe-Alexander, Mair & McLaughlin, 2021) to cultivate long-term healthy behaviours. The expectation is that PE would develop motor skills and positive attitudes towards PA that would persist across the lifespan with ongoing health benefits (Hills, Dengel & Lubans, 2015). However, the status of PE worldwide is less than ideal (Hardman, Murphy, Routen & Tones, 2013; Goslin, 2020). In South Africa, PE has long been overlooked in the school curriculum and lost its stand-alone status in recent years (Stroebel et al., 2016a). The low perceived status of PE among children, parents and school staff also does not bode well for children’s health outcomes and PA status, especially those taught by generalist PE teachers in underserved schools (Burnett, 2021). Against this background, the *KaziBantu* Project developed the multi-component *KaziKidz* toolkit tailored to under-resourced schools in low-income communities to improve the health and wellbeing of children living in under resourced and marginalised settings.

The primary aim of the present study was to investigate the effect of a school-based health intervention on the NCD risk status of primary school children in low-income communities. This chapter reviews the literature on the global NCD problem with reference to the prevalence, the leading causes of NCD mortalities, the NCD burden on low-income countries and preventative strategies. The subsections to follow also cover relevant details about selected NCD risk factors (malnutrition, dyslipidaemia, hypertension, and hyperglycaemia). The clustering of NCD risk factors has become increasingly prevalent among children and adolescents (Uddin et al., 2020) and is, therefore, discussed along with MetS. Given the relevance of PA and CRF for this study, these are also defined, and their benefits are elucidated. PE is considered an important vehicle to stimulate PA among children and develop the required skills and motivation for a lifelong active lifestyle. Therefore, this chapter also explored PE, the history of PE in South Africa, and its impact on the PE curriculum. Finally, this chapter concludes with a review of school-based health interventions and their impact on NCDs.

2.2 Non-communicable Diseases

Significant lifestyle changes in recent decades have intensified the global burden of NCDs. These chronic diseases are the leading cause of ill health, accounting for seven out of ten mortalities worldwide and at least 74% of annual deaths (Bradshaw, Nannan, Pillay-van Wyk, Laubscher, Groenewald & Dorrington, 2019; WHO, 2022). NCDs also account for about 17 million (57%) of 29.8 million mortalities in people younger than the age of 70 years (70 years is commonly used as a cut-off age to define premature death) (Norheim, Jha, Admasu, Godal, Hum, Kruk, Gómez-Dantés, Mathers, Pan & Sepúlveda, 2015). Although life expectancy has risen over the last two centuries (Wang, Naghavi, Allen, Barber, Bhutta, Carter, Casey, Charlson, Chen & Coates, 2016), current estimates show a potential decline in the life expectancy of future generations due to the increase in NCDs (Anderson & Durstine, 2019). NCDs have subsequently been included in the SDGs (target 3.4) to reduce premature mortality from NCDs by one-third through prevention and treatment and to promote mental health and wellbeing by 2030 (Bennett et al., 2020).

In the past, NCDs were widespread and typical of industrialised and developed countries (Barquera, Pedroza-Tobías, Medina, Hernández-Barrera, Bibbins-Domingo, Lozano & Moran, 2015); however, NCDs have swept across the globe affecting people from LMICs as well. Currently, more than three-quarters of global NCD deaths occur in LMICs, and 86% of premature deaths occur in LMICs (WHO, 2022). Omran (2005) described an epidemiological transition theory representing a disease shift that begins with a high incidence of infectious diseases and malnutrition caused by poor sanitation and famine, etc. and then shifts to a high prevalence of chronic and degenerative diseases (Popkin & Ng, 2022). The transition is often characterised by increased vaccinations, sanitation and general infectious disease prevention, causing the decline of communicable disease mortalities, followed by an exponential increase in NCD mortalities (Bradshaw et al., 2019). The disease burden in sub-Saharan Africa continues to be dominated by communicable diseases. However, countries in this region are transitioning toward an NCD disease burden (Bradshaw et al., 2019) and have subsequently been burdened with a coexistence of infectious diseases and NCDs, which has significant public health implications and substantial economic and societal impacts.

The epidemiology of NCDs in LMICs is multi-faceted and is based on trends like globalisation, rapid urbanisation, and increasingly sedentary lifestyles. In South Africa, NCDs are emerging in both rural and urban communities, with the burden most prominently affecting individuals with low SES (Ndinda, Ndhlovu, Juma, Asiki & Kyobutungi, 2018; Juma, Juma, Shumba, Otieno & Asiki, 2019). Strategies for preventing and treating NCDs are side-lined due to the overwhelming prevalence of infectious diseases like HIV/AIDS and TB (Mayosi et al., 2009; Modjadji, 2021). In most countries, individuals with low SES and those living in peri-urban and underprivileged areas are more susceptible to NCDs than the advantaged groups (Engelgau, Rosenhouse, El-Saharty & Mahal, 2011; Di Cesare, Khang, Asaria, Blakely, Cowan, Farzadfar, Guerrero, Ikeda, Kyobutungi & Msyamboza, 2013; Juma et al., 2019). Thus, LMICs are faced with considerable financial strain. Unfortunately, most people who live in LMICs have inadequate access to primary health care and treatment, which could help reduce the NCD burdens and prevent advanced-stage disease (Di Cesare et al., 2013; Bennett et al., 2020). Thus, individuals diagnosed with NCDs face high healthcare costs and perhaps a reduced ability to work, resulting in reduced work productivity, ultimately impacting economic development (Centers for Disease Control and Prevention, 2022). In South Africa, TB has maintained the number one position as the cause of death for 2016 - 2018 (Stats SA, 2018). With T2D being the second leading cause of death during the same period (Stats SA, 2018). The latter is an apt example of the dual burden of communicable and NCDs in South Africa. Unfortunately, attention to preventing and treating NCDs like T2D is marginalised in South Africa because of the overwhelming prevalence of communicable diseases like HIV/AIDS and tuberculosis (Mayosi et al., 2009; Modjadji, 2021).

The main types of NCDs are CVD, which accounts for most NCD-related mortalities, followed by some cancer types, chronic respiratory diseases and diabetes, the latter being the most common metabolic disease (Bennett, Stevens, Mathers, Bonita, Rehm, Kruk, Riley, Dain, Kengne & Chalkidou, 2018; WHO, 2018). The aetiology of NCDs may result from physiological, genetic, environmental, or behavioural factors (WHO, 2020). These factors can be categorised into non-modifiable or modifiable risk factors. For example, age, ethnicity, and genetics are non-modifiable traits that cannot be altered. Indirect modifiable risk factors that may negatively influence NCD risk include education level, SES, and employment (Anderson & Durstine, 2019). On the other hand, sedentary behaviour, physical inactivity, unhealthy diet, and substance abuse are direct modifiable risk factors. Over time, behavioural risk factors such as physical inactivity, smoking and diet may lead to high BP, elevated blood lipids and blood glucose, and excess weight, which may eventually advance to NCD onset if preventative action is not taken.

NCDs were previously typical of middle-aged and older adults, as these diseases emerge over time. However, NCD risk factors and unhealthy lifestyle behaviours are progressively seen among younger generations, such that children and adolescents present with overweight and obesity as well as CVD (elevated BP, cholesterol) and metabolic problems (elevated blood glucose) (Hills et al., 2015; Champion, Parmenter, McGowan, Spring, Wafford, Gardner, Thornton, McBride, Barrett & Teesson, 2019). A recent study using the Global School-based Student Health Survey collected from 89 countries reported that one in three adolescents had lifestyle-related risk factors (Uddin et al., 2020). Another population-based study determined the global prevalence of NCD risk among adolescents in 140 countries and reported a high prevalence of four or more NCD risk factors suggestive of the clustering of these risk factors in individuals (Biswas et al., 2022). Thus, greater attention and research focus have been given to addressing NCD risk among children and youth.

Most NCDs share predisposing risk factors like obesity, poor dietary habits, and physical inactivity (Bennett et al., 2018). Among adolescents (10 - 20 years), physical inactivity and sedentary behaviour have been linked with increased overweight and obesity, poor nutrition (low fruit and vegetable consumption, increased consumption of salt, sugar and saturated fat), depression and reduced quality of life (Afshin, Sur, Fay, Cornaby, Ferrara, Salama, Mullany, Abate, Abbafati, Abebe & Afarideh, 2019; Hinkley, Timperio, Watson, Duckham, Okely, Cliff, Carver & Hesketh, 2020). The adolescence period is a point of high plasticity (MacArthur, Caldwell, Redmore, Watkins, Kipping, White, Chittleborough, Langford, Er & Lingam, 2018) and, therefore, a crucial time to intervene and curb the tracking of poor health to adulthood (Champion et al., 2019). In fact, the first two decades of life are critical to building healthy lifestyle habits and averting future NCD burdens (Uddin et al., 2020). Nutritional imbalances (over and undernutrition) and environmental chemical (smoking) exposures during sensitive window periods like pregnancy, childhood and puberty may result in increased disease risk and dysfunction later in life (Barouki et al., 2012). A recent study reported that increased weight gain in mothers during their pregnancy is associated with their child's low PA levels, increasing the risk for overweight and obesity (Baran et al., 2020).

Of concern is the increased risk of cardiometabolic disease that children and adolescents may be exposed to later in life. Thus, the following subsections define the major predisposing risk factors of NCDs, such as malnutrition and dyslipidaemia, hypertension, hyperglycaemia, and MetS. Nutrition plays a crucial role in diet-related NCDs. The following section explores the incidence of malnutrition (including undernutrition, overweight and obesity) among children and adolescents and the implications of poor nutrition on the likelihood of NCDs later in life.

2.2.1 Malnutrition

Malnutrition is often associated with undernutrition; however, this term covers two broad and polar opposite conditions. Malnutrition includes undernutrition which encompasses nutrition-related deficiencies (underweight, stunting and wasting), and the other is overweight and obesity which refers to excess or imbalances in the individual's energy or nutrients (OECD/WHO, 2020). Both forms of malnutrition are discussed as South Africa experiences the coexistence of under and overnutrition, which contributes to diet-related NCDs such as diabetes and CVDs (May et al., 2022). Determining malnutrition among children and adolescents is more challenging than it is among adults. Simple anthropometric indicators like height and weight change dramatically with growth and development. Therefore, reference systems such as BMI, z-scores and percentiles are based on age and gender-specific thresholds to accurately classify the weight and nutritional status of children and adolescents (Katzmarzyk, Janssen, Morrison & Tremblay, 2007; Ahrens, Pigeot, Pohlabeln, De Henauw, Lissner, Molnár, Moreno, Tornaritis, Veidebaum & Siani, 2014)

Many countries have experienced a nutritional transition with rapid globalisation and urbanisation, which have caused dramatic lifestyle changes (Popkin, 1998; Popkin, 2003; Popkin & Ng, 2022). The accompanying socio-economic and demographic shifts brought dietary changes (high in saturated fats, sugar and refined foods that are low in fibre, known as the 'Western diet') and reductions in PA that have led to the exponential rise of obesity and overweight (OECD/WHO, 2020). Secular trends have shown that the global prevalence of overweight and obesity has almost tripled in a period of 40 years (1975 - 2016) (WHO, 2016). Recently published data also reported that in 2016, nearly 2 billion adults (39% of men and 40% of women) were overweight, and more than half a billion were obese (11% of men and 15% of women) (OECD/WHO, 2020). Obesity has been characterised as a nutritional disorder that has developed into an epidemic, affecting children and adolescents and threatening public health and mental health (Lobstein, Jackson-Leach, Moodie, Hall, Gortmaker, Swinburn, James, Wang & McPherson, 2015). In 2016, it was estimated that 41 million children (under the age of five years) were affected by overweight or obesity, and over 340 million children and adolescents (5-19 years) were overweight or obese (OECD/WHO, 2020; Mavrogeni, Bacopoulou, Markousis-Mavrogenis, Chrousos & Charmandari, 2021).

In terms of global weight status, the 2018 Global Nutrition Report showed that while overweight and obesity are rife in developed countries, some developing countries are still burdened with the coexistence of stunting, wasting, underweight and overweight, and obesity (Development Initiatives, 2018). Data collected from the Global School-Based Student Health and Health Behaviour in School-Aged Children surveys of 57 LMICs illustrated the following prevalence of malnutrition: stunting 10.2% (95% CI: 8.3% - 12.2%), thinness 5.5% (95% CI: 4.3% - 6.9%), and overweight/obesity 21.4% (95% CI: 18.6% - 24.2%) (Caleyachetty, Thomas, Kengne, Echouffo-Tcheugui, Schilsky, Khodabocus & Uauy, 2018). The nutritional transition on the African continent has been primarily driven by economic development. Researchers selected four African countries (Kenya, Malawi, Ghana, and South Africa) based on their Gross Domestic Product (low, middle and high-income) to assess shifts in nutritional status (Mbogori et al., 2020). This study reported that nutrition shifts from under to overnutrition seemed more severe in South Africa as trends indicated a higher incidence of overweight and obesity than the declining rate of underweight (5.9%) among children under five years. Moreover, while South Africa had the highest rates of overweight and obesity (13%), the incidence of stunting was considerably higher (27%) (Mbogori et al., 2020). This is significantly higher than the 10.2% stunting reported by the 2018 Global Nutrition Report (Development Initiatives, 2018).

In South Africa, Armstrong, Lambert & Lambert (2011) aimed to describe secular trends for the nutritional status of South African children over ten years (1994 - 2004) by using data from the South African Primary School's Anthropometric Survey (1994) and the Health of the Nation Study (2001 - 2004). A considerable increase in the prevalence of overweight (1.2% - 13%) and obesity (0.2% - 3.3%) was identified (Armstrong et al., 2011). The status of malnutrition in South Africa has been reported in the Healthy Active Kids South Africa (HAKSA) Report Card over the years. This report evaluates the latest available evidence on PA, nutrition and body composition of South African children and youth with a view to a call for action by all stakeholders with a vested interest in the health and wellbeing of South African children and adolescents (Draper, Tomaz, Bassett, Harbron, Kruger, Micklesfield, Monyeki & Lambert, 2019). From 2014 to 2018, the HAKSA report card allocated overweight and obesity an unsatisfactory D grade - the prevalence of overweight and obesity among

South African children and youth ranged between 21% - 40% over the four years (Draper, Basset, De Villiers & Lambert, 2014; Uys, Bassett, Draper, Micklesfield, Monyeki, De Villiers & Lambert, 2016; Draper, Tomaz, Bassett, Burnett, Christie, Cozett, de Milander, Krog, Monyeki & Naidoo, 2018). The recently published 2022 HAKSA Report Card reported no evidence of a significant change in overweight and obesity since the 2018 Report Card (Naidoo et al., 2022). Another recently published report, the South African Child Gauge report, highlighted that one in four South African children are stunted, and one in eight are overweight or obese (May et al., 2022).

Children and adolescents in LMICs are most vulnerable to nutritional imbalances as they are exposed to inadequate pre-natal, infant and childhood nutrition during crucial periods of development (Tzioumis & Adair, 2014; WHO, 2016; Caleyachetty et al., 2018). Such nutritional imbalances affect the individual's quality of life and impact the country's health burden, productivity, and growth potential. Dietary imbalances such as under or over-nutrition during sensitive development periods (e.g. pre-natal and early childhood) can alter tissue and impact organ function, causing increased susceptibility to chronic disease later in life (Barouki et al., 2012; May et al., 2022). Emerging research also points to the role of maternal nutrition, as stunted mothers are more likely to have stunted and overweight infants who become obese children (May et al., 2022). In addition, excess weight gain during pregnancy and gestational diabetes are also highlighted as factors influencing disease risk in the next generation (Magge, Goodman, Armstrong, Daniels, Corkins, de Ferranti, Golden, Kim, Schwarzenberg & Sills, 2017). Unfortunately, this perpetuates the intergenerational cycle of malnutrition and diet-related NCDs (May et al., 2022).

In summary, like many other LMICs, South Africa is in transition, experiencing the double burden of malnutrition with an increasing prevalence rate of overweight and obesity amidst a high incidence of stunting (Tzioumis, Kay, Bentley & Adair, 2016; Mbogori et al., 2020). This is typical of African countries, where the prevalence of overweight and obesity continues to rise despite the high rates of food insecurity and micronutrient deficiencies (Tzioumis et al., 2016). Amongst other vital contributors, unhealthy diets are significant drivers of NCDs. End-stage disease onset typically occurs later in life, but the development of conditions like atherosclerosis and arteriosclerosis generally stem from childhood (Wilson, McNeal & Blackett, 2015).

Therefore, the following section explores the global and national incidence of dyslipidaemia and the implications thereof regarding children.

2.2.2 Dyslipidaemia

Dyslipidaemia is an established CVD risk factor and may be defined as elevated serum total-C, LDL-C, TG or decreased serum HDL-C concentrations (Hedayatnia, Asadi, Zare-Feyzabadi, Yaghooti-Khorasani, Ghazizadeh, Ghaffarian-Zirak, Nosrati-Tirkani, Mohammadi-Bajgiran, Rohban & Sadabadi, 2020; Mosca, Araújo, Costa, Correia, Bandeira, Martins, Mansilha, Tavares & Coelho, 2022). Dyslipidaemias may be genetically determined (familial dyslipidaemia) or through secondary conditions such as obesity, T2D, or unhealthy lifestyles (Elkins, Fruh, Jones & Bydalek, 2019). Over the last three decades, dramatic lifestyle changes have increased the global burden of dyslipidaemia (Pirillo, Casula, Olmastroni, Norata & Catapano, 2021). In 2016, elevated serum total-C represented an estimated 4.4 million mortalities and 93.8 million disability-adjusted life-years (DALYs), globally representing the eighth and seventh leading risk factors of attributable DALYs for men and women, respectively (Hay, Abajobir, Abate, Abbafati, Abbas, Abd-Allah, Abdulkader, Abdulle, Abebo & Abera, 2017; Naghavi, Abajobir, Abbafati, Abbas, Abd-Allah, Abera, Aboyans, Adetokunboh, Afshin & Agrawal, 2017). In Africa, it is estimated that one in five adults in the general adult population has dyslipidaemias as the prevalence of dyslipidaemias is relatively high among the general adult population: 25.5% total-C, 28.6% for LDL-C, 37.4% for low HDL-C and 17% for TG (Noubiap, Bigna, Nansseu, Nyaga, Balti, Echouffo-Tcheugui & Kengne, 2018).

Dyslipidaemia is significantly associated with the development of arterial atherosclerotic (thickness which accelerates early vascular ageing) lesions in children (Berenson, Srinivasan, Bao, Newman, Tracy & Wattigney, 1998; Elmaoğulları, Tepe, Uçaktürk, Kara & Demirel, 2015). Generally, CVD events are atypical during childhood; however, early signs of atherosclerosis have been observed in children in autopsy studies (Berenson et al., 1998; Wilson et al., 2015). The Bogalusa Heart Study and the Pathobiological Determinants of Atherosclerosis in Youth Research also demonstrated that high serum LDL-C and low HDL-C in children and youth were associated with an increased risk of atherosclerosis and arteriosclerosis in adulthood

(Newman III, Freedman, Voors, Gard, Srinivasan, Cresanta, Williamson, Webber & Berenson, 1986). Extensive evidence also shows that risk factors for CVD are established during childhood and are likely to persist into adulthood, increasing the overall risk profile for chronic diseases (Freedman, Wang, Dietz, Xu, Srinivasan & Berenson, 2010; Climie, Park, Avolio, Mynard, Kruger & Bruno, 2021). Thus, monitoring blood lipids in children is an essential measure of atherosclerosis and CVD later in life.

There are two major approaches for paediatric dyslipidaemia screening: selective screening, where screening is only conducted based on family history and primary risk factors (obesity, hypertension, diabetes, poor diet, and sedentariness), and universal screening, which measures as many children as possible irrespective of family history (Elkins et al., 2019). Universal screening would be more costly, but this method enables early diagnosis and treatment of cases with an undiagnosed family history of dyslipidaemia. The United States National Institutes of Health Heart, Lung, and Blood Institute (NHLBI) Expert Panel recommends the following screening guidelines: universal screening for all children between 9 - 11 years and 17 - 21 years, with no screening during puberty or early adolescents (12 - 16 years) due to changes in lipid production (NHLBI, 2011). When screening plasma lipids and lipoproteins in children, several factors may influence outcome measures, including age, sex, ethnicity and other metabolic, genetic, and environmental factors (Gooding, Rodday, Wong, Gillman, Lloyd-Jones, Leslie & De Ferranti, 2015). Due to the founder effect, the prevalence of specific genetic (heterozygous) familial hypercholesterolemia in particular populations (like South Africans, Dutch Afrikaners, South Asian Indians, Ashkenazi Jewish and French Canadians) is also found to be higher (1 in 100) (Bouhairie & Goldberg, 2015; Elkins et al., 2019).

The global prevalence of childhood dyslipidaemia ranged from 1% to 23% among children and adolescents with healthy weight and up to 62% for those with an unhealthy weight status (Sharma, Coleman, Nixon, Sharples, Hamilton-Shield, Rutter & Bryant, 2019). Paediatric dyslipidaemia varies widely in different geographic locations. In Turkey, abnormal values were total-C=18.6%, TG=21.7%, HDL-C=19.7%, and LDL-C=13.7% (Elmaoğulları et al., 2015). In the United States, dyslipidaemia prevalence was 20.2% and is reported to affect one in five children and adolescents (8 – 17 years old) (Kit, Kuklina, Carroll, Ostchega, Freedman & Ogden, 2015). In Ghana, abnormal values were total-C=12.1%, TG=4.5%, HDL-C=28.4%, and LDL-C=9.2% (Lartey, Marquis, Aryeetey & Nti, 2018). Research in South Africa, a country of considerable sociodemographic and economic diversity, showed similar trends observed in Turkey and Ghana. Culture, ethnicity, SES, and dietary intake are only a few factors that may explain disease risk observed among South African children (Gooding et al., 2015).

A study conducted with 233 participants (6 - 18 years) in the rural community of Cofimvaba in the Eastern Cape reported abnormal serum concentrations: 1.3% total-C, 2.1% LDL-C, 7.3% TG, and 42.5% depressed HDL-C (Oldewage-Theron, Egal & Grobler, 2017). Another study by Negash, Agyemang, Matsha, Peer, Erasmus & Kengne (2017) measured 1559 children and youth, which comprised of Black African, Coloured and Caucasian learners (7 - 18 years) attending government schools in urban areas of the Western Cape and reported the following abnormal serum levels: 6.5% total-C, 5% TG, and 67.2% depressed HDL-C. A recent study described the unhealthy eating patterns among a cohort of South African children and adolescents who were reported to consume large quantities of processed foods such as fried bread dough (fat cakes), sweets and chips that are high in sugar and fat but low in micronutrients (Okeyo, Seekoe, de Villiers, Faber, Nel & Steyn, 2020; Wrottesley, Pedro, Fall & Norris, 2020). Prolonged consumption of these unhealthy food choices could cause overweight and obesity, which may later lead to dyslipidaemia. Thus, there is an urgent need to address the excess consumption of energy-dense processed foods, as these unhealthy foods may lead to serious health consequences.

In summary, a plethora of compelling evidence supports early signs of abnormally high cholesterol levels among children and adolescents, if they persist into adulthood, can cause premature organ damage associated with atherosclerosis and arteriosclerosis. Children and youth with genetic predispositions and those living with unhealthy lifestyles are at higher risk. However, early interventions that address lifestyle modifications may positively impact the future risk of developing dyslipidaemia. Thus, regular updates on the prevalence of childhood dyslipidaemia are needed to know the current health state of children and adolescents and to understand the consequences of conditions like atherosclerosis and arteriosclerosis with hypertension in children. The following section explores the prevalence of hypertension among children and adolescents and the implications thereof in later life.

2.2.3 Hypertension

Elevated BP or hypertension is a major modifiable risk factor for CVD and is associated with other CVD risk factors, such as obesity, impaired glucose tolerance and diabetes (Theodore, Broadbent, Nagin, Ambler, Hogan, Ramrakha, Cutfield, Williams, Harrington & Moffitt, 2015). Hypertension has become a global health problem affecting more than 1 billion adults, with the majority (two-thirds) living in LMICs (Zhou, Bentham, Di Cesare, Bixby, Danaei, Cowan, Paciorek, Singh, Hajifathalian & Bennett, 2017). In South Africa, hypertension has been listed as the sixth leading cause of death for three consecutive years (2016 - 2018) (Stats SA, 2018).

Besides predisposing genetic and environmental risk factors, unhealthy lifestyle habits have also led to the rise of NCDs (Falkner, 2015). The strong association between hypertension and factors like urbanisation, SES, and population growth are well established (Popkin, 2006; Zhou et al., 2017). For the majority, urbanisation and increased economic development have had a negative effect on lifestyle habits like reduced PA and unhealthy diets (high calories, salt, and fat), which have contributed to increased rates of obesity and overweight and other adverse cardiovascular outcomes in adults (Popkin & Doak, 1998; Monyeki, Kemper & Twisk, 2010; Kimani-Murage, 2013; Kagura, Ong, Adair, Pettifor & Norris, 2018). Excess weight gain, primarily increased visceral adiposity, is a significant contributor to hypertension, responsible for about 65 - 75% of the risk for primary hypertension (Hall, do Carmo, da Silva, Wang & Hall, 2015). Clinical evidence shows that simple measures to treat and prevent elevated BP in middle and old age, like maintaining a healthy BMI ($<25kg/m^2$), have proven effective in reducing the risk of primary prevention of hypertension (Theodore et al., 2015), although a significant burden remains.

Identifying the risk of elevated BP during earlier life years is another approach to mitigating the risk of hypertension. Extensive research shows that the origins of lifestyle-related NCDs, like hypertension, have been found to begin during critical developmental periods in the early years of life (Olsen, Angell, Asma, Boutouyrie, Burger, Chirinos, Damasceno, Delles, Gimenez-Roqueplo & Hering, 2016; Litwin & Feber, 2020). Hypertension is defined differently between adults and children and youth as the criteria in children and adolescents require correcting for age-, gender-, and height-specific reference thresholds (Hansen, Gunn & Kaelber, 2007; Falkner, 2015).

Hypertension is not as common among children and adolescents, but in recent years, elevated BP and related CVD health challenges have become increasingly prevalent among children and adolescents (Noubiap, Essouma, Bigna, Jingi, Aminde & Nansseu, 2017). The cause (aetiology) of primary hypertension is complex, but the main determinants are associated with BMI, waist circumference, sex, and other factors like low-birth weight and prematurity (Kagura et al., 2018; Amadi, Okeke, Ndu, Ekwochi, Nduagubam, Ezenwosu, Asinobi & Osuorah, 2019; Litwin & Feber, 2020). Modifiable risk factors like unhealthy diets, physical inactivity, psychosocial stress, tobacco use and obesity contribute to CVD morbidity and mortality (Yusuf, Hawken, Ôunpuu, Dans, Avezum, Lanas, McQueen, Budaj, Pais & Varigos, 2004; Falkner, 2015). However, other contributing factors, including poor maternal health and nutrition and a lack of primary healthcare, predispose children to premature organ damage and early vascular ageing (Kruger, Gafane-Matemane & Kagura, 2021). These factors lead to increased arteriosclerosis (arterial wall stiffness) and atherosclerosis (Nilsson, Lurbe & Laurent, 2008; Climie et al., 2021). Hence the regular screening of BP for early detection of hypertension risk is essential.

Worldwide the proportion of children and adolescents with hypertension ranges from 1% - 5% (Thompson, Dana, Bougatsos, Blazina & Norris, 2013; Amadi et al., 2019) but is higher among children who are overweight or obese, and 15% may be hypertensive (Sharma et al., 2019; Dionne, 2020). To mitigate the influence of weight on hypertension, the American Academy of Paediatrics developed normative charts based on overweight American children (Flynn, Kaelber, Baker-Smith, Blowey, Carroll, Daniels, de Ferranti, Dionne, Falkner & Flinn, 2017). Other high-income countries have also developed normative reference charts (Lurbe, Cifkova, Cruickshank, Dillon, Ferreira, Invitti, Kuznetsova, Laurent, Mancia & Morales-Olivas, 2009). Researchers like Xi et al. (2016) developed an internationally based reference chart using data from seven countries. However, no normative tables have been developed for the African paediatric population, which questions the use of internationally derived normative tables for African populations (Arnaiz, Müller, Seelig, Gerber, Bosma, Dolley, Adams, Degen, Gall & Joubert, 2022). The literature also presents substantial variability in the prevalence of paediatric elevated BP across Africa.

A systematic review investigated data from selected African countries (Nigeria, Côte d'Ivoire, Tunisia, South Africa, Seychelles, Uganda and Congo), which found that the prevalence of elevated BP varied widely across the different regions. Prevalence in the different regions was: Western region (0.2% - 24.8%), Southern region (4.5% - 21.2%), Northern region (4.8% - 19.7%), Eastern region (6.5% - 17.1%) and Central region (9.8% - 10.1%). According to this study, 12.7% (95% CI: 2.1 - 30.4) of children and adolescents were pre-hypertensive, and 5.5% (95% CI: 4.2 - 6.9) were hypertensive (Noubiap et al., 2017). In the 6 - 12 year age range, the overall prevalence of hypertension was 7% (95% CI: 0.4 - 20.0).

In South Africa, numerous studies conducted in different regions have reported a widely varying prevalence of hypertension among children and adolescents. In Johannesburg, Soweto results from the Birth to Twenty Cohort found a prevalence of 19% among 3273 participants measured between the ages of 5 and 18 years. (Kagura, Adair, Musa, Pettifor & Norris, 2015). In the North West province, in a sample of 310 14-year-old adolescents, the Physical Activity and Health Longitudinal (PAHL) Study found that 8.7% were pre-hypertensive and 4.3% were hypertensive (Awotidebe, Monyeki, Moss, Strydom, Amstrong & Kemper, 2016). In the Western Cape, Negash et al. (2017) measured 1559 participants ages 7 - 18 years, comprised of different ethnicities and reported a prevalence of 2.6% that were hypertensive. Two recent studies were conducted in Gqeberha in the Eastern Cape. The DASH study measured 785 participants aged 8 - 13 years and found that 18% of the cohort were hypertensive (Joubert, Walter, du Randt, Aerts, Adams, Degen, Gall, Müller, Nienaber, Nqweniso, des Rosiers, Seeling, Smith, Steinmann, Probst-Hensch, Utzinger, Pühse & Gerber, 2021) and in the KaziAfya study, 13.5% of the 853 participants aged 8 - 13 years were hypertensive (Nqweniso, Walter, du Randt, Aerts, Adams, Degen, Gall, Gani, Joubert & Müller, 2020).

In summary, childhood hypertension is a concern to public health. Therefore, efforts to address healthy dietary habits, weight management, and physical inactivity are needed to reduce the prevalence of paediatric hypertension. Greater attention should also be focused on detecting and preventing elevated BP during the early decades of life to curb the rise of cardiometabolic risk factors that persist into adulthood (Climie et al., 2021). Hypertensive children are also likely to present with comorbidities like insulin resistance (Serbis, Giapros, Kotanidou, Galli-Tsinopoulou & Siomou, 2021). Thus, the following subsection reviews the literature on hyperglycaemia and identifies the incidence of hyperglycaemia among children and adolescents on a global and national scale.

2.2.4 Hyperglycaemia

Diabetes mellitus is a chronic metabolic disease characterised by elevated blood glucose levels, referred to as hyperglycaemia. Left untreated over a prolonged period, it can lead to blindness, kidney failure, heart attacks, stroke and lower limb amputation . This metabolic imbalance results from defective mechanisms between insulin synthesis and release and the tissue's response to insulin (Galicia-Garcia, Benito-Vicente, Jebari, Larrea-Sebal, Siddiqi, Uribe, Ostolaza & Martín, 2020). More than 90% of global diabetic cases are T2D, caused by impaired insulin secretion of the pancreatic beta cells or the inadequate response of insulin-sensitive tissues to insulin (Roden & Shulman, 2019). In 2018, about 405.6 million people were living with T2D, which is estimated to increase to an alarming 510.8 million in 2030 (Basu, Yudkin, Kehlenbrink, Davies, Wild, Lipska, Sussman & Beran, 2019). Although many cases tend to go undiagnosed, according to the International Diabetes Federation (IDF), about 50% of diabetic patients worldwide are undiagnosed, and most (75%) diabetic cases occur in LMICs (International Diabetes Federation, 2021). In 2019, approximately 1.5 million mortalities were caused by diabetes, and almost 50% were premature mortalities (before the age of 70 years) (WHO, 2019). The health of children and youth is a concern if policies and lifestyle interventions are not put in place; it is postulated that the next generation will be the first with children who have a shorter lifespan than their parents (Serbis et al., 2021).

Risk factors for T2D include genetics and environmental factors. Predisposition, for example, to factors like ethnicity and heredity are non-modifiable; however, convincing evidence exists that T2D is preventable if modifiable risk factors like obesity, physical inactivity and poor dietary habits are improved (Schellenberg, Dryden, Vandermeer, Ha & Korownyk, 2013; Kolb & Martin, 2017). Children and youth with T2D generally have families with a high incidence of T2D in relatives of the first and second generation (Copeland, Zeitler, Geffner, Guandalini, Higgins, Hirst, Kaufman, Linder, Marcovina & McGuigan, 2011; Constantino, Molyneaux, Limacher-

Gisler, Al-Saeed, Luo, Wu, Twigg, Yue & Wong, 2013). Furthermore, the prevalence of T2D occurs in all ethnicities but varies depending on heredity, and geographic location, as the overall incidence of T2D is higher in populations such as Africans, African-Americans, American Indians, Canadian First Nations, Latinos, Indigenous Australians, and Pacific Islanders (Zeitler, Arslanian, Fu, Pinhas-Hamiel, Reinehr, Tandon, Urakami, Wong & Maahs, 2018; Galicia-Garcia et al., 2020). Apart from non-modifiable genetic predispositions, studies conducted in Europe and the United States have reported that youth-onset T2D is more prevalent in populations of low SES and education status (Copeland et al., 2011). Whereas in countries like China (Fu & Prasad, 2014) and India (Prasad, 2011), the condition is more prevalent among affluent children (Zeitler et al., 2018), this demonstrates the intricate interactions of T2D risk factors.

T2D was previously described in studies of adults; however, in recent decades, the incidence of T2D has increased among children and youth (Haines, Wan, Lynn, Barrett & Shield, 2007; Liu, Lawrence, Davis, Liese, Pettitt, Pihoker, Dabelea, Hamman, Waitzfelder & Kahn, 2010; Nadeau, Anderson, Berg, Chiang, Chou, Copeland, Hannon, Huang, Lynch & Powell, 2016). While the upsurge of T2D risk among children and adolescents has been observed with the rise in paediatric obesity, it may seem that the onset of T2D has not been as prevalent among children. Thus, researchers question whether T2D may be considered an epidemic among children (Goran, Davis, Kelly, Shaibi, Spruijt-Metz, Soni & Weigensberg, 2008; Serbis et al., 2021). There is, however, evidence of a sudden increase in T2D in early adulthood, which suggests a long latency period between the onset of obesity and the later appearance of T2D in early adulthood (Serbis et al., 2021). Therefore, it is accepted that T2D is emerging as a concern of public health (Kasmauski, 2018), and strategies to halt the onset of T2D should be aimed at promoting prevention by means of a ‘diabetes-protective lifestyle’ (Kolb & Martin, 2017).

The pathogenesis of T2D is said to be a complex interaction between behavioural, environmental, and metabolic factors (Galicia-Garcia et al., 2020). While genetic and ethnic predispositions cannot be changed, extensive evidence points to excess weight gained during pregnancy, leading to an increased risk of childhood obesity and T2D in offspring (Hivert, Rifas-Shiman, Gillman & Oken, 2016; Soepnel, Nicolaou, Slater, Chidumwa, Levitt, Klipstein-Grobusch & Norris, 2021). A study by

Lahti-Pulkkinen, Bhattacharya, Wild, Lindsay, Räikkönen, Norman, Bhattacharya & Reynolds (2019) reported that the incidence of T2D in children born to overweight and obese women was 3.5 times higher than the 1.4-fold incidence of T2D among children born to normal-weight mothers. Sex seems to be another genetic risk factor associated with T2D, as adolescent girls were found to be 1.3 to 1.7 times more likely to develop T2D than boys (Dabelea, Mayer-Davis, Saydah, Imperatore, Linder, Divers, Bell, Badaru, Talton & Crume, 2014). Puberty also plays a central role in T2D due to puberty-induced insulin resistance - physiologically increased insulin resistance in adolescence (Astudillo, Tosur, Castillo, Rafaey, Siller, Nieto, Sisley, McKay, Nella & Balasubramanyam, 2021). Puberty-induced insulin resistance occurs around the median age of 13.5 years, which is the peak of physiologic puberty insulin resistance (Copeland et al., 2011; Astudillo et al., 2021). Therefore, testing of clinical diabetic cases among children and adolescents should be after the age of ten years or after puberty onset (whichever comes first) (Zeitler et al., 2018).

The estimated prevalence of T2D is said to be increasing, although T2D onset is not typical among children and adolescents. A global prevalence of youth-onset T2D was recently reported by Lynch, Barrientos-Pérez, Hafez, Jalaludin, Kovarenko, Rao & Weghuber (2020). This study found the highest reported incidence of T2D in China (520 cases per 100,000) and the United States (212 cases per 100,000), and the lowest was found in Denmark (0.6 cases per 100,000). Few studies in South Africa have reported on youth-onset T2D. A study conducted in the rural parts of the Eastern Cape reported a prevalence of 10.3% for hyperglycaemia in a sample of 233 participants aged 6 - 18 years (Oldewage-Theron et al., 2017). Based on a recent study, the incidence of T2D seems to be more prevalent in higher SES groups (Mutyambizi, Booysen, Stokes, Pavlova & Groot, 2019). However, many diabetic cases in LMICs seem to go undiagnosed (Berry, Parker, Mchiza, Sewpaul, Labadarios, Rosen & Stokes, 2017).

In summary, the pathogenesis of youth-onset T2D is complex and aggressive, and if left undiagnosed and untreated, this condition can cause serious long-term complications. Therefore, strategies should be aimed at obesity prevention through dietary modification and increased PA, given the aetiology of T2D and its association with increased body fat and MetS (Noubiap, Nansseu, Lontchi-Yimagou, Nkeck, Nyaga, Ngouo, Tounouga, Tianyi, Foka & Ndoadoumgue, 2022). Risk factors such as central obesity, hyperglycaemia, hypertension, and dyslipidaemia largely contribute to metabolic changes, thereby increasing NCD risk. These metabolic risk factors are also known to cluster, which causes physiological changes that increase the risk for CVD and T2D. This condition was commonly diagnosed among adults: however, the prevalence of MetS has become increasingly evident among children and adolescents. Therefore, the following subsection expands on the aetiology and diagnosis of MetS and the global and national prevalence thereof among children.

2.2.5 Metabolic Syndrome

The clustering of CVD risk factors has been well documented. Reaven (1988) described this specific grouping of cardiometabolic risks as 'syndrome x', which later evolved into MetS (Magge et al., 2017). The MetS cluster of cardiometabolic abnormalities (central obesity, hypertension, elevated TG, low HDL-C and high blood glucose) occurs together more often than by chance and increases the risk of CVD and T2D (Reaven, 1988; Gregory, 2019). MetS may be defined as dysregulated cellular metabolism, leading to insulin resistance (Shulman, 2014; DeBoer, 2019) and increased risk of diabetes and CVD (Magge et al., 2017). Ageing, hormones, sedentary behaviour, genetics, unhealthy dietary habits and obesity have been implicated in the pathogenic process of Mets (Reaven, 1988). The dramatic rise in childhood obesity has caused NCD risk factors to become increasingly prevalent among children and adolescents, as MetS has been observed in young populations (Cook, Weitzman, Auinger, Nguyen & Dietz, 2003; Cruz, Weigensberg, Huang, Ball, Shaibi & Goran, 2004; Weiss, Dziura, Burgert, Tamborlane, Taksali, Yeckel, Allen, Lopes, Savoye & Morrison, 2004; Zimmet, Alberti, Kaufman, Tajima, Silink, Arslanian, Wong, Bennett, Shaw & Caprio, 2007; Weihe & Weihrauch-Blüher, 2019).

Diagnostic criteria for MetS were first defined for adults, which were based on clear guidelines (the presence of three or more risk factors, as mentioned earlier, are generally predictive of MetS). Diagnostic criteria for children and adolescents have been attempted by organisations like the National Cholesterol Education Program (NCEP) (Cook et al., 2003), the National Health and Nutrition Examination Survey III (NHNES III) (de Ferranti, Gauvreau, Ludwig, Neufeld, Newburger & Rifai, 2004), and the International Diabetes Federation (IDF) (Alberti, Zimmet & Shaw, 2005; Zimmet et al., 2007). Table 1 is adapted from Weihe & Weihrauch-Blüher (2019) and provides detail of selected diagnostic criteria for MetS in children and adolescents. According to the criteria below, MetS can be diagnosed if ≥3 of the risk factors is present.

Table 1: Comparison of selected diagnostic criteria for MetS in children and adolescents.

	Cook et al. (2003)	Weiss et al. (2004)	de Ferranti et al. (2004)	Zimmet et al. (2007)
Criteria	NCEP	NCEP and WHO		IDF
WC	≥ 90th percentile	-	≥ 75th percentile	≥ 90th percentile
BMI	-	z-score ≥2	-	-
Systolic BP	≥ 90th percentile	≥ 95th percentile	≥ 90th percentile	≥ 130 mm Hg
Diastolic BP	≥ 90th percentile	≥ 95th percentile	≥ 90th percentile	≥ 85 mm Hg
Glucose	FG ≥ 6.11 mmol/L	IGT (ADA)	FG ≥ 6.11 mmol/L	FG ≥ 5.6 mmol/L
Total-C	-	-	-	-
TG	≥ 1.24 mmol/L	≥ 95th percentile	≥ 1.1 mmol/L	≥ 1.07 mmol/L
HDL-C	≤ 1.03 mmol/L	≤ 5th percentile	≤ 1.17 mmol/L(girls), ≤ 1.3 mmol/L (boys)	≤ 1.03 mmol/L
LDL-C	-	-		-
Age range for diagnostic criteria	12 to 19 yrs	4 to 20 yrs		• 6 to >10 yrs • 10 to >16 yrs • ≥16 yrs
Prevalence per BMI category	• Overall: 4.2% • Overweight/obese: 8.7%	• Mod. obese: 38.7% • Sev. obese: 49.7%		• Overweight: 0.4% • Obese: 3.6

Notes: ADA=American Diabetes Association, BMI=body mass index, BP=blood pressure, HDL-C=high-density lipoproteins, IDF= International Diabetes Federation, IGT=Impaired Glucose Tolerance, LDL-C=low-density lipoproteins, Mod=moderately, NCEP=National Cholesterol Education Program, Yrs=years, Sev=severely, Triglycerides=TG, Total-C=total cholesterol, WC=waist circumference.

Applying these MetS definitions has not been as straightforward; thus, to date, there is no consensus on how to define MetS among children and adolescents. The controversy lies in the MetS definitions' cut-offs and several physiological limitations that make these measures tricky. Factors such as age (Aradillas-Garcia, Rodriguez-Moran, Garay-Sevilla, Malacara, Rascon-Pacheco & Guerrero-Romero, 2012), puberty (Lee, 1980; Aradillas-Garcia et al., 2012; Eissa, Mihalopoulos, Holubkov, Dai & Labarthe, 2016), ethnicity (Walker, Gurka, Oliver, Johns & DeBoer, 2012), gender (Lee, Gurka & DeBoer, 2016) and geographical location (DeBoer, Filipp & Gurka,

2019) have been found to cause variation and influence the MetS prevalence. The numerous definitions of paediatric MetS thus lead to inconsistent results. Researchers cannot make direct comparisons between data sets, and clinicians are left without a clear direction for risk assessment and diagnosis (Ahrens, Moreno, Mårild, Molnar, Siani, De Henauw, Böhmann, Günther, Hadjigeorgiou & Iacoviello, 2014).

Tailor, Peeters, Norat, Vineis & Romaguera (2010) conducted a systematic review to provide a worldwide update on the prevalence of MetS among children and adolescents, which ranged from 1.2% to 22.6%. The included studies used IDF, NCEP, and a modified WHO definition. However, none of the included studies was from Africa. Noubiap et al. (2022) recently published a study showcasing the global burden of MetS from 44 countries in 13 regions but seemingly no included studies from South Africa or Africa. Among children (6 - 12 years), Noubiap et al. (2022) reported the prevalence of MetS was 2.2% (95% CI: 1.4 - 3.6) in high-income countries, 3.1% (95% CI: 2.5 - 4.3) in upper-middle-income countries, 2.6 % (95% CI: 0.9 - 8.3) in LMICs and 3.5% (1.0 - 8.0) in low-income countries. Meanwhile, Bitew, Alemu, Ayele, Tenaw, Alebel & Worku (2020) conducted a systematic review and meta-analysis of MetS in LMICs. The MetS prevalence among the general population of children and youth was 3.98% using the IDF definition, 6.71% using the NCEP and 8.91% with the de Ferranti et al. (2004) criteria. The incidence of MetS was much higher for the overweight and obese population. The reported prevalence was 24.09%, 36.5% and 56.32% using the IDF, NCEP and de Ferranti et al. (2004) criteria. In addition, Bitew et al. (2020) reported a pooled prevalence of MetS in Africa (6.03% to 11.28% using the IDF definition; and 6.71% to 7.91% using the NCEP definition), which only included two studies from South Africa. To the researcher’s knowledge, two South African studies have investigated the prevalence of METs in South Africa. The first study was conducted in Cape Town, Western Cape, by Matsha, Hassan, Bhata, Yako, Fanampe, Somers, Hoffmann, Mohammed & Erasmus (2009). They did a comparison study and reported a 6.5% prevalence using the NCEP definition and only 1.9% using the IDF definition among 10-16-year old learners. The second study was conducted in the rural parts of Mthatha in the Eastern Cape, where Sekokotla, Goswami, Sewani-Rusike, Iputo & Nkeh-Chungag (2017) identified a MetS prevalence of 5.9% using the adjusted NCEP definition among 13-18-year old adolescents.

An alternative to applying a MetS definition among children is calculating a clustered risk score (CRS) based on CVD risk factors. Clustering of CVD risk factors has also been proven to be a better measure of CVD health in children than single risk factors (Andersen, Wedderkopp, Hansen, Cooper & Froberg, 2003; Andersen, Harro, Sardinha, Froberg, Ekelund, Brage & Anderssen, 2006). As previously mentioned, several of these risk factors have origins during sensitive developmental periods (maternal gestational diabetes or low birth weight), which are associated with the development of obesity or other MetS components later in life (Magge et al., 2017). Thus, a CRS provides a 'physiological' variable that accounts for risk as gradual changes and better reflects the continuum between an unhealthy and a healthy metabolic profile. Such a continuous variable is particularly useful for research purposes and the evaluation of interventions. Researchers such as Andersen et al. (2006) and Ekelund, Anderssen, Froberg, Sardinha, Andersen, Brage & Group (2007) constructed a CRS by summing the z-scores of the risk factors. Others, such as Peterson, Liu, IglayReger, Saltarelli, Visich & Gordon (2012), used principal component analysis (PCA) to calculate the CRS. The PCA method calculates the factor coordinates (multipliers) for each risk factor instead of assuming that all risk factors have an equal contribution to the CRS. Thus, the inconsistent standardised diagnostic criteria for children make it difficult to compare prevalence rates or draw conclusions based on previous research findings. As a result, the prevalence of paediatric MetS or clustered CVD risk is relative to the diagnostic criteria used.

Literature shows that increased weight status in early childhood significantly increases the risk of cardiometabolic comorbidities in later life (DeBoer, 2019). The treatment of overnutrition is grounded in lifestyle modification which includes a balanced diet and increased PA. For children, 60 min MVPA per day has been shown to reduce disease risk (WHO, 2017; Baran et al., 2020). Researchers have questioned whether achieving the daily 60 min of MVPA guideline would prevent the clustering of CVD risk factors in children (Andersen et al., 2006; Füssenich, Boddy, Green, Graves, Foweather, Dagger, McWhannell, Henaghan, Ridgers & Stratton, 2015). Two recent cross-sectional studies by Müller, Schindler, Adams, Endes, Gall, Gerber, Htun, Nqweniso, Joubert & Probst-Hensch (2019a) and Nqweniso, Walter, du Randt, Adams, Beckmann, Degen, Gall, Joubert, Lang & Long (2021) have tested the independent association of CRF and PA with clustered CVD risk factors among South

African children. Both studies were conducted in Gqeberha, Eastern Cape. Müller et al. (2019a) measured a cohort of 650 children aged 10 - 15 years old (mean age: 12.4±0.9 years), while Nqweniso et al. (2021) tested 832 Gr 1 - 4 children (mean age: 8.3±1.4 years). Both studies reported a decrease in the clustered CVD risk of children with higher CRF or MVPA.

In summary, the lack of consensus on paediatric diagnostic criteria (and the physiological limitations) makes it difficult to interpret the prevalence of MetS among children and adolescents. Furthermore, this review identifies a gap in existing research as limited data is available on the incidence of MetS among South African children and youth. More research on South African populations is needed to support the development of evidence-based preventative strategies for MetS among children and youth.

This section has provided a literature review on major NCDs such as undernutrition, overweight and obesity, dyslipidaemia, hypertension, and hyperglycaemia and illustrated the global and national prevalence of NCDs among children and adolescents. One way to reduce the incidence of chronic disease among children and youth is to modify behaviours like physical inactivity and dietary habits. Thus, the following section provides insights into the benefits of PA and guidelines for PA and CRF to promote children's health and wellbeing.

2.3 Physical Activity and Cardiorespiratory Fitness

The rise of diet-related NCDs like obesity, dyslipidaemia, hypertension, and hyperglycaemia all share a familiar modifiable risk factor profile of poor diet (increased calorie-dense foods and reduced fruit and vegetable intake) and physical inactivity. PA plays a vital role in the functioning capacity of every individual. In the prevention and management of NCDs, PA helps to reduce sympathetic activation and BP, improves insulin sensitivity and lipid profile, and assists in weight reduction through the expenditure of excess energy from adipose tissue (Baran et al., 2020).

PA is defined as bodily movements produced by the contraction of skeletal muscles, causing a rise in energy expenditure above the resting metabolic rate (one metabolic equivalent) (WHO, 2017; Thivel, Tremblay, Genin, Panahi, Rivière &

Duclos, 2018). For many, PA can be an unstructured activity performed during leisure time. For children, PA constitutes a large variety of options and includes activities that involve free play, games, sports, PE, and even household chores. Evidence confirms that PA in children and youth is associated with improved physical, mental, cognitive, and social outcomes (Boreham & Riddoch, 2001; Bull et al., 2020). Recent studies have found that children with higher PA levels were less likely to be obese (Roman-Viñas et al., 2016) and more likely to have better motor skills (van Niekerk et al., 2016) and quality of life (Salvini, Gall, Müller, Walter, du Randt, Steinmann, Utzinger, Pühse & Gerber, 2017). The systematic review conducted by Janssen & LeBlanc (2010) already affirmed the health benefits associated with regular PA for schoolchildren: the more time dedicated to PA, the greater the health benefit. Previous World Health Organisation (WHO) guidelines required children and youth (5 - 17 years) to participate in "at least" 60 min MVPA per day (WHO, 2017). However, the new WHO 2020 guidelines recommend an "average of" 60 min MVPA per day for children and youth (5 - 17 years) (Bull et al., 2020). WHO guidelines also specify that more time should be spent in aerobic MVPA activities, thereby increasing CRF (WHO, 2017; Bull et al., 2020).

CRF is defined by VO_2 max, which reflects the body's capacity to transport oxygen to the exercising muscles (Rowland, 2007). The literature has shown a strong relationship between CRF and mortality from coronary heart disease among adults (Boreham & Riddoch, 2001; Kavanagh, Mertens, Hamm, Beyene, Kennedy, Corey & Shephard, 2003). Evidence of relationships between VO_2 max and CVD risk factors is not as compelling in children, but the relationships change from adolescence to adulthood (Rowland, 2007). Rowland (2007), among other researchers (Kemper, Twisk, Koppes, van Mechelen & Post, 2001), has postulated a downward trend in VO_2 max in children and youth as a result of declines in PA and increased body fat content.

Globally, more than 80% of school-age children do not meet the average of at least 60 min MVPA per day (WHO, 2017). WHO has initiated global efforts to reduce the prevalence of insufficient PA (10% relative reduction) by 2025, but this target may not be met if global inactivity continues (Guthold, Stevens, Riley & Bull, 2018). The Global Matrix 4.0 represents 57 countries and is the most extensive compilation of children's and adolescents' PA characteristics. The Global Matrix 4.0 affirms that the PA of children and adolescents is still a serious public health concern worldwide.

Estimates show that only one-third (27% - 33%) of children and adolescents meet the recommended amount of PA (Healthy Active Kids Global Alliance, 2022). In South Africa, the 2018 HAKSA Report Card found that 51.7% of children and adolescents (3 - 18 years) met the recommendation for PA, averaging between 57 and 65 min of MVPA per day (Shilubane, Ruiter, van den Borne, Sewpaul, James & Reddy, 2013; Wushe, Moss & Monyeki, 2014; Roman-Viñas et al., 2016; Draper et al., 2018). The recently published 2022 HAKSA Report Card has shown more positive estimates, with 60% to 73% of South African children and adolescents meeting the 60 min MVPA per day recommendation (Naidoo et al., 2022).

It is important to note that PA participation will likely decrease as children transition to adulthood. Various factors influence PA behaviours. South African studies have reported that girls (Mlangeni, Makola, Naidoo, Chibi, Sokhela, Silimfe & Mabaso, 2018), children with less-educated parents (McVeigh et al., 2004; Muthuri, Onywera, Tremblay, Broyles, Chaput, Fogelholm, Hu, Kuriyan, Kurpad & Lambert, 2016), children living in urban areas (McVeigh et al., 2004; Hanson, Munthali, Micklesfield, Lobelo, Cunningham, Hartman, Norris & Stein, 2019) and those living in unsafe communities with high traffic risks (Uys, Broyles, Draper, Hendricks, Rae, Naidoo, Katzmarzyk & Lambert, 2016; Naidoo et al., 2022) were less likely to be physically active. Furthermore, children of higher SES were more likely to participate in PE than those of lower SES (McVeigh et al., 2004; Micklesfield et al., 2014).

In summary, participation in regular PA provides numerous physiological and psychosocial health benefits and has proven effective in preventing and managing NCDs (Anderson & Durstine, 2019). However, many children and adolescents engage in insufficient PA with increased sedentary behaviours, which are not conducive to curbing the exponential rise of NCDs. Schools provide an easy and accessible setting to promote PA because of its relatedness to PE, where children can learn the skills, knowledge, and values for lifelong PA participation (Stroebel et al., 2016a; Yuksel, Şahin, Maksimovic, Drid & Bianco, 2020). However, across the world, the state and status of PE are far from ideal (Hardman et al., 2013; Goslin, 2020). Therefore, the following section provides context on the state of PE from a global and South African perspective. The discussion below also provides a context on the history of PE in South Africa and the challenges faced by schools, specifically in underserved communities.

2.4 Physical Education

In the first two decades of their lives, children spend a large portion of their day at school, making the school setting ideal for promoting PA participation and all-round healthy lifestyles. Schools also offer an accessible environment to promote PA participation for all children, irrespective of their social background. Promoting regular PA among children can be a complex and challenging endeavour. Therefore, a strategy to address physical inactivity is to create opportunities for children to build their knowledge and movement skills and instil positive values and attitudes toward PA. Opportunities to influence children's lifestyles with positive PA habits are fostered during PE classes. PE during primary school is especially critical for children (Pangrazi & Beighle, 2019). The United Nations Educational, Scientific and Cultural Organisation (UNESCO) defines PE as "a learning experience offered to all children and youth to help them acquire the psychomotor skills, cognitive understanding, and social and emotional skills that they need to lead a physically active life" (McLennan & Thompson, 2015). To elaborate on this definition: PE aims to teach children to discover, master, and refine a wide variety of movement skills, thus teaching children to move, which defines the '*physical'* component of PE (Van Deventer, 2002). *'Education'* implies a transfer of knowledge and understanding (cognitive) learning about movement of the body; while learning to develop personal behaviour and meaning (affective) as well as social interaction and cultural values through participation (Van Deventer, 2002). According to Cleland Donnelly, Mueller & Gallahue (2016), *'failure to develop and refine movement skills during the critical periods often leads to children's frustration and failure during adolescence and adulthood.'* Therefore, this negative association with movement may lead to a decline in activity as children may become self-conscious of their poor movement patterns and fear being taunted by their peers (Van Deventer, 2002; Cleland Donnelly et al., 2016).

Global perspectives on the quality of PE show that its apparent benefits do not seem to be enough to ensure its delivery and implementation (Hardman et al., 2013; Goslin, 2020). Despite high-level advocacy at global forums, there remains a significant gap as policy intent, reports, and action plans do not lead to the implementation of PE (Goslin, 2020). The final report of the Worldwide Survey of School PE Hardman et al. (2013) identifies several concerns, such as reductions in time allocation, inadequate facilities and equipment, poor teacher training and provision of professional development, curriculum deficiencies, assessment practices and low perceived value of PE. These are challenges that are also all too familiar within South Africa.

PE in South Africa has undergone four curriculum reforms as political agendas did not match the realities within the classroom. PE was first a non-examinable stand-alone subject before 1994, taught by specialist PE primary school teachers who were trained at national teacher-training colleges (Stroebel et al., 2016a). However, while PE was a recognised and approved subject, most South African children received little to no purposeful participation in PE (Rajput & Van Deventer, 2010). In the former years of apartheid, each ethnic group had its own education department responsible for its syllabus; however, race inequalities meant that children of different ethnicities had varied opportunities for PE participation. Revising the apartheid education system was a necessary process to correct these inequalities. Nonetheless, the DoE was ill-prepared for the mammoth task ahead of them. Against recommendations, PE lost its stand-alone status post-1994 (Cleophas, 2014), and teacher training colleges were gradually phased out, and the training of primary school teachers moved to universities (Rajput & Van Deventer, 2010).

In 1997, Curriculum 2005 (C2005) introduced outcomes-based education (OBE), which saw the former stand-alone PE subject amalgamate with other learning outcomes into the diverse Life Orientation (LO) learning area taught by generalist teachers (Rajput & Van Deventer, 2010; Stroebel et al., 2016a). In the General Education and Training (GET) Band (Gr R-9), PE (referred to as physical development and movement) was one of five learning outcomes (health promotion, social development, personal development and orientation to world of work) (Van Deventer, 2009). Whereas in the Further Education Training (FET) Band, PE formed part of four learning areas (personal wellbeing, citizenship education and career and career choices) (Rajput & Van Deventer, 2010). However, teachers were not adequately equipped and did not respond well to the OBE system's outcomes rather than aims, objectives, and assessment criteria. Primary school teachers, in particular, also struggled to confidently deliver the PE content (Van Deventer & Van Niekerk, 2009).

Thus, a revision of the C2005 was mandated, and the Revised National Curriculum Statement (R-NCS) was launched in 2002 (Stroebel et al., 2016a). Not long after (2009), the curriculum had undergone yet another revision. By 2011, the Curriculum and Assessment Policy Statement (CAPS) was implemented and is still in effect today (Stroebel et al., 2016a). The CAPS committee developed a curriculum for each subject. PE now forms part of Life Skills (LS) for GET (Gr R - 6) and LO for FET (Gr 7 - 12). LS in the foundation phase (Gr R - 3) comprises four learning areas (beginning knowledge, personal and social wellbeing, PA and creative arts) and is taught for six hours per week, of which PE is allocated two hours per week (Department of Basic Education, 2011c). In the intermediate phase (Gr: 4 - 6), LS consists of three learning areas (personal and social wellbeing, PA and creative arts), taught for four hours per week, and PE is allotted one hour per week (DBE, 2011b). In the senior phase (Gr: 7 - 9) (DBE, 2011b) and FET phase (Gr: 10 - 12) (DBE, 2011a), LO is prescribed two hours per week, of which one is given to PE.

In the South African school curriculum, PE has not been prioritised as part of LO. In a 12-country study, South Africa had the highest percentage of learners (32.1%) who were not participating in PE (Silva et al., 2018). This multinational, cross-sectional study comprised 5874 children (9 - 11 years) from LMICs (Brazil, Colombia, India, Kenya, and South Africa) and high-income (Australia, Canada, China, Finland, Portugal, the United Kingdom, and the United States) sites. This study found that children from LMICs who participated in at least one to two PE lessons per week were more likely to achieve the 60 min MVPA per day and spend less time in sedentary behaviour than those who did not engage in PE lessons (boys: odds ratio (OR) = 1.80, 95% CI = 1.17 - 2.77; girls: OR = 2.17, 95% CI = 1.44 - 3.27). Furthermore, girls from LMICs who took part in at least one to two PE lessons per week were more likely to spend time in MVPA on weekends (OR = 1.86, 95% CI = 1.17 - 2.95). These findings are encouraging, as this demonstrates that children are likely to be active if given opportunities to participate in PE classes.

A recent national study investigated the state and status of PE across lower (Quintiles 1 - 3) and higher-income (Quintiles 4 - 5) South African public schools.[1] This study was commissioned by the United Nations Children's Fund (UNICEF) in partnership with the South African Department of Basic Education (DBE) and

[1] In South Africa, schools are ranked into five quintiles, from Quintile 1, the poorest, to Quintile 5, the least poor: Q1-Q3 are non-fee-paying schools

conducted by the South African University PE Association (SAUPEA) (Burnett, 2021). Findings showed that 62.3% of the 175 PE teachers (representing lower- and higher-income schools) were non-specialists (Burnett, 2021). Moreover, 51.3% were interested in PE, and only 42% of teachers felt equipped to teach PE (Burnett, 2020).

Generalist teachers do not have the content knowledge or pedagogical understanding to teach PE adequately, but they are still expected to deliver the content. Less than half (45%) of non-specialist teachers in Quintile 4 - 5 schools implement PE (Stroebel, 2020; Burnett, 2021). However, these schools (20% of Quintile 4 – 5) have the financial resources to contract qualified coaches or specialised service providers to deliver extramural sports coaching and PE (Burnett, 2021). NGO and/or volunteer services have created opportunities for outsourcing PE classes, with 15% of Quintile 2 - 3 schools reporting having access to these opportunities (Burnett, 2021), although these external resources are funding-dependent and may wither in the absence of funds. In most low-income schools, classroom teachers are responsible for teaching PE (94.7% in Quintile 1 and 65% in Quintile 2 - 3 schools) (Burnett, 2020). Therefore, the delivery of PE in South Africa remains unequal.

Underserved schools are severely constrained by underdeveloped infrastructure, insufficient physical resources and professional development, as well as hostile and unsupportive environments (Burnett, 2020). Without the foundational knowledge or pedagogical understanding of PE, generalist PE teachers in underserved communities have had to rely on their sports knowledge to deliver some sort of movement activity in their PE lessons. Results from the national study by Burnett (2021) showed that PE delivery in under-resourced schools has an over-emphasis on sport-focused approaches with an offering of soccer for boys or netball for girls. Although children are being exposed to movement, this scenario is not ideal as it may exclude children who are less proficient in their movement patterns, moreover, it is not supportive of quality PE (Burnett, 2020). Meanwhile, other generalist teachers were reported to implement a self-learning or non-teaching approach and may 'send children out to play while they do administration' during the PE curriculum time (Burnett, 2021). These approaches highlight the inadequacies of the PE being taught in underserved schools.

The literature presented in this section underscores the lack of equity in the delivery of PE in South Africa due to the economic wealth gap between the various quintile schools. Generalist teachers in high-income schools (private and quintile 5 schools) may enjoy resources like specialist teachers to implement PE. Meanwhile, generalist teachers in underserved schools (quintile 1 to 3) are compelled to deliver PE while struggling with overcrowded classes and long hours of administrative duties, not to mention the surrounding communities' systemic challenges and social ills. A universal and all-purpose solution may also not be the answer, as each social context is unique; this also raises the question of support strategies that generalist PE teachers (especially those in underserved communities) may need to deliver PE. Strategies to improve the delivery of PE and increase PA participation may be addressed through school-based PA interventions. The section to follow reviews school-based health interventions aimed at promoting PA and health. This section also elaborates specifically on school-based health interventions implemented in low-income settings.

2.5 School-based Health Interventions

Schools provide an ideal setting to engage with children as they may establish lifestyle behaviours during a stage of their life when they are highly impressionable. Schools also offer an environment to journey with those at higher risk of NCDs, where greater attention can be given from a young age to promote healthy and active lifestyles grounded in the knowledge, skills and values of the movement (Yuksel et al., 2020). Schools also offer the opportunity for a wider reach of children regardless of social background.

There is extensive evidence to support a widespread range of PA-promoting and health-promoting strategies in schools (Seljebotn, Skage, Riskedal, Olsen, Kvalø & Dyrstad, 2019; Norris, van Steen, Direito & Stamatakis, 2020; Milton et al., 2021). The intervention strategies may include modifying the school environment, active classrooms, activities during school breaks, extracurricular activities or promoting active transport to and from school, and PE short courses, to name a few (Milton et al., 2021). Nonetheless, intervention studies report varying efficacy outcomes, which creates conflicting evidence on whether intervention efforts are effective in increasing daily time spent in PA or if the benefits can be sustained beyond the intervention period (Love, Adams & van Sluijs, 2019). Determining the efficacy of different intervention studies can be complicated due to the heterogeneous samples, the varied measured health outcomes, and the variation in the testing methodologies, not to mention the various components of the intervention. Thus, the comparison of findings must be examined and interpreted with caution. High-income countries like America and Australia have also begun to explore using internet-based interventions to prevent obesity (Nollen, Mayo, Carlson, Rapoff, Goggin & Ellerbeck, 2014), promote PA (Smith, Morgan, Plotnikoff, Dally, Salmon, Okely, Finn & Lubans, 2014) and to provide teachers with standardised online learning (Lonsdale, Sanders, Parker, Noetel, Hartwig, Vasconcellos, Lee, Antczak, Kirwan & Morgan, 2021). Findings from the teacher's online intervention showed modest improvements in the learner's CRF and PA. This low-cost intervention also showed potential for scalability to improve children's health at the population level (Hartwig, Sanders, Vasconcellos, Noetel, Parker, Lubans, Andrade, Ávila-García, Bartholomew & Belton, 2021).

A global review of the effectiveness of school-based RCT interventions included studies from 20 countries across Europe, the United States, Oceania, Argentina, Canada, Chile and Mexico (Nally, Carlin, Blackburn, Baird, Salmon, Murphy & Gallagher, 2021). About 70% of the studies included multi-component interventions that targeted change in *obesity-related behaviours* such as diet, PA and sedentary behaviour. The strategies included in these multi-component interventions comprised school environment adaptations, extra-curricular PA, modified PE lessons, interactive drama sessions, gardening, cooking workshops, educational sessions, counselling and increased opportunities to be physically active like active homework and break times as well as PA clubs. Meanwhile, interventions that only comprised of a single component, either targeting change in PA (e.g. active in-class lessons, brisk walking during school, school environment modifications and education workshops) or nutrition (e.g. adaptations to the school tuckshop, salad bars, health fairs, providing free fruit, family newsletters, school wellness committees and education workshops). Findings from this meta-analysis showed significant effects on BMI in favour of the intervention group, but results were inconclusive for sedentary behaviour, nutrition behaviour and MVPA compared to the control group. It was noteworthy that the single-component interventions were more effective at modifying *obesity-related behaviours* than the multi-component interventions (including diet, PA and change in sedentary behaviour). It is plausible that implementing too many intervention strategies at once may be burdensome for the schools. Perhaps sequencing the delivery of the intervention strategies may be a more effective mode of delivery.

Another global review aimed to investigate the effectiveness of school-based interventions in preventing modifiable NCD risk factors such as physical inactivity, nutrition (high consumption of energy-dense foods and low intake of fruit and vegetables) and tobacco consumption (Saraf, Nongkynrih, Pandav, Gupta, Shah, Kapoor & Krishnan, 2012). This study also aimed to assess the effectiveness of the interventions in modifying the attitude, knowledge and behaviour of the schoolchildren at the school, family and community levels to prevent NCDs. This review included 37 studies from India, Australia, China, the United States, and Europe (United Kingdom, Switzerland, Greece, Norway, France, Netherlands, Spain and Germany), excluding any African countries. Findings from this review also revealed that the school environment is recognised as an ideal setting for addressing behaviour change. However, the influence of family relationships and the sociocultural community should not be overlooked, as positive results were found among 83% (10/12) of studies which involved the family, 87% (7/8) which included family and the community, and 76% (13/17) which involved the school. Regarding intervention strategies, many of these studies included teacher training, a modified school environment, media campaigns and newsletters. However, active participation in PA was the most common strategy targeting active lifestyles and PA promotion. As a result, most of these studies (80%) showed positive intervention effects in changing behavioural risk factors contributing to NCDs.

From an African perspective, Adom, De Villiers, Puoane & Kengne (2019) reviewed ten school-based interventions of African origin (six from South Africa and four from Tunisia). The duration of interventions ranged from four months to three years and included programmes presented as games and sports as well as group discussions and exercise. This study could not report definitive conclusions from the interventions as the included studies presented inconsistent results on weight status and PA outcomes. This review also highlighted that these interventions lacked a theoretical basis and that the included studies were of low methodological rigour. Adom et al. (2019) lamented the limited literature on African school-based health interventions and highlighted the need for large, multi-site, well-designed interventions with harmonious methodologies. The following paragraphs will elaborate on the methodologies and the efficacy of school-based interventions which implemented single or multi-component school-based interventions conducted in South African low-income communities. These studies specifically address various intervention strategies aimed at increasing PA participation.

Several longitudinal and cross-sectional school-based intervention studies have been conducted in South Africa. Some studies have reported positive school-based intervention effects on PA. For example, Walter (2014) implemented a 6-week low-cost intervention of playground games (hopscotch and 2-square, etc.), playground circuits (balance beams and tyre stations, etc.) and basic PE equipment (skipping ropes and tennis balls, etc.). Walter (2014) tested the intervention using quantitative and qualitative methods among 79 learners (ages 9 - 12, Gr. 3 - 6) and nine teachers at three underprivileged primary schools in Gqeberha. In-school PA was measured pre- and post-intervention using device-based accelerometers worn for five consecutive school days. Results showed a significant improvement (12% increase of MVPA, $p=0.001$) in children’s MVPA per day. When interviewed, the teachers responded positively to the improved playground conditions. Thus, the intervention effectively increased children's in-school MVPA in the short term. It is, however, also important to know the long-term changes to children’s PA habits, given the decline of children’s PA levels (Healthy Active Kids Global Alliance, 2022). School grounds of many South African primary schools in low-income communities are barren, with little to no play structures for the children. Thus, creating environments that encourage free play and upcycling household materials to make PE equipment is highly recommended for underserved schools in disadvantaged communities. However, with dire financial constraints, these schools may also struggle to maintain these play structures, especially when the school management staff or the teachers are not interested and invested in children's PA (Burnett, 2021).

In KwaZulu-Natal, Naidoo & Coopoo (2012) implemented an 18-month Nutrition and PA (NAP) intervention at six schools in three different settings: 1 urban, 2 peri-urban and 3 rural). A total of six principals, 16 teachers and 427 Gr.6 learners (9 - 16 years old) participated in the study. The intervention had three components (PA, nutrition, and school policies to establish a health-promoting environment) and was implemented at five schools, with one school serving as the control. The intervention teachers received training workshops with knowledge and skills to promote PA. The NAP intervention was integrated into the school curriculum with cost-effective classroom-based materials implemented by the school staff with minimal external support. Quantitative data collection comprised the testing of selected components of the Eurofit PF test battery among learners. Qualitative data was collected from the learners on their knowledge, attitudes and behaviours of PA and nutrition. In addition, the principals and teachers from the intervention schools also participated in focus group discussions pre-intervention, during and post-intervention.

The Naidoo & Coopoo (2012) study was conducted in three different settings, and it was assumed that the SES of the majority of the learners ranged from low to middle-income groups. It is known that the implementation of PE differs from urban to rural school settings (Burnett, 2021), so it is assumed that the delivery of PE may vary since South Africa is such a diverse country. However, this study did not report whether the implementation of the NAP intervention differed across the three settings. Overall, the intervention schools demonstrated improvements in fitness compared to the control group. For PA participation: significant ($p \leq 0.05$) increases were observed in sport participation (soccer, dancing, and netball) as a result of the PE/LO lessons. There also seemed to be increased sports participation during lunch breaks due to the equipment (soccer balls, netballs and skipping ropes, etcetera) made available to the learners. Lastly, Naidoo & Coopoo (2012) found that classroom teachers (who are not PE specialists) could deliver effective PA lessons with the specific training they received. Thus, they highlighted the need for training workshops to be made accessible for non-specialist PE teachers to equip them to deliver this specialised learning area.

In the North West province, Tian et al. (2017) used a pre-test and post-test control-group design with a 12-week intervention period. Participants included 110 Gr. 7 learners (12 - 13 years old) from two low-income schools. The data collection included qualitative methods to determine the participants' PA levels via a self-reported questionnaire and quantitative methods to obtain BMI and body fat percentage. The intervention was delivered as a 60 min once-a-week CAPS-based PE lesson. It included five quality-enhancing components, which encompassed the following: (1) well-trained pre-service PE teachers (B.Ed PE degree), (2) improvised

PE apparatus made from upcycled materials, (3) homework activities which were accompanied by (4) a reward system to ensure learners' compliance to the programme, and then (5) monitoring of activity intensities. This enhanced PE intervention proved to be effective as results showed significant improvements in total PA ($p=0.008$), moderate PA ($p=0.014$), vigorous PA ($p=0.012$) and an overall decrease in sedentary behaviours ($p=0.041$). However, sustaining such a high-quality PE programme with homework activities and a reward system is questioned, especially in low-income schools burdened with large class sizes and teachers with high workloads.

Three recent large-scale longitudinal intervention studies were conducted in South Africa. The DASH project (Yap et al., 2015) implemented a multi-component intervention focused on creating healthy school environments in low-income settings by implementing a toolkit comprising four components: PA, health education, nutrition and deworming in Gqeberha, Eastern Cape. The PA component comprised in-class activity breaks, PE and moving to music lessons and modifications to the playground to promote PA (monkey bars, over- and under bars, a jungle gym, and colourful floor-painted games). Meanwhile, the health and nutrition component consisted of nutritional supplements, health, hygiene and nutrition lessons and deworming treatment where necessary. This study used a cluster RCT to test the effect of the intervention implemented at four schools, with an additional four schools serving as the control. The first round of testing included 1009 Gr 4 learners (9 - 14 years, mean age=11.2 years), which was repeated at 10 and 20 weeks. A fourth and final round of testing was conducted at 36 months. This study highlighted significant results.

A high prevalence of soil-transmitted helminths (STH) was identified (60.4% Trichuris trichiura and 47.7% Ascaris lumbricoides) (Müller, Beyleveld, Gerber, Pühse, du Randt, Utzinger, Zondie, Walter & Steinmann, 2016). Children with high self-reported PA levels were also more likely to be infected with STH than those with low PA levels, which was likely due to poor sanitation and children playing outside in unhygienic conditions (Gerber, Müller, Walter, du Randt, Adams, Gall, Joubert, Nqweniso, Smith & Steinmann, 2018). In addition, intestinal parasite infection appeared to have a negative effect on children's VO_2 max (Müller, Yap, Steinmann, Damons, Schindler, Seelig, Htun, Probst-Hensch, Gerber & du Randt, 2016). The repeated deworming intervention had reduced the intensity of the STH infections

(Müller, Gall, Beyleveld, Gerber, Pühse, Du Randt, Steinmann, Zondie, Walter & Utzinger, 2017). Although it is clear that oral treatment alone would not be as effective in controlling STH infections, thus these results may also be attributed to the health education which incorporated lessons on water, sanitation and hygiene.

Results from cross-sectional analyses showed that one-quarter of all schoolchildren had elevated BP, about 20% were either overweight or obese, 11.5% had stunted growth, 4.5% were underweight, and four out of ten children failed to meet the 60 min MVPA per day target (Gerber et al., 2018; Smith, Adams, du Randt, Degen, Gall, Joubert, Müller, Nqweniso, Pühse, Steinmann, Utzinger, Walter & Gerber, 2020; Joubert et al., 2021). In addition, children with stunted growth had significantly lower grip strength, and those who were overweight/obese had significantly lower scores in weight-bearing activities like the 20-m shuttle run and the standing broad jump (Smith et al., 2020). Increased levels of PA were also associated with increased health-related quality of life (HRQoL) (Salvini et al., 2017) with lower BF%, lower BMI and a lower risk of elevated BP (Gerber et al., 2018). The multi-component PA intervention did not improve children's HRQoL or selective attention, but it did have a positive effect on children's academic performance (Gall, Adams, Joubert, Ludyga, Müller, Nqweniso, Pühse, du Randt, Seelig & Smith, 2018; Gall, Walter, Du Randt, Adams, Joubert, Müller, Nqweniso, Pühse, Seelig & Smith, 2020). The PA intervention also showed reduced increases in children's BF% and BMI-for-age (Müller et al., 2019a), but it was recommended that specific PA interventions be targeted to girls as the PA intervention had no effect on girls' BMI. Furthermore, after 36 months of the PA intervention, children with normal weight and high CRF at baseline showed less of a decrease in their CRF. Those who participated in extracurricular sports and had high CRF were less likely to be hypertensive (Nqweniso et al., 2020). Using a multi-component intervention, the DASH study presented data that was useful and relevant to our understanding of school-based interventions. While the DASH study protocol (Yap et al., 2015) mentions that focus-group discussions were conducted to gather information on the 'feasibility and acceptability of the intervention measures', there were no published findings on the outcome of these focus-group discussions. However, feedback from the sub-groups involved such as the principals, teachers, and learners, would provide crucial insights into implementing such intervention designs. It is also necessary to consider whether such interventions could be implemented in real-world settings outside the confines of the controlled intervention.

The HealthKick study assessed the impact of a low-touch intervention among 16 low-income primary schools in the Western Cape; although novel, this intervention was reported as unsuccessful (de Villiers, Steyn, Draper, Hill, Dalais, Fourie, Lombard, Barkhuizen & Lambert, 2015). Baseline testing was conducted on Gr. 4 learners, then repeated at 18 and 24 months. This study implemented a multi-component intervention. The primary aim of the HealthKick study was to promote healthy eating habits and increase regular participation in health-enhancing PA in children in order to prevent overweight and reduce the risk of chronic diseases (particularly T2D). It also sought to develop an environment within the school and community that facilitated the adoption of healthy lifestyles. Results reported that educators played a crucial role in implementing the school-based intervention and that the task of developing capacity within school staff and stakeholders is not as simple. Few staff members were willing to take on an active role because it was additional work, thus resulting in limited cooperation. Consequently, the outcomes of HealthKick were disappointing concerning PF and PA participation (Uys, Draper, Hendricks, de Villiers, Fourie, Steyn & Lambert, 2016). The authors concluded that low-touch interventions do not seem effective in changing lifestyle-related behaviours in a low-income primary school setting in South Africa.

In summary, this discussion has elaborated on selected school-based interventions that revealed several lessons learned. Very few intervention studies addressed PA, nutrition, health, hygiene, and awareness. Given the rise of modifiable risk factors, there is a dire need to promote healthy lifestyles in schools. In a systematic review which investigated intervention programmes addressing obesity prevention and PA and CRF promotion, Yuksel et al. (2020) point out that PA should be the priority in comprehensive school-based interventions. However, the latter point should be expanded as school-based interventions should also ensure that children learn the skills, knowledge, and values required for lifelong PA participation. This can be achieved through interventions focusing on teacher training, content, and curriculum design. Teachers play an important role in promoting PA in the school environment, and evidence shows that children appreciate and enjoy PE taught by their class teacher (Hills, Mokhtar & Byrne, 2014; Telford, Olive, Keegan, Keegan, Barnett &

Telford, 2021). However, challenges highlighted in the South African context relate to a lack of PE delivery in resource-scarce schools (Roux, 2020), where teachers are neither trained nor qualified to teach PE (Stroebel et al., 2016a). Given this background, a school-based intervention programme that includes training of generalist PE teachers and PE lesson content to supplement the current CAPS curriculum may offer significant potential in preventing overweight and obesity and other NCD risk factors and fostering PA habits to adopt active lifestyles. Thus, further research on comprehensive school-based health programmes is needed to identify the efficacy of such interventions.

2.6 Summary

This chapter has reviewed the literature concerning four main themes: NCDs in children, PA and CRF in children, PE in the South African context, and school-based health interventions. While NCDs typically appear in adulthood, the literature shows a rise in the prevalence of NCD risk factors among children and youth over the past years. Children's health is further compromised as the protective function of PA, and CRF is reduced if PA is not performed within recommended guidelines. Furthermore, PE in South Africa has undergone significant curriculum reform and, while still officially part of the curriculum, has often been reduced to a non-teaching or self-learning subject in schools across the board. In this context, the need to implement school-based interventions targeting PA behaviour and NCD risk factors, specifically among children attending under-served schools in underserved communities, is evident. The following chapter delivers the published *KaziBantu* study protocol, which discusses the research methodology conducted within the overarching *KaziBantu* study. Only selected research protocols of the research methodology were implemented to achieve the objectives set of this PhD thesis; these are referred to in the relevant publications included in Chapters 4 to 6.

Chapter 3: Methodology of the *KaziBantu* Study

Protocol

Effects of a School-Based Health Intervention Program in Marginalized Communities of Port Elizabeth, South Africa (the KaziBantu Study): Protocol for a Randomized Controlled Trial

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Abstract

Background: The burden of poverty-related infectious diseases remains high in low- and middle-income countries, while noncommunicable diseases (NCDs) are rapidly gaining importance. To address this dual disease burden, the *KaziBantu* project aims at improving and promoting health literacy as a means for a healthy and active lifestyle. The project implements a school-based health intervention package consisting of physical education, moving-to-music, and specific health and nutrition education lessons from the *KaziKidz* toolkit. It is complemented by the *KaziHealth* workplace health intervention program for teachers.

Objectives: The aim of the *KaziBantu* project is to assess the effect of a school-based health intervention package on risk factors for NCDs, health behaviors, and psychosocial health in primary school children in disadvantaged communities in Port Elizabeth, South Africa. In addition, we aim to test a workplace health intervention for teachers.

Methods: A randomized controlled trial (RCT) will be conducted in 8 schools. Approximately 1000 grade 4 to grade 6 school children, aged 9 to 13 years, and approximately 60 teachers will be recruited during a baseline survey in early 2019. For school children, the study is designed as a 36-week, cluster RCT (*KaziKidz* intervention), whereas for teachers, a 24-week intervention phase (*KaziHealth* intervention) is planned. The intervention program consists of 3 main components; namely, (1) *KaziKidz* and *KaziHealth* teaching material, (2) workshops, and (3) teacher coaches. After randomization, 4 of the 8 schools will receive the education program, whereas the other schools will serve as the control group. Intervention schools will be further randomized to the different combinations of 2 additional intervention components: teacher workshops and teacher coaching.

Results: This study builds on previous experience and will generate new evidence on health intervention responses to NCD risk factors in school settings as a decision tool for future controlled studies that will enable comparisons among marginalized communities between South African and other African settings.

Conclusions: The *KaziKidz* teaching material is a holistic educational and instructional tool designed for primary school teachers in low-resource settings, which is in line with South Africa's Curriculum and Assessment Policy Statement. The ready-to-use

lessons and assessments within *KaziKidz* should facilitate the use and implementation of the teaching material. Furthermore, the *KaziHealth* interventions should empower teachers to take care of their health through knowledge gains regarding disease risk factors, physical activity, fitness, psychosocial health, and nutrition indicators. Teachers as role models will be able to promote better health behaviors and encourage a healthy and active lifestyle for children at school. We conjecture that improved health and well-being increase teachers' productivity with trickle-down effects on the children they teach and train.

Trial Registration: International Standard Randomized Controlled Trial Number (ISRCTN): 18485542; http://www.isrctn.com/ISRCTN18485542

International Registered Report Identifier (IRRID): DERR1-10.2196/14097

(JMIR Res Protoc 2019;8(7):e14097) doi: 10.2196/14097

KEYWORDS

anthropometry; cardiovascular; cognitive function; diabetic complications; children's health; marginalization; physical activity; physical fitness; schools; South Africa

Introduction

Background

Children's health and well-being are influenced by cultural, environmental, and socioeconomic factors as well as living conditions and social and community networks [1]. In low- and middle-income countries (LMICs), infectious diseases remain an important public health problem [2-4] with negative impacts on child development [5]. Over 200 million children are infected with parasitic worms (helminths) [6,7] leading to chronic infections causing abdominal pain, diarrhea, and anemia, and may impair cognitive and physical development [8], which in turn might result in reduced fitness and work productivity [9]. In addition, helminth infections can negatively impact children's nutritional status [10].

Although helminth infections and other neglected tropical diseases (NTDs) do not feature prominently in the burden of disease statistics of South Africa, some NTDs are common in disadvantaged populations, especially among children of poor communities [11]. The nutritional status of school children from poor neighborhoods is adversely affected by food outlets in close proximity to the schools. Indeed, many school children routinely purchase unhealthy foods from local vendors and tuck shops that are generally low in nutritional value, often refined, processed, and of low fiber content [12]. In a 12-country study (Australia, Brazil, Canada, Colombia, Finland, India, Kenya, People's Republic of China, Portugal, South Africa, United Kingdom, and United States of America) [13], South African children showed the highest intake of sugar-sweetened beverages [14]. Schools located in poor communities in South Africa are part of the National School Nutrition Program, where members of the community, usually unemployed parents, are employed as food preparers. They do not have any food- or nutrition-related qualification.

A deprived socioeconomic environment can put children at risk of malnutrition resulting in growth retardation [15]. Studies have shown that malnutrition is associated with stunting and poor cognitive development, resulting in a low intelligence quotient, cognitive delays, and negative impact on motor development [15]. This, in turn, negatively affects children's ability to concentrate, process information, and focus on academic tasks [16]. Children from low socioeconomic status (SES) families are also less likely to have access to health care or health insurance [17]. Together, this leads to a greater risk of illness, school absence, and ultimately poor academic performance and life prospects [18]. These deficiencies, caused mainly by the socioeconomic environment, can prevent school-age children from realizing their full potential and perpetuate a vicious cycle of poverty and poor health.

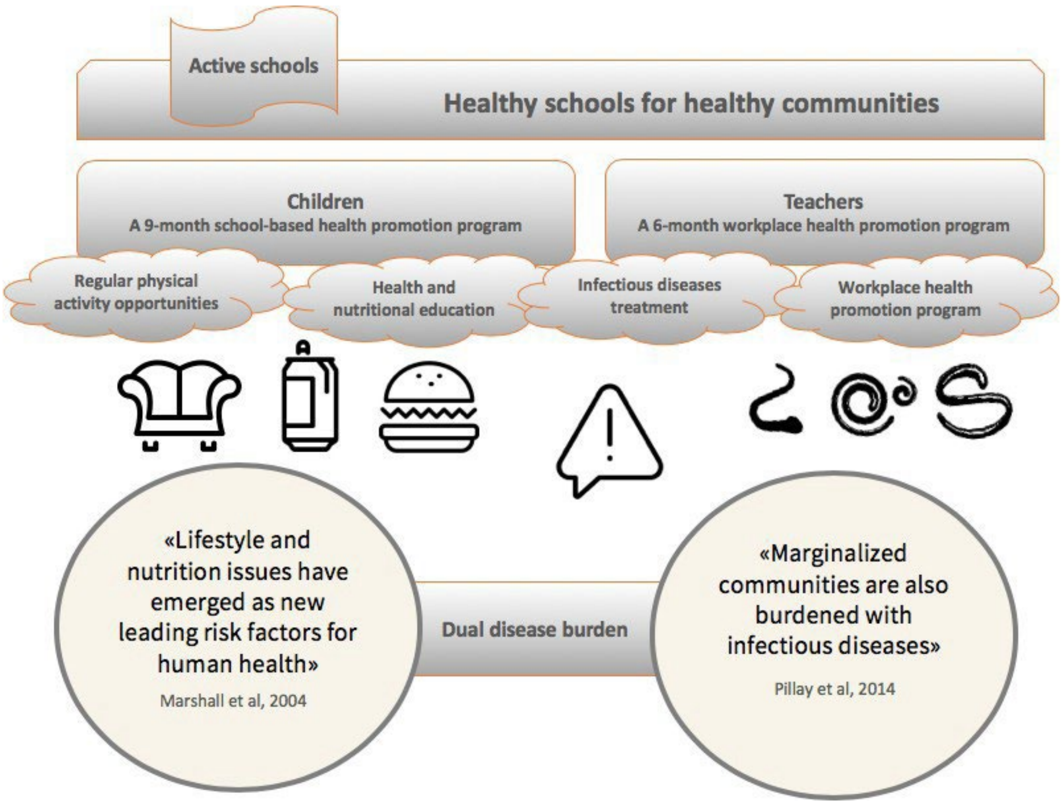
In addition, noncommunicable diseases (NCDs) are a rapidly evolving public health problem worldwide, especially in LMICs, imposing a growing burden on population health [2,19] including that of children [20]. Urban African populations have moved toward a disease profile similar to western countries, with increasing proportions of deaths attributed to chronic, lifestyle-related diseases [20]. The coexistence of under- and overnutrition has resulted in a double burden of nutrition-related diseases in Africa [21]. Children may, already at a young age, develop risk factors predisposing them to NCDs in adulthood [22,23]. Hence, children are at risk of compromised health because of a dual burden of disease, which may hamper their development and well-being [2,24]. Potential drivers of this double burden may be related to the shift in dietary habits and reduced energy consumption. This dual burden constitutes a large and growing challenge for health systems in African countries.

With up to 80% of all chronic diseases, stroke, and diabetes being preventable through healthy nutrition and regular exercise, more emphasis should be placed on prevention and awareness campaigns [25]. Physical education (PE) plays a critical role in holistic health education of the child. A randomized controlled trial (RCT) with Swiss elementary school learners (first and fifth graders) has shown that a 1-year school-based intervention can markedly improve physical activity and fitness, while simultaneously reducing obesity [26]. Regular physical activity contributes to the development of physical competence and fitness, as well as to the cognitive, social, and emotional development of the child [27]. As a rule of thumb, children should undertake at least 60 min of moderate-to-vigorous physical activity (MVPA) daily [28].

The Healthy Active Kids South Africa Report Card (2018) has shown that many children, particularly from marginalized communities, do not achieve the minimal daily requirements of MVPA [14]. Schools play an important role in making a meaningful contribution to the goal of achieving the recommended daily physical activity guidelines by incorporating PE lessons, among others, into the school curriculum. One plausible strategy to promote children's health is through school-based health promotion programs. An attempt by a Swiss-South African research team to increase health literacy in South African children at school was the *Disease, Activity and Schoolchildren's Health* (DASH) project [4]. The study focused on grade 4 children and the creation of an enabling school environment. The intervention program consisted of 4 main components, including (1) a medical examination and anthelmintic treatment, (2) micronutrient supplementation in the form of a nutrient-dense paste enriched with protein, essential vitamins (vitamin A), minerals, energy, and essential fatty acids, (3) health education (eg, hygiene and healthy nutrition), and (4) physical activity (dancing and playful games).

Our experiences with the DASH project also revealed that many South African teachers are at risk of cardiovascular diseases [29,30]. This insight was confirmed in a representative sample of South African educators (n=21,307) in public schools. Educators reported high stress levels, and there were significant associations between stress, lack of job satisfaction, and stress-related illnesses [31]. In South Africa, NCDs among adults have steadily increased. Indeed, although 42.90% (256,645/598,240) of deaths in 2005 were attributable to NCDs, the proportion rose to 57.40% (262,096/456,612) in 2016 [32]. Furthermore, in 2017, more than 1.8 million cases of diabetes were recorded in South Africa, representing 5.41% (1,826,100/33,762,000) of the adult population [33]. The project *Healthy Schools for Health Communities* presented here addresses this dual burden of disease, both in school children and teachers in South Africa (Figure 1).

Figure 1. A conceptual framework of the *KaziBantu* study.



Rationale

Having identified the potential for health status improvement among teachers and knowing the importance of teachers as role models in the education process of children, teachers will also participate in the proposed research project by involving themselves in a workplace health intervention. We will capitalize on the experiences from the aforementioned DASH project by scaling up the intervention program and monitoring and improving the efficacy and effectiveness of the intervention program. The goal of the *KaziBantu* project is to assess the impact of a school-based health intervention package on communicable diseases, risk factors for NCDs, health behaviors (beliefs and actions relating to health and well-being), and psychosocial health in primary school children in disadvantaged communities in Port Elizabeth, South Africa. In addition, we aim to test a workplace health intervention targeted at teachers.

Methods

Ethical Approval and Considerations

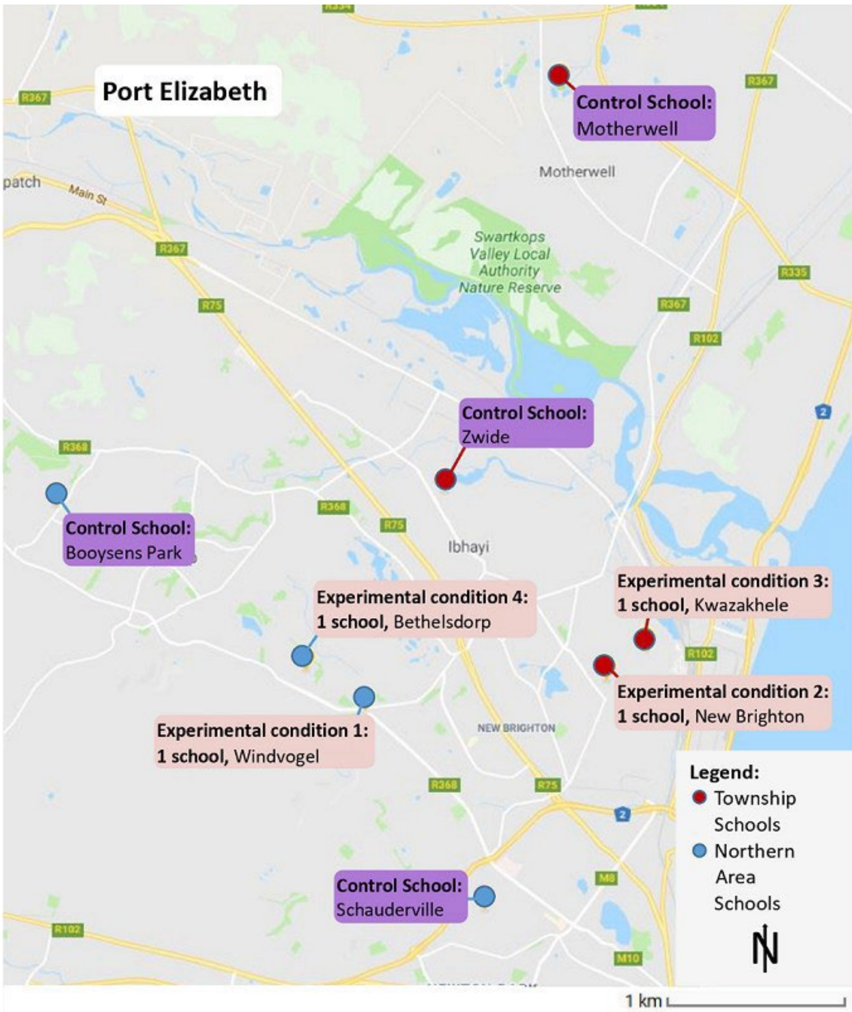
Ethical approval for the study has been received from the following ethics committees in Port Elizabeth, South Africa: (1) The Nelson Mandela University Ethics Committee (reference #H18-HEA-HMS-001; obtained on 26 March 2018), (2) Eastern Cape Department of Education (obtained on 9 May 2018), and (3) Eastern Cape Department of Health (reference #EC_201804_007; obtained on 5 June 2018). The study is registered at the ethical review board of the Ethics Committee Northwest and Central Switzerland (EKNZ; reference #R-2018-00047; registered on 1 March 2018).

On the basis of a uniform study information sheet, the investigators will explain to each participant (children and teachers) the purpose of the study, procedures involved, expected duration, and potential risks and benefits. Participation is voluntary, and hence, participants can withdraw at any time without any further obligations. All participants will be provided with an information sheet and a consent form describing the study. Individual medical information obtained during this study will be treated confidentially. Subject confidentiality will be ensured by utilizing subject identification code numbers to correspond to treatment data in password-protected computer files. For data verification purposes, authorized representatives of the EKNZ and the Nelson Mandela University Human Ethics Committee may require direct access to parts of the clinical records relevant to the study, including participants' medical history.

Study Area

The study will be conducted in historically black and colored primary schools in Port Elizabeth townships (Motherwell, Zwide, Kwazakhele, and New Brighton) and northern areas (Schauderville, Bethelsdorp, Windvogel, and Booysens Park), which form part of the Nelson Mandela Bay Municipality (Figure 2). These schools and communities are characterized by poverty and high unemployment rates. They represent the typical institutional and teacher-related PE barriers faced by the schools [34], including (1) shortage of qualified, accountable, and engaged PE teachers; (2) PE is marginalized as priority–it lost its standalone subject status in 1997 and is placed within the life skills and life orientation learning area, as more importance is given to other (examinable) subjects; (3) teachers lack the ability to integrate PE with other study areas within the life skills and life orientation subject (personal and social well-being, creative arts, and PE); (4) large class sizes; (5) insufficient and inadequate infrastructure and equipment; and (6) safety and security challenges.

Figure 2. Study area (Port Elizabeth, South Africa) and location of the 8 schools participating in the *KaziBantu* study. Source: Kartendaten, AfriGID (Pty) Ltd.



Study Design

The intervention arm targeting school children is designed as a 36-week RCT, including an intervention group (4 schools) and a control group (4 schools). The 4 intervention schools, assigned through randomization, will be further allocated randomly to the following intervention conditions: all schools will receive the teaching materials (*KaziKidz* and *KaziHealth*), but the components workshop and coaching will be assigned as follows: (1) teaching materials only, (2) teaching materials plus workshops, (3) teaching materials plus coaching, and (4) teaching materials plus workshops plus coaching (Figure 3).

The 4 remaining schools will be assigned to the control group. In the control schools, there will be documentation of routine PE and sports in school.

The primary comparison will be made between the 4 intervention schools and the 4 control schools to assess the benefit of teaching materials. Secondary comparisons will be between teaching materials plus coaching and teaching materials without coaching or teaching materials plus workshop and teaching materials without workshop. In view of the factorial design of our study, each comparison group consists of 2 schools.

By focusing on change in quantitative outcomes from baseline to follow-up, preexisting differences between schools should play less of a role. Although the intervention covers grades 1 to 7, in each school, 1 class each from grades 4, 5, and 6 will be randomly selected for evaluation of the intervention. After completion of the baseline assessment, children of the intervention schools will take part in a school-based health promotion program (32 school weeks, 1 PE lesson of 40 min per week, 1 moving-to-music lesson of 40 min per week, 3 health education lessons, and 3 nutrition education lessons of 40 min per year across the whole study period). The follow-up will be after 36 weeks (Figure 4). Qualitative data on the feasibility and acceptability of the intervention measures will also be collected from teachers through focus group discussions (FGDs).

For teachers, the study is designed as a 20-week RCT (Figure 5). The baseline assessment will also be offered to the teachers in the control schools. Intervention schools will be randomly assigned to the 4 different combinations of the additional components. After completion of the baseline assessment, all teachers will be informed about their personal health profile, providing an overview of cardiovascular health markers and mental health parameters. For each parameter, established internationally accepted cut-off and normative values will be used to estimate teachers' health risks.

Figure 3. A pictorial display of the *KaziBantu* study design.

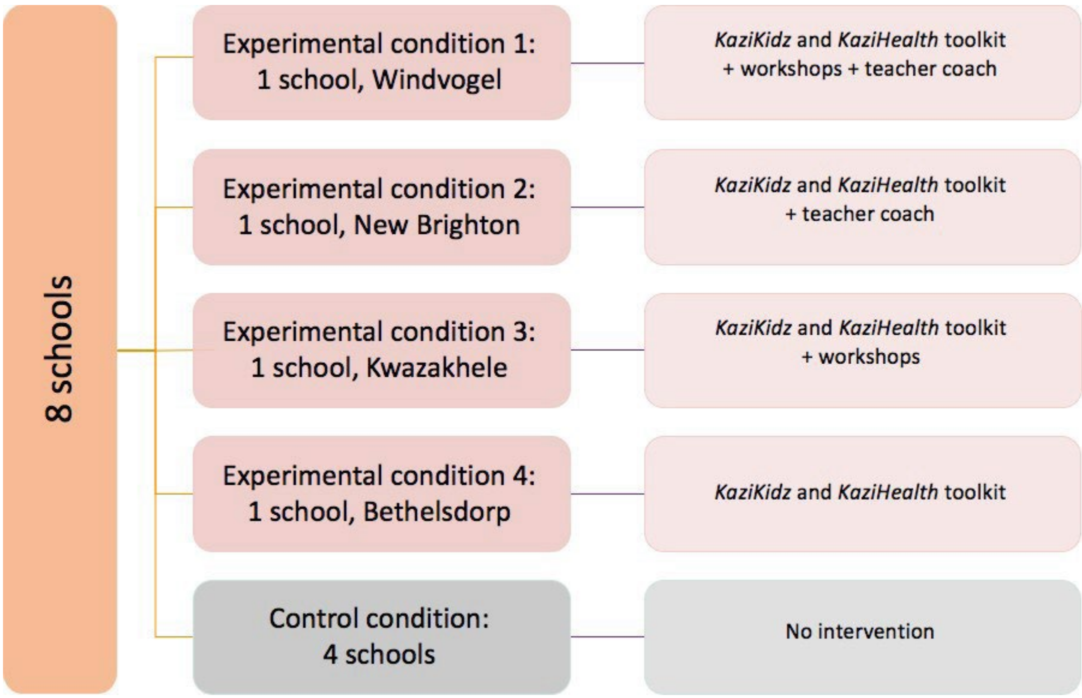


Figure 4. *KaziBantu* study design of testing the *KaziKidz* teaching material.

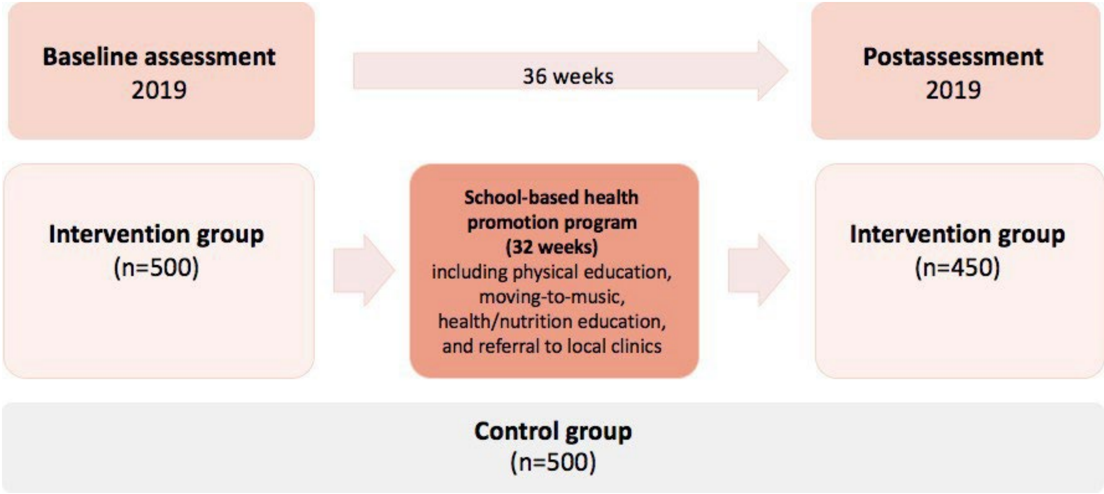
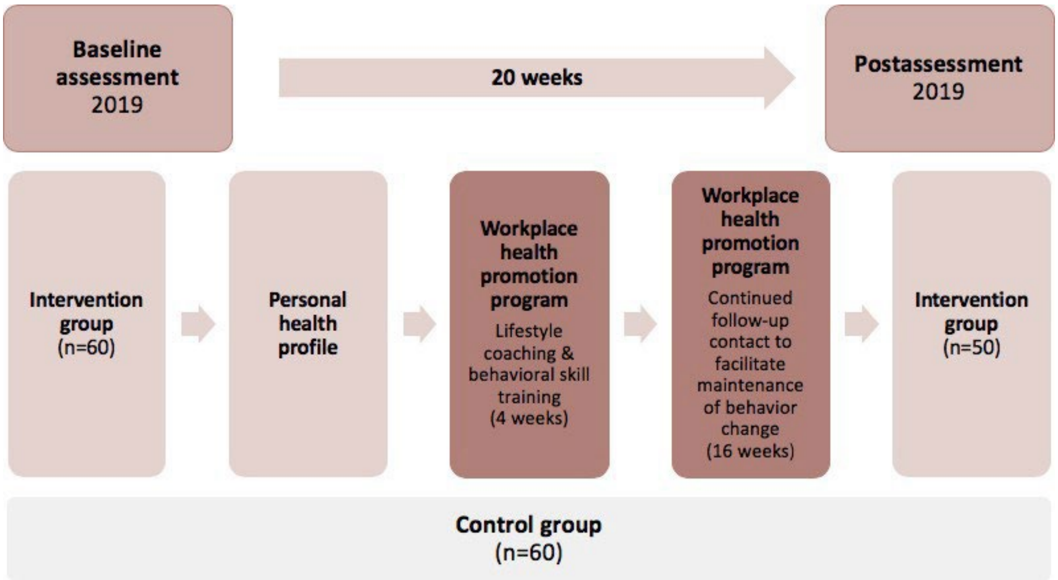


Figure 5. *KaziBantu* study design of testing the *KaziHealth* tools.



The intervention program consists of the 3 main components discussed below.

Component 1: KaziKidz and KaziHealth Teaching Material

It is a holistic education and instructional tool designed for primary school teachers. This teaching material was pilot tested at 2 elementary schools in the Port Elizabeth area in August 2018. Feedback from teachers was obtained and the material revised accordingly. Through the implementation of 3 content pillars—(1) PE, (2) moving-to-music, and (3) health and hygiene and nutrition education lessons—the toolkit aims to enhance children's overall health in disadvantaged South African primary schools. The *KaziKidz* teaching material consists of lesson plans within each of the 3 content pillars. The lessons have been designed in line with South Africa's Curriculum and Assessment Policy Statement. Ready-to-use assessments can be found at the end of each section, which may be integrated into formal assessments of children's performance and can complement the school's academic curriculum. The purpose is to lead children through content, games, and activities, partly supported by music and conducted in a joyful manner that encourages and promotes a healthy lifestyle throughout childhood and into adolescence. *Kazi* (an animated active mascot, designed to encourage children to participate in *KaziKidz*) and lesson plans will guide teachers through the teaching material. We expect that by using the *KaziKidz* teaching material, teachers will contribute to further the health and well-being of the children they teach and educate.

- Physical activity: Regular physical activity opportunities (1 PE lesson of 40 min per week) will be incorporated into the main school curriculum in grades 1 to 7 over 32 weeks of the school year. A physical activity–friendly school environment will be created. These interventions are designed toward improving children's physical activity levels and positively affecting their psychosocial well-being.
- The moving-to-music classes have been designed to promote physical activity through song and dance. The music utilized was developed by professional musicians from the Nelson Mandela University and is locally known

and age-appropriate. Weekly lessons of 40 min each are designed with easy-to-follow illustrations that allow teachers to instruct without participating physically in the lessons. Schools or teachers who have a sound system available can make use of movement songs that have been created with cues specifically tailored to the lessons. Options for creating music through drums or any other form of percussion or clapping hands are also provided. Within the lessons, direct speech is used to address the children for easy application [35].

- Health, hygiene, and nutrition education: A series of classroom-based lessons have been developed [36]. School children will be educated on the prevention and treatment of intestinal parasite infections, such as proper hygiene, sanitation habits, and the importance of consuming clean water and food. By addressing these factors and educating children about appropriate health and hygiene behaviors, both the teachers and the school children are at a reduced risk of infection. Another series of classroom-based lessons will help to increase awareness about the importance of healthy nutrition. The South African National School Nutrition Program attempts to address micronutrient deficiencies and alleviate short-term hunger by providing food that supplies at least one third of the daily energy requirements of a child. To complement this, the nutrition education lessons (3x 40-min lessons per grade for grades 1-7) should bring dietetics closer to the learners in a playful way and encourage sustainable healthy eating habits throughout the learners' lives. In addition, an analysis of the schools' feeding program will be done to identify ways to improve their present diet. The food preparers in schools will also be trained in basic nutrition and hygiene during preparation of the school meals as unhygienic circumstances and poorly prepared meals can lead to infections and low nutrient intake [37].

KaziHealth is a workplace health promotion program that aims to educate and improve health behaviors among teachers. The program starts with an individualized health risk assessment followed by face-to-face lifestyle coaching sessions and self-monitoring and motivation through the *KaziHealth* mobile app. All teachers willing to participate in the program will undergo a comprehensive health risk assessment. In addition, teachers of the intervention schools will have the option to participate in a 20-week workplace health promotion program (Figure 6).

Figure 6. The 20-week workplace health promotion program for teachers.

Component 2: Workshops

Teachers of 2 schools will participate in workshops for both *KaziKidz* and *KaziHealth*. The teaching content (lessons and assessments) of *KaziKidz* will be explained to the teachers before the implementation of the teaching material (2 sessions of 90 min each, as well as practical demonstrations and instruction at schools) and for *KaziHealth*, individually tailored lifestyle coaching workshops (2 sessions of 90 min each). The workshops will be relatively small (maximum of 20 teachers per workshop) and led by health professionals specializing in physical activity promotion, diet, nutrition, and psychosocial health. Furthermore, education, motivation, and self-monitoring will be provided through the *KaziHealth* mobile app [35] to assist individuals in making healthier lifestyle choices and decrease health risks.

The *KaziHealth* mobile app [35] integrates 3 lifestyle interventions; namely, physical activity, nutrition, and stress management to guide individuals in achieving personal health goals. To test the efficacy of the workplace health promotion program over time, teachers will be assessed a second time after 20 weeks.

Component 3: Teacher Coaches

In the 2 schools where teachers will be offered coaching, trained sports students from the Department of Human Movement Science at the Nelson Mandela University will act as teacher coaches assisting the teachers in teaching and ensuring that the intervention is implemented in the schools correctly and as intensively as planned. Furthermore, they will also monitor the intervention process.

Sample Size and Randomization

Assuming that the prevalence of obesity varies across schools according to a log-normal distribution with a mean value of 3% and a SD of 2%, 125 children per school in each of the 8 schools would provide a prevalence estimate between 1.5% and 5% with a probability of 95%. Under this assumption, 95% of school-specific prevalence would range between 0.8% and 8.2%. Hence, our aim is to recruit 125 children per school.

The power calculation for the intervention study is based on the change in a quantitative outcome variable from baseline to follow-up. We denote the SD of its change across schools and children by sigma (σ). Assuming an intervention effect size of 0.5 x σ and an intraclass correlation of .04 for the clustering of individual changes within schools (corresponding to a random effect SD of 0.2 x σ), 400 children in the 4 intervention schools (ie, 100 children per school) participating in baseline and follow-up, and 400 children in the 4 control schools would provide over 85% power to observe a statistically significant difference in the mean change of the respective outcome variable between intervention and control schools at the 5% level.

Enrollment of schools will be done by the local research team. To prevent contamination of the intervention effects, schools rather than classes were randomized in January 2019. Before randomization, schools were divided into 2 geographic groups; namely, township areas and northern areas, each containing 4 schools. Township areas are predominantly inhabited by black Africans and northern areas by colored people (after an apartheid-era classification, which refers to people from a multiracial ethnic background and can include persons of Khoi and San origin).

The randomization into intervention and control schools was done separately in each of the 2 groups so that each group was assigned 2 intervention and 2 control schools. To keep the design as balanced as possible, the 4 intervention schemes (ie, teaching materials only, teaching materials plus teacher workshops, teaching materials plus teacher coaching, and teaching materials plus teacher workshops plus teacher coaching) will be assigned in such a way that the intervention schools of 1 group will get teaching materials plus either teacher workshops or teacher coaching. Randomization will allow to determine which of the 2 groups gets which of the 2 pairs of intervention schemes. Sequentially numbered, opaque, sealed envelopes will be used for the assignment of the intervention arms to the schools.

Study Participants

The effect of the *KaziKidz* teaching material will be evaluated in 1 randomly selected class in grades 4, 5, and 6 (=intermediate phase) in each of the 8 study schools (interventions are randomly assigned to any of the 4 northern area or 4 township schools) even though *KaziKidz* teaching material will be offered to all classes in grades 1 to 7 as part of the life skills and life orientation courses in the school curriculum.

For *KaziHealth*, all teachers from the 8 schools will be invited to participate in the program. All participating teachers will undergo the full health risk assessment, and teachers at the intervention schools will have the option to participate in the 20-week intervention. The teachers from the control schools will be offered the intervention program after the completion of the study.

School Selection, Participant Recruitment, and Written Informed Consent

South African public schools are classified into 5 groups, with quintile 5 representing the least poor and quintile 1 representing the poorest. The quintiles are determined through the national poverty table developed by the treasury [38]. Areas are being ranked on the basis of income levels, dependency ratios, and literacy rates in the area. The quintile ranking of a school determines the no-fee status of the school and the amount of money that a school receives from the government, with the poorest schools receiving the greatest per-child allocation. Approximately 200 principals and/or representatives from 349 quintile 3 primary schools (no-fee paying schools) of the Nelson Mandela Bay Municipality attended information-sharing sessions at the Eastern Cape Department of Education in October 2018. The intention was to be inclusive and invite as many interested principals as possible to inform them of the study. A total of 64 responses were received from interested schools; however, only 8 of the responses (representative of typical quintile 3 primary schools) matched the following criteria:

1. Geographical location and representation of the target communities: *township areas* inhabited predominantly by black African people and the *northern areas* inhabited by predominantly colored people; both these communities needed to be represented equally.
2. Spoken language (IsiXhosa, Afrikaans, or English).
3. Commitment by school principal to support the project activities.

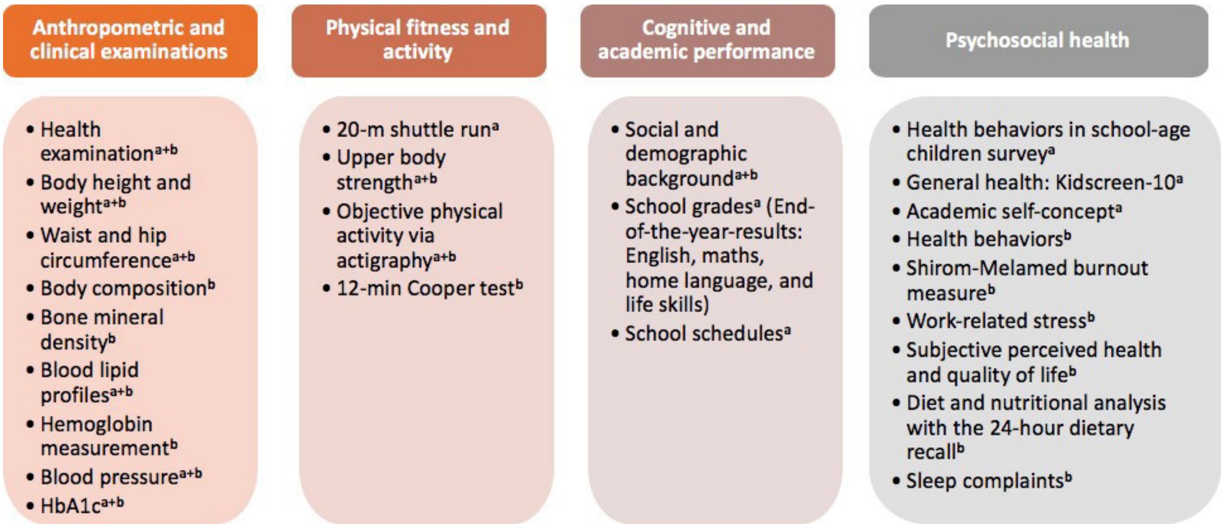
The school authorities will be informed about the project and asked for their interest and consent. Interested schools will be visited, and the investigators will consult with the school administrators to find out if the school environment is conducive for conducting the study. Principals and teachers from selected schools will be informed about the objectives, procedures, and potential risks and benefits of the study. Teachers, children, and parents or guardians will be informed and teachers and children invited to participate in the study. Before enrollment, a participant information sheet will be provided in English, IsiXhosa, or Afrikaans (local languages) to all potential participants and in case of the children, their parents or guardians. For the evaluation part of the study, oral assent of each participating child will be obtained, whereas written informed consent will be obtained from parents or guardians and teachers. Participation is voluntary; hence, children and teachers can withdraw anytime without any further obligations.

Potential participants will be enrolled in the project for evaluation purposes if they meet the following inclusion criteria: (1) are willing to participate in the study, (2) have a written informed consent (for children by a parent or guardian), (3) are not participating in other clinical trials during the study period, and (4) do not suffer from severe medical conditions, as determined by qualified medical personnel. Approximately 1000 grade 4 to 6 school children, aged 9 to 13 years, and approximately 60 teachers from 8 primary schools will be recruited during the *KaziBantu* baseline survey in early 2019.

Assessment Methods

Primary outcomes for the *KaziKidz* testing battery include (1) anthropometric and clinical examinations, (2) physical fitness and self-reported and objectively assessed activity, (3) cognitive and academic performance, and (4) questionnaire for assessment of psychosocial health. Primary outcomes for the *KaziHealth* testing battery include (1) anthropometric and body composition assessments, (2) clinical examinations, (3) self-reported and objectively assessed physical activity and physical fitness, and (4) questionnaire results from psychosocial health assessment. Further measures include diet and nutritional analysis with the 24-hour dietary recall. Secondary outcomes for both tests are gender, ethnicity, SES, age, weight, and height. Figure 7 summarizes the assessment methods to be utilized in this study. For baseline and follow-up surveys, the same scientifically recognized procedures will be selected and conducted by professional staff, adhering to standardized, quality-controlled protocols.

Figure 7. Measurements and tests performed among school children (a) and teachers (b) in the *KaziBantu* study.



KaziKidz Assessment Protocol

Anthropometric Measurements

The anthropometric measurements are as follows:

1. For each participant, body weight and height will be measured by standing on a digital weighing scale and against a stadiometer with back erect and shoulders relaxed, recorded to the nearest 0.1 kg and to the nearest 0.1 cm, respectively. Age- and gender-specific height or height-for-age and weight-for-age z-scores will be calculated from the current Centers for Disease Control and Prevention (CDC)/World Health Organization (WHO) growth reference data. Body mass index (BMI) and specific z-scores will be calculated as follows: (1) BMI=weight (kg)/height (m)^2, (2) BMI for children older than 5 years, an indicator for weight-for-height proportion (WHO growth reference for children older than 60 months) [20], (3) height-for-age, an indicator of growth disorders (WHO growth reference for children older than 60 months), and (4) weight-for-age.
2. A measuring tape will be used to determine the waist circumference of the participant, measured midway between the rib cage and the iliac crest on a gender-appropriate basis. After measuring the hip circumference, the waist-to-hip ratio will be calculated, a risk indicator for heart disease (ie, the smaller the waist in comparison with the hips, the lower the risk of heart disease) [39].

Questionnaires

To gather information on children's social and demographic background, SES, self-perceived stress, school satisfaction, academic self-concept, self-reported physical activity behavior, and general health status, the following questionnaires will be applied:

1. The demographic data and SES of each participant will be determined.
2. The KIDSCREEN-10 will be implemented to determine children's physical and psychological well-being, moods and emotions, self-awareness, autonomy, parenting and family life, financial resources, peers and social support, school environment, and bullying. The questionnaire comprises 10 points and has proven to be a valid tool for assessing the psychosocial health of children aged 8 to 18 years [40-42].
3. A total of 3 items from the Health Behavior in School-age Children survey [43] will be used to assess individual perceived stress, school satisfaction, and academic self-concept. Learners will be asked how they perceive the pressure, including from homework, related to school [44]. To estimate school satisfaction, children will be asked to respond to the question: *How do you feel about school at present*?
4. Children will also be asked questions about their physical activity behavior, including sports participation, being physically active during school hours, and type of play during school hours and in their free time. Information will be collected over a 7-day period. The questions are adjusted using the Physical Activity Questionnaire for Children, an

instrument used to gain insights into general levels of physical activity throughout the elementary school year for children attending grades 4 to 8, aged between 8 and 14 years [45].

Clinical Examinations

Clinical examinations will include:

1. The children's health review will include a detailed history and physical examination. Self-reported health status will focus on intestinal symptoms, including abdominal pain and changes in bowel movements. In addition, we will assess children's evolution of cognitive and physical development. The physical examination is directed toward evidence of anemia (eg, conjunctival pallor), abdominal conditions (eg, hepatomegaly and splenomegaly), and evidence of pulmonary hypertension (eg, jugular venous pressure and cardiac auscultation).
2. Regarding high blood pressure detection, each participant's blood pressure will be measured 3 times after the participant has been seated for 5 min with a calibrated Omron digital blood pressure monitor (Omron M6 AC model; Hoofddorp, The Netherlands). The cuff is wrapped around the left arm so that only a finger can fit between the cuff and arm. The bottom of the cuff is placed about 4 cm above the elbow with the palm facing up, while the blood pressure is taken. For children, a cuff size of 17 to 22 cm will be used (Omron CS2 Small Cuff; Hoofddorp, The Netherlands). As the first measurement often results in higher values, the average of the second and third measurements will be utilized to estimate systolic and diastolic blood pressure. To analyze the data, children will be categorized into a normotensive, prehypertensive, or hypertensive group, based on percentiles, taking into account the age, sex, and height of the children (normotensive: less than the ninetieth percentile; prehypertensive: at or above the ninetieth percentile to at or below the ninety-fifth percentile; and hypertensive: at or above the ninety-fifth percentile).
3. For determination of the full blood lipid profile (total cholesterol, low-density lipoprotein cholesterol [LDL-C], high-density lipoprotein cholesterol [HDL-C], triglycerides, non-HDL cholesterol [non-HDL], cholesterol high-density lipoprotein ratio [C-HDL ratio]), glycated hemoglobin (HbA1c) affecting diabetes, and a point-of-care (POC) instrument (Alere Afinion AS 100 Analyzer, Abbott Technologies; Abbott Park, United States of America) will be used, providing results within 8 min. The HbA1c level reflects the average plasma glucose concentration levels over the last 8 to 12 weeks. After the participant's fingertip is cleaned with an alcohol swab, a nurse will prick the fingertip with a safety lancet and gently squeeze out 2 drops of blood. The first drop will be wiped away, and the second drop will be collected for analysis. Before the assessments, all machines will be tested and calibrated with controls.

Physical Fitness Tests

For the purpose of this study, selected tests from the Eurofit fitness battery [46] will be utilized:

1. Cardiorespiratory fitness of children will be measured with the 20 m shuttle run test by Léger et al [47]. In brief, a 20 m flat course, measured by tape and marked with cones will serve for the test. A total of 10 tracks are set. The prerecorded sound signals are played to the children, and they are prompted for the test run in 2 intervals (2x 20 m). Once the children are familiar with the test procedures, they are invited to run back and forth in groups of 10, following the preset pace of the sound signals. Starting at a speed of 8.5 km/h, the frequency of the signal is gradually increased so that the speed increases by 0.5 km/h from 1 min to the next. If children cannot follow the signal and do not reach the 20 m line for 2 consecutive intervals, they will be asked to stop the test and the distance traveled (in full laps) will be recorded. To calculate cardiorespiratory fitness, the number of laps is converted to a speed value, and along with the participant's age, used in the formula provided by Léger et al [47] to estimate the maximal oxygen uptake (VO_2 max; ml x kg^{-1} x min^{-1}).
2. Upper body strength will be determined using the handgrip resistance test, which measures the maximum isometric grip force. The field investigator will demonstrate how to grip the dynamometer. Each participant will have 1 preliminary trial per hand (with a 30-sec rest in between) to grip the dynamometer as hard as possible. In addition, the dominant hand will be noted. The participants will remain in a standard bipedal pose with their shoulder adducted and neutrally rotated, elbow flexed at 90 degrees, forearm in neutral position holding the Saehan hydraulic dynamometer (MSD Europe BVBA; Tisselt, Belgium) without making contact with any body part. The dynamometer will be adapted to the hand size of each participant, and the maximum readings of 6 trials (measured to the nearest 0.1 kg, 3 trials per hand) will be recorded. The highest score will be used as the final result. Higher values indicate better performance.

Objective Activity Measurements

Physical activity behavior will be assessed with an ActiGraph wGT3X-BT accelerometer [48]. Participants will be instructed to wear the device at all times (except during activities involving water contact) for 7 days around the hip. The measured period will include 5 school days and 2 weekend days. Devices will run on the most recent firmware version (version 1.9.2 at the time of writing) and will be initialized with the ActiLife version 6.13.3 (Actigraph LLC) at a sampling rate of 30 Hz. Analyses will be performed using the ActiLife software.

Cognitive Performance

In cooperation with the schools, the school exam grades for the following subjects will be obtained: English, mathematics, home language, and life skills. The sum score of these 4 subjects will be used to estimate the academic achievements. In addition, we will obtain school schedules to monitor the overall academic progress of the children. A school schedule is a quarterly summative tool used by schools to measure and track the progress of the learners, across all their subjects, in an academic year. In addition to tracking the child's progress in the grade, the school schedule is used at the end of the academic year to determine whether the child will proceed to the next grade or be retained in the present grade.

KaziHealth Assessment Protocol

At baseline and follow-up testing, a comprehensive health risk assessment by health care personnel will be performed on the participating teachers via the *KaziChat*, a comprehensive health assessment tool, which will be used to capture and interpret all assessed health parameters. Internationally accepted cut-off and normative values will be used to rate each tested parameter based on a traffic light model. A personal health risk profile will be generated, with easy-to-understand explanations of the tested parameters as well as further referrals to a general practitioner, if needed.

Anthropometry and Body Composition

Utilizing the same protocol as for *KaziKidz*, each participant's body weight and height will be measured to calculate the BMI. Utilizing the same protocol as for *KaziKidz*, waist and hip circumferences will be measured to determine waist-to-hip ratio, a risk indicator for heart disease [39]. Bone mineral density and body fat percentage will be measured with the Discovery Hologic Dual-Energy X-ray Absorptiometry (DXA) QDR 4500A (APEX System Software Version 4.0.2) by a qualified radiographer. Pregnant individuals, individuals who underwent investigations using radioisotopes in the previous 10 days, and individuals with internal metal artifacts will be excluded from the DXA scan. Calibration will be conducted before testing, using the quality check test. Participant's height, weight, gender, birth date, and ethnicity will be entered before the participant is instructed to lay supine on an open X-ray table within specified position boundaries. The participant will be instructed to lay still and breathe normally while the scan is being conducted, a process that takes approximately 7.5 min.

Clinical Measures

The clinical measures are as follows:

1. A detailed family and medical history will be taken from each participant by a health care professional. Current and previous signs or symptoms of cardiac disease (eg, myocardial infarction, palpitations, and arrhythmias), NCDs (eg, hypertension, dyslipidemia, and diabetes) and psychological conditions (eg, headaches, sleep disorders, and depression) will be recorded. The Physical Activity Readiness Questionnaire will be used to determine whether medical clearance from a general practitioner will be required before the physical fitness assessment [49].
2. Each participant's blood pressure will be measured 3 times after the participant has been seated for 5 min with a calibrated Omron digital blood pressure monitor (Omron M6 AC model; Hoofddorp, The Netherlands) for the detection of prehypertension and hypertension. A medium or large adult cuff size, 22 to 32 cm or 32 to 42 cm, respectively (Omron Medium and Large Cuff; Hoofddorp, The Netherlands) will be used depending on the participant's arm circumference. The same protocol as indicated for *KaziKidz* will be followed to determine the final systolic and diastolic blood pressure values.
3. Dyslipidemia and glycosylated hemoglobin will be tested with a POC instrument (Alere Afinion AS 100 Analyzer, Abbott Technologies; Abbott Park, United States of America) using a full lipid profile (TC, LDL-C, HDL-C, TG, non-HDL, and C-HDL ratio) and HbA1c test, respectively. The same protocol used for *KaziKidz* in this regard will also be applied for assessing these variables.
4. For the detection of anemia, the hemoglobin concentration will be measured to the nearest 0.1 g/L, using a HemoCue Hb 301 system (HemoCue AB; Ängelholm, Sweden). The Eurotrol Hb 301 Control will be used to verify the precision and accuracy of the measuring device.

Physical Activity and Physical Fitness

Using the same protocol as for *KaziKidz*, physical activity behavior will be assessed with accelerometry. Cardiorespiratory fitness will be assessed through the Cooper 12-min run-walk test. The test is a simple, self-paced, maximal running test that is used to determine an individual's maximal oxygen uptake (VO_2 max). The aim of the test is to run or walk as far as possible within 12 min. VO_2 max is then calculated with the following formula:

$$VO_2 \text{ max (ml x kg}^{-1} \text{ x min}^{-1}) = (d_{12} + 504.9)/44.73$$

where d_{12} refers to the total distance covered in 12 min in meters [50]. Before the test starts, blood pressure and heart rate are measured and a 10-min warm-up period is offered. All participants will receive the same instructions, and no verbal encouragement is allowed throughout the test. After the test is completed, a 5-min cool-down period will be given. Although all possible measures will be taken to reduce risk, all maximum exercise tests involve some risk. The test will be supervised by trained health care professionals with the necessary knowledge to deal with any medical emergency that may arise. Furthermore, an automated external defibrillator will be available on site.

Upper body strength will be determined with the handgrip resistance test utilizing the same procedure as described in the *KaziKidz* protocol.

Psychosocial Health Questionnaires

To gather information about the demographic profile and SES, health behaviors, and psychosocial health indicators of each participant, the following assessments will be completed by each participant by means of a questionnaire survey:

1. Demographic data and SES determined through household income and assets (property and car ownership).
2. Cigarette smoking, alcohol use, and screen time per day.
3. Subjective perceived health measured with 2 items from the 12-item short form health survey, adapted from the SF-36 [51]. Participants will be asked to rate the following questions: *In general, would you say your health is?* and *How motivated are you to improve your lifestyle?*
4. Work-related stress will be assessed using the short version of the original Effort-Reward Imbalance questionnaire [52].
5. The Shirom-Melamed Burnout Measure, a validated and widely used tool, will be used to assess occupational burnout [53].
6. Diet and nutritional analysis with a 24-hour dietary recall.

7. The General Health Questionnaire will assess mental distress or minor psychiatric morbidities [54].
8. Subjective sleep complaints will be assessed utilizing the brief 7-item self-report Insomnia Severity Index [55].

Data Collection and Statistical Analysis

The following data will be collected: (1) quantitative data on blood pressure, glycated hemoglobin and blood lipids, anthropometry and levels of physical fitness, cognitive performance and psychosocial health, (2) SES and demographic data, and (3) qualitative data on the feasibility and acceptability of the intervention measures implemented through FGDs. Quantitative data will be entered twice and cross-checked using EpiData version 3.1 (EpiData Association; Odense, Denmark). Cleaned data will be transferred to STATA version 13.0 (STATA Corp, College Station, TX, United States of America). Questionnaire data will be collected using the software package EvaSys (Survey Automation Suite, version 7.1) and analyzed with STATA.

Clinical and anthropometric indicators, physical fitness, cognitive performance, and psychosocial health values will be summarized by their mean and SD at normal distribution and otherwise by their median and interquartile ranges. Questionnaire information on psychosocial health will be expressed as a percentage.

For the analysis of cross-sectional and longitudinal associations, mixed linear or mixed logistic regression models will be used, depending on the type of outcome variable. These models will be adjusted for clustering within classes and schools using random intercepts. In analyses of cross-sectional associations, the models will include personal characteristics of children, such as gender and age, SES of parents or guardians, and other potential confounders of the associations of interest. Models assessing intervention effects will additionally include 3 indicator variables, as defined at the level of schools, 1 for schools of the intervention arm, 1 for schools receiving teacher workshops, and 1 for schools receiving teacher coaching. In addition, these models may include the value of the respective outcome variable at baseline. As intervention effects may also depend on the child's initial characteristics, stratified analyses and analyses with interaction terms will be performed. Potential effect modifiers to be tested include gender, age, SES, ethnicity, health status, and physical fitness at baseline.

The primary objectives of the statistical analyses are (1) to assess the physical fitness of the participants and their associations with cognitive performance and psychosocial health at the beginning and over the course of the intervention, and (2) the effect of interventions on disease status and other health parameters. The secondary objective is to assess the feasibility and acceptability of the health interventions, as determined by FGDs.

Availability of Data and Materials

The datasets generated and/or analyzed during the present study are not publicly available due to confidentiality but are available from the corresponding author on reasonable request.

Results

Overview

The project was funded in April 2017 and enrollment of the participants was completed in January 2019. The baseline survey was conducted from January to March 2019. At the time the present paper is being written, the *KaziKidz* and *KaziHealth* intervention are underway. The follow-up survey is planned for September to October 2019. At the end of the study, the results will be communicated to the Department of Health and the Department of Education in Port Elizabeth, as well as the involved schools. All intervention materials will be made available to the control schools after completion of the study. Workshops will be offered to the control schools to prepare teachers to implement the *KaziKidz* teaching material. Furthermore, teachers of the control schools will have the possibility to take part in the workplace health promotion intervention program after the completion of the second health assessment. The key findings will be submitted for publication to the peer-reviewed literature and presented at national and international conferences.

Discussion

Principal Findings

Results from the DASH study revealed that the prevalence of soil-transmitted helminth infections among grade 4 children was above 60% (90/149) in several schools in Port Elizabeth [56]. Moreover, infected children had lower VO_2 max compared with their noninfected peers [56]; helminth infections and low physical fitness were significant predictors of low selective attention and poor academic achievement [16]; physical activity was associated with health-related quality of life [57]; almost one-third of all school children were classified as hypertensive [58]; and the physical activity intervention component contributed to the maintenance of academic performance [27] and resulted in a significantly delayed increase in children's BMI [59]. Importantly, the DASH intervention package was well received in all schools.

The *KaziBantu* project is a logical continuation and expansion of the DASH project and aims at contributing to healthy schools and healthy communities. Teachers, as leaders in communities, have an important role to play in this regard. We conjecture that teachers as healthy role models will be able to promote better health behaviors and encourage a healthy, active, and inspiring environment for learners and peers at school. Various health professionals will empower teachers with specific knowledge related to infectious and NCD risk factors, physical activity and fitness, and psychosocial health and nutrition. Improved health and well-being increase teachers' productivity, benefiting their own health and well-being and that of the children they teach and educate. We hypothesize that implementing *KaziBantu* will result in less absenteeism, a reduction in stress, and better coping with work demands.

Pursuing the present study protocol will provide specific answers to the following questions: Are *KaziKidz* teaching materials useful? What are the difficulties in using the teaching materials from the perspective of the teachers? What are the teachers' experiences with regard to the coaching by the teacher coaches? What experiences do the coaches have in their work with the teachers? What attitudes do teachers have with regard to the lessons proposed? What are the conditions for an effective and sustainable implementation of this teaching material? Does the acceptance of the *KaziKidz* teaching material by the teachers moderate its effectiveness?

With regard to the implementation of *KaziKidz* and *KaziHealth*, 3 languages are spoken by the communities in the study area, namely, Afrikaans, IsiXhosa, and English. To ensure comprehension, questionnaires translated into the local languages have been pretested by native speakers, with an emphasis on those that focus on mental health indicators to match the educational attainment of children and help them to understand and answer the questions. The study will be conducted in impoverished and harsh environments where illiteracy, neglect, and violence are common [60,61], which might have an impact on the granting of informed consent by parents and guardians. For illiterate parents or guardians, a literate witness will be invited to sign, whereas participants will be asked to provide a thumbprint. To ensure return of the signed consent forms, we might ask potential study participants several times. Specific safety measures are in place to implement the research. Although it is difficult to predict the extent of people's mobility and movement, we anticipate a substantial loss to follow-up as people show considerable mobility in this setting.

Multiple imputations will be used to deal with missing data, as appropriate.

Conclusions

Taken together, the *KaziBantu* project presented here builds upon the previous DASH study and aims to improve physical health and well-being, cognitive performance, and psychosocial and clinical health of children and teachers. The South African Department of Education seeks to create a lifelong learner who is confident, independent, literate, numerate, multiskilled, compassionate, and has respect for the environment and the ability to participate in society as an active citizen. The Department of Education also envisions healthy teachers who are qualified, competent, dedicated, and caring and who will be able to fulfill the various roles of an educator. Hence, the project aspires to assist the Department of Education by contributing to the development of the full potential of each learner and the transformation of education in South Africa. In addition, developed and validated *KaziKidz* workshop material may be translated into short learning programs for accreditation of Teachers' Continued Professional Development. The *KaziChat* app will be made available to the Department of Education's directorate responsible for human resources for distribution to all teachers together with encouragement for implementation. This study builds on local evidence and offers the opportunity of providing new evidence on health intervention responses to NCD risk factors as a benchmark for future controlled studies that will enable comparisons among marginalized communities between South Africa and other African countries.

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Authors' Contributions

All authors were involved in the design of the study and contributed to the development of the study protocol. UP and CW are the principal investigators. IM wrote the first manuscript draft. All authors reviewed, edited, and critically commented on the draft. All authors read and provided comments on the drafts and approved the final version of the paper before submission and resubmission. UP and CW are guarantors of the paper.

Conflicts of Interest

AA, ZG, and CW and are employees of the Novartis Foundation (Basel, Switzerland). All other authors declare no financial competing interests.

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Abbreviations

BMI: body mass index
CDC: Centers for Disease Control and Prevention
DASH: Disease, Activity and Schoolchildren’s Health
DXA: dual-energy x-ray absorptiometry
EKNZ: Ethics Committee Northwest and Central Switzerland
FGD: focus group discussion
HDL-C: high-density lipoprotein cholesterol
LDL-C: low-density lipoprotein cholesterol
LMIC: low- and middle-income country
MVPA: moderate-to-vigorous physical activity
NCD: noncommunicable disease
non-HDL: nonhigh density lipoprotein cholesterol
NTD: neglected tropical disease
PE: physical education
POC: point-of-care
RCT: randomized controlled trial
SES: socioeconomic status
VO_2max: maximal oxygen uptake
WHO: World Health Organization

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Clustered cardiovascular disease risk among children aged 8–13 years from lower socioeconomic schools in Gqeberha, South Africa

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ABSTRACT

Objectives To determine the prevalence of individual cardiovascular disease (CVD) risk factors and clustered CVD risk among children attending schools in periurban areas of Gqeberha and to investigate the independent association between clustered CVD risk, moderate to vigorous physical activity (MVPA) and cardiorespiratory fitness (CRF).

Methods Baseline data were collected in a cross-sectional analysis of 975 children aged 8–13 years. We measured the height, weight, waist circumference, blood pressure, fasting glucose, full lipid panel, 20 m shuttle run performance and accelerometry. The prevalence of individual risk factors was determined, and a clustered risk score (CRS) was constructed using principal component analysis. Children with an elevated CRS of 1 SD above the average CRS were considered 'at-risk'.

Results We found 424 children (43.3%) having at least one elevated CVD risk factor: 27.7% elevated triglycerides, 20.7% depressed high-density lipoprotein cholesterol and 15.9% elevated total cholesterol. An elevated clustered risk was identified in 17% (n=104) of the sample; girls exhibited a significantly higher CRS >1 SD than boys (p=0.036). The estimated odds of an elevated clustered risk are doubled every 2 mL/kg/min decrease in VO_2max (95% CI 1.66 to 3.12) or every 49 min reduction in MVPA (95% CI 27 to 224).

Conclusion A relatively high prevalence of elevated individual and clustered CVD risk was identified. Our results have also confirmed the independent inverse association of the clustered CVD risk with physical activity and CRF. These indicate that increased levels of CRF or MVPA may aid in the prevention and reduction of elevated clustered CVD risk.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Evidence shows that children with clustered risk factors are at an increased risk of developing cardiovascular disease and type 2 diabetes in adulthood, but little is known about the prevalence of clustered cardiovascular disease risk in underserved communities and schools such as those in the Gqeberha, Eastern Cape region of South Africa.

WHAT THIS STUDY ADDS

⇒ This is the first known study to present both individual and clustered risk factor prevalence for cardiovascular disease among children aged 8–13 years attending non-fee-paying government schools.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ This study contributes to the growing body of knowledge highlighting the importance of moderate to vigorous physical activity and cardiorespiratory fitness and emphasises their separate pathways in reducing risk for clustered cardiovascular disease risk in children.

⇒ These findings underscore the importance of an active lifestyle to counteract early-life cardiovascular risk.

INTRODUCTION

Globally, the leading causes of death are cardiovascular diseases (CVD).[1] Closely related CVD risk factors (central obesity, hypertension, hyperglycaemia and dyslipidaemia) are known to cluster and cause physiological changes, a phenomenon referred to as metabolic syndrome (MetS).[2] MetS is a condition where elevated CVD risk factors increase the risk for CVD and type 2 diabetes.[3] MetS was usually diagnosed among adults: however, the prevalence of MetS has become evident among children and adolescents.[3 4] Attempts have been made to establish the diagnostic criteria for MetS among children and adolescents by organisations such as the International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), and the WHO.[2] However, there is still no clear consensus for MetS in the paediatric population as the definitions and their cut-offs vary. An alternative to applying a MetS definition is calculating a clustered risk score (CRS) based on CVD risk factors. There is evidence that children with clustered risk factors are at an increased risk of developing CVD and type 2 diabetes in adulthood.[5] Researchers like Andersen *et al*[6] and Ekelund *et al*[7] constructed a CRS by summing the z-scores of the risk factors. Others like Peterson *et al*[8] used principal component analysis (PCA) to calculate the CRS: the PCA calculates the factor coordinates (multipliers) for each risk factor instead of assuming all risk factors have an equal contribution to the CRS.

Only two South African studies have investigated the prevalence of CVD risk among children and adolescents. The first was conducted by Matsha *et al*[9] who compared the NCEP ATP III and IDF definitions in the Western Cape. The second was conducted by Sekokotla *et al*[10] in Mthatha, Eastern Cape, using an adjusted definition of the NCEP ATP III criteria. Two recent studies conducted in the Eastern Cape tested the independent association of cardiorespiratory fitness (CRF) and physical activity (PA) with clustered CVD risk. Still, they did not investigate the clustered CVD prevalence.[11 12] However, CVDs are one of the predominant categories of non-communicable diseases (NCDs). NCDs are major drivers of healthcare costs in countries like South Africa (SA) which have a high NCD profile.[13] Moreover, in the periurban zones of SA, harsh socioenvironmental conditions perpetuate the NCD cycle.

Given the inconsistency in standardised MetS criteria, and the limited research on South African children, the aim of the current study was twofold: first, to determine the prevalence of both individual and clustered CVD risk factors among children attending primary schools in under-resourced periurban settings; second, to examine the independent association of a clustered CVD risk with PA and CRF, respectively.

METHODOLOGY

Study design

A cross-sectional analysis of the baseline data derived from the KaziBantu study was conducted. The KaziBantu study aimed to assess the effect of a school-based health intervention on risk factors for NCDs, health behaviours and psychosocial health in primary school children in disadvantaged communities in Gqeberha, SA.

All required procedures were followed, including Good Clinical Practice guidelines and the ethical principles defined in the Declaration of Helsinki.[14]

Patient and public involvement

School principals were informed about the study at a meeting 3 months before data collection (October 2018), and parents/guardians were informed about the project through study information newsletters. The research question and methods were developed and based on literature.[11 12] Participants and the public were not involved in the study design, recruitment and implementation of the study nor the choice of outcome measures. The study outcome and recommendations will be communicated to the Eastern Cape Department of Education so children, especially those attending schools in under-resourced communities, can benefit from these recommendations.

Participants

In SA, schools are divided into five quintiles (Q), with the poorest schools allocated to Q1 (Q1–Q3 are non-fee-paying schools and are considered 'disadvantaged'). About 64 principals from Q3 primary schools expressed interest in the study, of which 40 schools invited the research team to share the study information with their staff. Eventually, eight schools matched the inclusion to participate.[15] Children were selected from grades 4–6 (8–13 years old). One class was selected per grade based on the highest consent return rate, totalling three classes per school. Children were included if they met the following criteria: (1) oral assent, (2) written informed consent from parent/guardian, (3) not involved in other clinical trials during the study period, (4) and not suffering from medical conditions that prevented participation in the study, as determined by medical personnel. Recruitment closed in January 2019. A total of n=1020 children agreed to participate. Due to incomplete data sets, the data of 975 children (474 girls) were available for further analysis.

Socioeconomic status

Children completed a questionnaire on asset ownership and housing characteristics to determine their socioeconomic status (SES). Asset ownership was based on the availability of items. In contrast, housing characteristics were based on infrastructure and utilities, such as the type of building, the number of people per number of rooms, toilet type, access to running water, access to electricity and the fuel used for cooking. The data were used to generate an SES index created using PCA. Evidence of the reliability and validity of asset ownership and housing characteristics questionnaires has been published in a prior study.[16]

Assessment of cardiovascular risk factors

A detailed description of the procedures can be found in the *KaziBantu* study protocol.[15] Standardised guidelines were used to obtain anthropometric measurements: weight, height and waist circumference.[17] To determine the body composition, the authors calculated the body mass index (BMI) and measured the body fat percentage (BF%) via bioelectrical impedance analysis (Tanita MC-580; Tanita, Tokyo, Japan). Blood pressure (BP) was assessed with a validated oscillometric digital BP monitor (Omron M6 AC; Hoofddorp, Netherlands). Capillary blood samples were assessed using the Alere Afinion AS100 analyser (Abbott Laboratories, Illinois, USA). Via fingerprick, two drops of blood were taken to assess total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol

Table 1 Critical levels for eight risk factors

Risk factor	Critical level	Reference
BMI	≥90th percentile of the sample	Cole *et al*[38]
Waist circumference	≥90th percentile of the sample	Zimmet *et al*[2]
BP	≥90th percentile of the sample	Flynn *et al*[39]
HbA1c	≥39 mmol/mol	American Diabetes Association[40]
HDL-C	<1.03 mmol/L	McNeal *et al*[41]
LDL-C	≥2.8 mmol/L	McNeal *et al*[41]
Total cholesterol	≥4.4 mmol/L	McNeal *et al*[41]
Triglycerides	<10 years, ≥0.85 mmol/L ≥10 years, >1.02 mmol/L	McNeal *et al*[41]

BMI, body mass index; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

(LDL-C), triglycerides and glycated haemoglobin (HbA1c). Evidence of this fingerprick method's clinical utility and accuracy has been described previously.[18 19]

Cardiovascular risk factor cut-offs

Cut-offs were defined for each risk factor to determine the CVD risk. See table 1.

Physical activity

PA was measured using a light triaxial accelerometer device (ActiGraph wGT3X-BT; ActiGraph, Pensacola, USA), which has proven to accurately measure daily activities for children.[20] Children wore the device around the hip for seven consecutive days except during activities involving water contact. A 30 Hz sampling rate was used, and data were stored as GT3X raw files. Analyses were performed with the ActiLife software (V.6.13.2; ActiGraph) using 10 s epoch lengths. Non-wear time was calculated with the algorithm developed by Troiano and colleagues.[21] The data were considered valid if the child wore the device for at least 8 hours out of 24 hours on ≥4 weekdays and ≥1 weekend day.[22] Cut points for children defined by Evenson *et al*[23] were used to calculate an overall index for moderate to vigorous physical activity (MVPA).

Estimated VO_2max

Children's CRF was assessed with the 20 m shuttle run test adhering to the protocol by Léger *et al*.[24] The number of fully completed laps was recorded after the learner failed to reach the 20 m turn-line on two consecutive intervals. The number of laps was used to calculate the estimated VO_2max (adjusted for age and sex).

Statistical analysis

The collected data were double entered and validated in EpiData V.3.1 (EpiData Association; Odense, Denmark). All statistical analyses were obtained using Statistica V.13 (TIBCO Software, Palo Alto, USA) and Microsoft Office Excel 2013 (Microsoft, Redmond, USA). Descriptive data are displayed as the sample size (n), mean (M) and SD for all measured variables. The authors used analysis of variance to determine whether the observed differences between the means of the variables for both sexes were statistically significant. To validate inferential statistics, the eight risk factors listed in table 1 were first transformed to normality using the Box-Cox transformation and were subsequently z-standardised.

First, the individual CVD risk factors were selected, and then binary variables were created using cut-offs given in table 1. Children were assigned a *one* (1) when they exceeded the given cut-off or a *zero* (0) otherwise.

Second, a CRS was calculated as a linear combination of the eight CVD risk factors, where the individual weights associated with each risk factor were obtained using a PCA. The factor coordinates of the first extracted PCA were used as multipliers for the eight risk factors to calculate the CRS. The CRS was also z-transformed to facilitate the interpretation in SD units. We followed previously published recommendations[6] to determine the degree of clustering. Participants who exhibited an elevated CRS of 1 SD above the average CRS (CRS >1 SD) were defined as at risk and were assigned a *one* (1) or *zero* (0) otherwise. Pearson's χ^2 test determined whether differences observed for an elevated CRS between boys and girls were statistically significant.

Finally, to determine the independent effects of MVPA and VO_2max on the risk of an elevated CRS, a logistic regression model was used, where the dependent binary variable was CRS >1 SD. The model included age, SES and sex as covariates. To study the effect of VO_2max on CRS >1 SD, the model was controlled for age, SES, sex and MVPA. The logistic model did not detect a significant difference between the probabilities of a CRS >1 SD of girls and boys (p=0.144). Thus, in the subsequent logistic regression, the sex of the children was ignored. The estimated probabilities of CRS >1 SD at various levels of VO_2max were calculated. To study the effect of MVPA on CRS >1 SD, the model controlled for the confounding effects of age, SES and VO_2max. Using the estimated coefficients produced by the logistic regression, the probabilities of CRS >1 SD were calculated for various levels of MVPA.

RESULTS

A total of 424 (43.3%) children presented with at least one risk factor. Table 2 shows the descriptive statistics for the total group and separately for boys and girls.

According to table 2, girls presented with higher mean values for all CVD risk factors except HbA1c and HDL-C. Statistically significant sex differences were noted for weight (p=0.0008), BMI (p=0.0001), BF% (p<0.0001), total cholesterol (p=0.0287) and triglycerides (p<0.0001). The effect size was of small practical significance for weight (d=0.22), BMI (d=0.25) and triglycerides (d=0.36), while BF% (d=0.85) showed large practical significance. Boys had significantly higher CRF (p<0.0001; d=0.54) and MVPA values (p<0.0001; d=0.93) than girls. These differences were both statistically and practically significant.

Table 3 shows the percentage of children at risk for each CVD risk factor and the corresponding 95% CI for the total group and girls and boys separately. Almost 30% of the children had elevated triglycerides. More girls had elevated triglycerides than boys (p<0.001), but this difference was of small practical significance (φ=0.171). The three individual risk factors with the highest number of children at risk were triglycerides, total cholesterol and depressed HDL-C from the lipid test battery. The glucose test (HbA1c) was the fourth most prevalent. BMI was the only CVD risk factor to show a sex difference that was statistically (p=0.008) and practically (φ=0.089) significant.

Seventeen per cent (n=104; 62 girls) of the sample had an elevated CRS. Girls presented with a significantly higher risk of an elevated CRS than boys (χ^2=4.39, p=0.036). The estimated odds for girls to present with an elevated CRS is 1.6 times higher than for boys (95% CI 1.02 to 2.42).

Figure 1 gives the average trend for the probability of an elevated CRS as a function of VO_2max at the medians of age, SES and MVPA. The estimated probability of CRS >1 SD for 10-year-old children at median SES, MVPA and VO_2max values was 8.9%. At any given value for age, SES and MVPA, the estimated odds of an elevated CRS are halved for every increase of 2.17 mL/kg/min in VO_2max (95% CI 1.66 to 3.12).

Figure 2 shows the estimated probability of an elevated CRS as a function of MVPA at the medians of age, SES and VO_2max. The probability of an elevated CRS above the average CRS for a 10-year-old child, at 60 min of MVPA per day and median values for the covariates, is 10.1%. The estimated odds of an elevated CRS above the average CRS are halved for every increase of 49 min spent in MVPA (95% CI 27 to 224).

DISCUSSION

The purpose of the current paper was to determine the prevalence of individual risk factors and clustered CVD risk among children in selected periurban zones of Gqeberha, SA, and investigate the independent association of clustered CVD risk with MVPA and CRF.

Individual and clustered CVD risk

Results showed that 43.3% of children presented with at least one elevated CVD risk factor. The three most common CVD risk factors were elevated triglycerides (27.7%), depressed HDL-C (20.7%) and elevated total cholesterol (15.9%). However, these results are relative to pubertal development[25 26] and should be interpreted with caution as 9.92% of girls in the current sample had self-reported age at menarche. Our findings correlate with a recently published study which also found depressed HDL-C to be a common risk factor in a sample of 142 142 children and adolescents.[27] A general and yet consistent finding is for total cholesterol to decrease during sexual maturation while patterns of change vary across studies for triglycerides and lipoprotein-cholesterol fractions.[25]

Age-related developmental differences impact MetS diagnostic criteria among children and adolescents. In a cohort with a similar age range to the present (8–13 years old), Cruz *et al*[28] used a MetS definition (NCEP ATP III) and reported a MetS prevalence of 30% among Hispanic children who were overweight and at high risk of type 2 diabetes. Literature[2 3] does, however, urge researchers not to diagnose MetS in children younger than 10 years old, hence why we constructed a CRS instead of applying a specific MetS definition to the current sample in which more than 500 children were younger than 10 years old. Using the CRS >1 SD, a clustered CVD risk prevalence of 17% was found in the present sample. Literature reflects varying MetS rates. Tailor *et al*[29] provided a worldwide update on the prevalence of MetS among children and adolescents, ranging from 1.2% to 22.6%; however, none of the included studies were from Africa. A systematic review and meta-analysis[27] of 76 studies reported a pooled prevalence of MetS in Africa (6.03%, 95% CI 0.24% to 11.28% for the IDF definition; and 6.71%, 95% CI 5.51% to 7.91% for the ATP III definition) which only included two studies from SA,[9 10] the other study was from Ethiopia (a prevalence of 12.4% was reported among an adolescent sample).[30] The two South African studies included children older than 10 years old. Therefore, applying a MetS definition was acceptable. From the rural parts of Mthatha in the Eastern Cape of SA, Sekokotla *et al*[10] identified a MetS prevalence of 5.9% using the NCEP ATP III definition among adolescents aged 13–18 years. Meanwhile, in the metropolitan city of Cape Town in the Western Cape, Matsha *et al*[9] did a comparison study and reported a prevalence of 6.5% when applying the NCEP ATP III definition and only 1.9% using the IDF definition among participants aged 10–16 years.

The function of CRF and PA for CVD risk

The present study corroborates the findings of the previous studies[6 11 12 31] where the protective function of both CRF and PA reduced the probability of elevated clustered CVD risk factors in children. Our results showed a halving of an elevated clustered CVD risk for every 2.17 mL/kg/min increase in VO_2max (95% CI 1.66 to 3.12) or every 49 min increase in MVPA (95% CI 27 to 224).

Table 2 Demographics of children as assessed in underprivileged primary schools in Gqeberha, SA, in February/March 2019

	Total			Girls			Boys				
	n	M (SD)	95% CI	n	M (SD)	95% CI	n	M (SD)	95% CI	P value	Cohen's d
Age	922	10.41 (1.19)	10.34 to 10.49	451	10.23 (1.13)	10.12 to 10.33	471	10.59 (1.22)	10.48 to 10.70	<0.0001	−0.31
SES	848	74.73 (14.17)	73.77 to 75.68	429	74.16 (13.82)	72.85 to 75.47	419	75.31 (14.52)	73.91 to 76.70	0.2370	−0.08
Height (cm)	932	139.88 (8.86)	139.31 to 140.5	455	140.22 (8.96)	139.39 to 141.04	477	139.56 (8.76)	138.77 to 140.35	0.2568	0.07
Weight (kg)	922	35.61 (10.13)	34.95 to 36.26	451	36.75 (11.00)	35.73 to 37.77	471	34.51 (9.09)	33.69 to 35.33	0.0008	0.22
BMI (kg/m^2)	922	17.98 (3.68)	17.74 to 18.21	451	18.45 (4.04)	18.08 to 18.82	471	17.52 (3.24)	17.23 to 17.82	0.0001	0.25
Body fat (%)	922	23.64 (6.88)	23.20 to 24.09	451	26.41 (6.28)	25.83 to 26.99	471	21.00 (6.37)	20.42 to 21.57	<0.0001	0.85
Waist circumference (cm)	917	58.43 (7.89)	57.92 to 58.94	452	58.81 (8.25)	58.04 to 59.57	465	58.07 (7.52)	57.39 to 58.76	0.1584	0.09
Systolic BP (mm Hg)	944	108.92 (13.43)	108.06 to 109.78	466	109.29 (13.75)	108.04 to 110.54	478	108.57 (13.12)	107.39 to 109.74	0.4101	0.05
Diastolic BP (mm Hg)	944	67.17 (10.93)	66.47 to 67.87	466	67.84 (10.83)	66.85 to 68.83	478	66.51 (11.01)	65.52 to 67.50	0.0619	0.12
HbA1c (mmol/mol)	766	35.6 (2.60)	35.47 to 35.83	383	35.61 (2.46)	35.36 to 35.86	382	35.68 (2.68)	35.41 to 35.95	0.6870	−0.03
Total cholesterol (mmol/L)	757	3.74 (0.66)	3.69 to 3.78	379	3.79 (0.63)	3.72 to 3.85	378	3.68 (0.69)	3.61 to 3.75	0.0287	0.16
LDL-C (mmol/L)	748	2.03 (0.54)	2.00 to 2.07	375	2.07 (0.53)	2.01 to 2.12	373	2.00 (0.56)	1.94 to 2.06	0.1004	0.12
HDL-C (mmol/L)	757	1.29 (0.31)	1.27 to 1.32	379	1.27 (0.29)	1.24 to 1.30	378	1.31 (0.32)	1.28 to 1.35	0.0725	−0.13
Triglycerides (mmol/L)	757	0.92 (0.55)	0.88 to 0.96	379	1.02 (0.66)	0.95 to 1.08	378	0.82 (0.38)	0.78 to 0.86	<0.0001	0.36
CRF/VO_2max (mL/kg/min)	918	46.98 (5.77)	46.62 to 47.38	455	45.48 (5.05)	45.01 to 45.94	462	48.46 (6.04)	47.91 to 49.01	<0.0001	−0.54
MVPA (min/day)	920	72.99 (28.25)	71.16 to 74.82	456	61.01 (21.96)	58.99 to 63.03	464	84.76 (28.80)	82.14 to 87.39	<0.0001	−0.93

Statistical significance at p<0.05. The variation in the n values per variable results from missing data. Effect sizes (Cohen's d) are interpreted as follows: d<0.2, no difference; d=0.20–0.49, small difference; d=0.50–0.79, medium difference; d≥0.80, large difference.

BMI, body mass index; BP, blood pressure; CRF, cardiorespiratory fitness; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MVPA, moderate to vigorous physical activity; SA, South Africa; SES, socioeconomic status.

Table 3 Percentage of children at risk for each risk factor in underprivileged primary schools in Gqeberha, SA, in February/March 2019

Risk factor	Total group n (%)	Total group 95% CI	Girls n (%)	Girls 95% CI	Boys n (%)	Boys 95% CI	P value	Phi
BMI (kg/m^2)	895 (11.5)	9.4 to 13.6	445 (14.4)	11.1 to 17.6	450 (8.7)	6.1 to 11.3	0.008	0.089
Waist circumference (cm)	879 (10.4)	8.3 to 12.4	442 (10.4)	7.6 to 13.3	437 (7.4)	7.4 to 13.1	0.118	0.053
Systolic BP (mm Hg)	898 (12.5)	10.3 to 14.6	447 (11.9)	8.9 to 14.9	451 (13.1)	10.0 to 16.2	0.587	−0.018
Diastolic BP (mm Hg)	898 (11.4)	9.3 to 13.4	447 (10.7)	7.9 to 13.6	451 (12)	9.0 to 15.0	0.539	−0.020
HbA1c (mmol/mol)	766 (13.7)	11.3 to 16.1	383 (12.5)	9.2 to 15.8	382 (14.7)	11.1 to 18.2	0.375	−0.032
Total cholesterol (mmol/L)	757 (15.9)	13.3 to 18.5	379 (16.4)	12.6 to 20.1	378 (15.3)	11.7 to 19.0	0.679	0.015
LDL-C (mmol/L)	748 (7.2)	5.4 to 9.1	375 (7.2)	4.6 to 9.8	373 (7.2)	4.6 to 9.9	1.000	0.00
HDL-C (mmol/L)	757 (20.7)	17.9 to 23.6	379 (24.0)	19.7 to 28.3	378 (17.5)	13.6 to 21.3	0.027	0.080
Triglycerides (mmol/L)	757 (27.7)	24.6 to 30.9	379 (35.4)	30.5 to 40.2	378 (20.1	16.1 to 24.1	<0.001	0.171

Statistical significance at p<0.05. The variation in the n values per variable results from missing data. The effect size was determined by using phi (φ). A value of φ=0.1 represents a small effect, 0.3 a medium effect and 0.5 a large effect.
BMI, body mass index; BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SA, South Africa.

In SA, it is estimated that 35.8%–51.7% of children,[32 33] and about 36% of adolescents,[34] meet the international recommendation of at least 60 min of daily MVPA. A large percentage of the current sample (72.99%) achieved this recommendation (table 2). Even though girls managed to reach the ≥60 min daily recommendation, the difference between the sexes was still of statistical (p<0.001) and practical significance (d=−0.93). Consequently, girls should be encouraged to be more active as they exhibited a significantly higher probability of CRS >1 SD than boys (p=0.036).

The gender difference for CRF was also of statistical significance (p<0.001) with a medium effect size (d=−0.54). Girls achieved an average value of 45.48 mL/kg/min, and boys an average of 48.46 mL/kg/min (table 2). According to Ruiz *et al*,[35] the 95% CI region of CRF associated with low CVD risk for children (8–17 years old) ranges from 41.8 to 47.7 mL/kg/min for boys and 34.6 to 39.5 mL/kg/min for girls. To avoid CVD risk, the CRF cut points are 41.8 and 34.6 mL/kg/min for boys and girls, respectively.[35] Based on these cut points, the fitness levels of the current sample did not raise a red flag in respect of CVD.

Limitations

Due to the cross-sectional design of this study, we are unable to report on causal inference. Furthermore, our findings cannot be generalised to all South African children, as only children from one out of the nine provinces were included in this investigation. In addition, our restricted inclusion of sexual maturity may limit our understanding of the influence of maturation on CVD

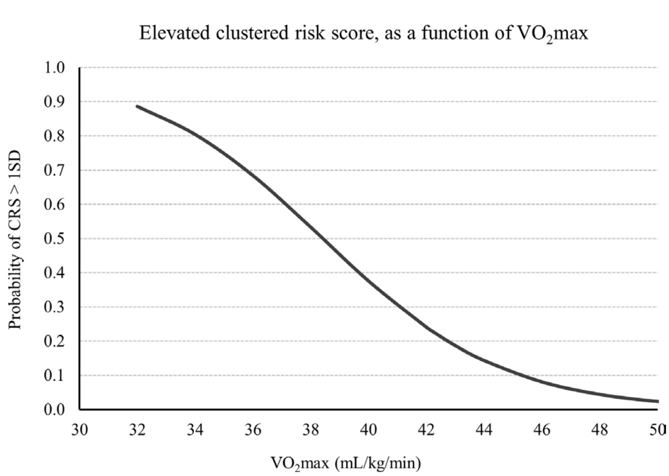

Figure 1 Estimated probability of clustered risk score (CRS) >1 SD, as a function of VO_2max, at the median values for age, socioeconomic status (SES) and moderate to vigorous physical activity (MVPA).

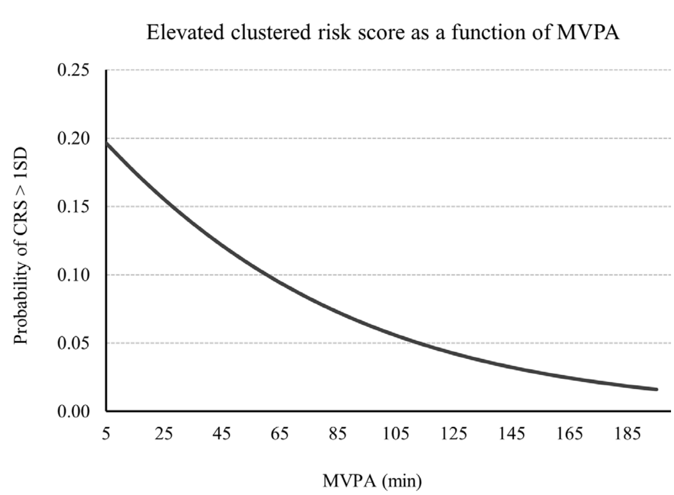

Figure 2 Estimated probability of clustered risk score (CRS) >1 SD, as a function of moderate to vigorous physical activity (MVPA), at the median values for age, socioeconomic status (SES) and VO_2max.

variables during puberty. Finally, estimating children's VO_2max via the 20 m shuttle run test is not without criticism.[36] However, this test is currently the most widely used field-based measurement of CRF in children.[37]

CONCLUSION

A relatively high prevalence of elevated individual and clustered CVD risk was identified in this cohort of children from Q3 schools living in selected communities of Gqeberha, SA. Our findings confirm the independent association of the clustered CVD risk with PA and CRF, respectively. Our findings also support previous work among South African primary school children showing that elevated clustered CVD risk decreases with an increase in CRF or MVPA.[11 12]

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

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Chapter 5: Relationship between Body Mass Index and Physical Activity

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MDPI

Article

Relationship between Body Mass Index and Physical Activity among Children from Low-Income Communities in Gqeberha, South Africa: A Cross-Sectional Study

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Abstract: This study aimed to establish the prevalence of underweight, overweight and obesity, the level of moderate-to-vigorous physical activity (MVPA) and the association thereof among vulnerable children from low-income communities in South Africa. Cross-sectional data were collected from 916 children (467 boys and 449 girls) aged 8–13 years ($\bar{x}$ = 10.4 ± 1.2 years) attending eight low-income schools in Gqeberha, South Africa. Measured outcomes included accelerometery-measured physical activity (PA), weight, height and body mass index (BMI). Analysis of variance was used to determine the mean difference of total MVPA stratified by sex and BMI classification. Overall, 13% of the cohort were underweight, 19% were overweight/obese and 64% engaged in 60 min of MVPA per day. Girls presented nearly twice the odds of being overweight or obese than boys (95% CI: 1.40–2.77). Underweight to normal-weight children (boys: OR = 3.89, 95% CI: 2.18–6.93; girls: OR = 1.78, 95% CI: 1.13–2.80) were more likely to engage in 60 min/day of MVPA than overweight to obese children. There is an inverse association between BMI categories and theduration of MVPA achieved per day. Special attention should be aimed at increasing awareness of healthy nutrition and promoting a variety of PA, especially among girls and children with excess weight.

Keywords: children; body mass index; underweight; overweight; obesity; moderate-to-vigorous physical activity; low-income schools

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Introduction

Non-communicable diseases (NCDs) are a leading cause of morbidity and account for seven of ten global mortalities [1]. Global efforts have emerged to prioritise the prevention and treatment of NCDs, which were included in the United Nation's Sustainable Development Goals (target 3.4). Meanwhile, NCD mortalities are higher in low- and middle-income countries (LMICs) as access to primary healthcare needed to treat and manage NCDs is often lacking [1,2]. Moreover, while South Africa is classified as an upper-middle-income country, it is also ranked as the most unequal country in the world (0.63 Gini coefficient) [3], where social and economic inequalities exacerbate the NCD cycle.

South Africa has vastly unequal socioeconomic societies with diverse cultures, ethnicities and dietary preferences, which may impact the weight status of the different population groups [4]. Evidence describing national demographics have reported that the prevalence of underweight was highest amongst Coloured (mixed ancestry) children, whereas Caucasian children had the highest incidence of overweight and obesity compared to Black African and Coloured children [5]. Moreover, studies have found that children in more urbanised areas are more likely to suffer from overnutrition, while children from rural areas are mostly affected by stunting and being underweight [5,6]. Emerging research has also pointed to the role of maternal nutrition, as stunted mothers are more likely to have stunted and overweight infants who become obese children, thereby perpetuating the intergenerational cycle of malnutrition and diet-related NCDs [7,8].

South Africa is experiencing a nutritional transition, where the incidence of overweight and obesity continues to rise despite the high prevalence of micronutrient deficiencies and food insecurity. According to the South African Child Gauge Report, one in eight children are overweight or obese, and one in four are stunted [8]. These high proportions of malnutrition are consistent with poor dietary habits and a low intake of micronutrients [9]. A recent systematic review by Wrottesley, Pedro, Fall et al. [10] confirmed that South African children and adolescents are consuming higher quantities of energy-dense processed foods that are high in sugar and fat but low in micronutrients. A study (which assessed the food and nutrition environment of 16 low-income schools in the Eastern Cape province of South Africa) further corroborated these findings as it reported that a high incidence of unhealthy dietary practices was observed and that energy-dense food items such as fried bread dough (fat cakes), sweets and chips were the main items purchased at school tuckshops [11].

Unfortunately, children in LMICs are the most vulnerable and susceptible to nutritional imbalances as they may be exposed to inadequate nutrition during critical periods of their development [12]. A recent study investigated the shift in nutritional status in four selected African countries (South Africa, Ghana, Kenya and Malawi) with different socioeconomic development status. This study found a high prevalence of overweight and obesity (13%) compared to underweight (5.9%) among children under five years, although the incidence of stunting was considerably higher (27%) [13]. These rates are markedly higher than the global average. The 2018 Global Nutrition Report illustrated the extent of malnutrition, where every country in the world is afflicted by some form of malnutrition. It is reported that 150.8 million (22.2%) children (0–59 months) are stunted, and 38.3 million (5.6%) children are overweight [7].

There is an urgent need to address the excess consumption of refined grains and sugary food and beverages as this 'Westernised diet' negatively affects the health and wellbeing of children and increases the risk of NCDs in adulthood [14]. The consequences of such nutritional imbalances are likely to affect the individual's quality of life and may impact the country's health burden, productivity and growth potential. Unhealthy dietary habits and physical inactivity are established contributors to NCDs, which are associated with the risk of low self-esteem and psychiatric disorders during adolescence [15,16]. Thus, a strategy to curb intergenerational malnutrition and combat the rising prevalence of NCD risk is to promote healthy and active lifestyles from a young and impressionable age.

Physical activity (PA) is associated with numerous health benefits, which include the reduced risk of NCDs, improved body composition, self-perception and self-esteem and reductions in depression [17]. Evidence-based recommendations stipulate that children and adolescents should participate in at least 60 min of daily moderate-to-vigorous physical activity (MVPA) to realise these health benefits [18]. However, many children and youths are insufficiently active and do not meet these targets. The Global Matrix 4.0 confirms that the PA levels of children and youths are a critical public health concern. Estimates show that only one-third (27–33%) of children and adolescents meet the recommended amount of PA [19]. The recently published 2022 Healthy Active Kids South Africa (HAKSA) Report Card has shown more positive estimates, with 60% to 73% of children and adolescents achieving the recommended 60 min of MVPA/day [20]. Seemingly, the majority of South African children may be meeting the PA guideline, but vulnerable populations, in particular, girls, overweight and obese children, children with less-educated parents and those of a lower socioeconomic status (SES), are less likely to participate in the recommended amount of PA than boys, children of a normal-weight status, children with educated parents and those with a higher SES [21–24]. Evidence also shows that PA is likely to decrease with increasing age, with annual declines in MVPA starting from the ages of six years for girls and nine years for boys [25].

Against this background, the current study aimed to establish the prevalence of underweight, overweight and obesity as well as the level of MVPA among primary school-aged children from selected low-income communities in Gqeberha, South Africa. In addition, this study also sought to determine the association between children's BMI classification and PA behaviour.

1. Materials and Methods

1.1. Study Design

The present study is a substudy of the larger *KaziBantu* project [26], which aims to improve the health conditions of both teachers and learners, thereby creating 'Healthy Schools for Healthy Communities' in under-resourced settings. The present study is a cross-sectional analysis of the baseline data collected for the *KaziBantu* study from January to March 2019 [26].

1.2. Participants

Eight quintile 3 primary schools from peri-urban areas of Gqeberha were included in the study. South African schools are ranked into five quintiles, from quintile 1, the poorest, to quintile 5, the least poor. Quintile 1–3 are non-fee-paying schools. Altogether, 1020 children from grades (Gr.) 4–6 (8–13 years, mean age: 10.4 ± 1.2 years) were recruited, and 975 were enrolled in the umbrella *KaziBantu* study. For the present study, 916 children (467 boys and 449 girls) had a complete data set for the body composition calculation.

1.3. Ethics Statements

Ethics approval was obtained from the Nelson Mandela University Research Ethics Committee (Human) (H19-HEA-HMS-003), the Eastern Cape Department of Health (EC_201804_007) and the Eastern Cape Department of Education. The study was registered with the ethical review board of the Ethics Committee Northwest and Central Switzerland (R-2018-00047). All required procedures were followed, including good clinical practice guidelines and the ethical principles defined in the Declaration of Helsinki [27]. The participant's parents/guardians provided written informed consent, and each participant gave oral assent to participate in this study.

1.4. Anthropometric Measures

Body height was measured once to the nearest 0.1 cm using an SECA portable stadiometer as each child stood erect, shoulders relaxed and barefoot with their back and heels touching the height meter. Body weight was measured once to the nearest 0.1 kg using a wireless body composition monitor (Tanita MC-580) as each child stood barefoot on the scale with minimal clothing. Body composition was determined by calculating the BMI using the standard formula of weight (kg) divided by the square metre of height (m^2). Underweight, normal, overweight and obesity status were assessed using age- and gender-specific cut-off points provided by the International Obesity Task Force (IOTF) and developed by Cole, Bellizzi, Flegal et al. [28].

1.5. Physical Activity

Device-based PA was measured using a light triaxial ActiGraph® wGT3X-BT accelerometer (Actigraph LLC., Pensacola, USA), which has been proven to accurately measure the daily activity of children [29]. The device was fitted at the hip and worn for seven consecutive days, except during activities involving water contact. A 30 Hz sampling rate was used, and data were stored as GT3X raw files. Analyses were performed with the ActiLife software (version 6.13.2; Actigraph LLC, Pensacola, FL, USA) using 10-sec epoch lengths. Non-wear time was calculated and eliminated using the Troiano, Berrigan, Dodd et al. [30] algorithm. Evenson et al. (2008) cut points were used to calculate the PA intensities for children. The data were considered valid if the child wore the device for a minimum wear time, defined as total PA (6 am–12 am, ≥480 min/day on ≥4 weekdays and ≥1 weekend day) [31]. MVPA was calculated as minutes per day in moderate and vigorous intensities.

1.6. Statistical Analysis

The collected data were double-entered and validated in EpiData version 3.1 (EpiData Association; Odense, Denmark). All statistical analyses were obtained using Statistica® version 13 (TIBCO Software Inc, Palo Alto, CA, USA) and Microsoft® Office Excel 2016 (Microsoft Corporation, Redmond, WA, USA). Continuous variables were descriptively analysed by means (M) and standard deviations (SD). The various levels of the categorical variables were presented as percentages (%). The chi-squared test of independence was used to determine the differences in weight status in the compared groups. Analysis of variance was performed to determine the mean difference between total MVPA per sex and BMI classification. The level of statistical significance was set at $p < 0.05$. The effect sizes were determined using Cohen's d, which are interpreted as follows: d < 0.2, no difference; d = 0.20–0.49, small difference; d = 0.50–0.79, medium difference; and d ≥ 0.80, large difference. Odds ratio (OR) analyses were also performed to determine the odds of children meeting ≥60 min MVPA/day depending on their BMI classification. A 95% confidence interval (CI) is presented for OR.

2. Results

Table 1 presents the descriptive statistics. The gender distribution of the sample is equally split (51% boys and 49% girls). The mean age of the boys was 3.3% higher than that of the girls; this difference showed a statistical significance ($p < 0.005$; d = 0.297). The mean height of the boys and girls in this sample was equal within the sampling error ($p = 0.237$; d = 0.078). The mean weight of the girls was 6.5% higher than that of the boys, and this difference was statistically significant ($p < 0.001$, d = 0.22). The mean BMI of the girls was 5.2% higher than that of the boys, and the difference was statistically significant ($p < 0.001$; d = 0.25). The average body fat % of the girls was almost 26% higher than that of the boys; this difference showed strong statistical significance ($p < 0.001$; d = 0.85). The mean total MVPA of the boys was 32.58% higher than that of the girls; this difference was statistically significant ($p < 0.001$; d = 0.93).

Table 1. Descriptive statistics were presented for the whole group and by sex comparison.

	Total (*n* = 975)		Boys (*n* = 474)		Girls (*n* = 501)			
	n	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*n*	$\bar{x}$ (SD)	*p*-Value	Cohen's d
Age (years)	916	10.4 (1.2)	467	10.6 (1.2)	449	10.2 (1.1)	<0.001 *	0.297
Height (cm)	927	139.8 (8.8)	473	139.5 (8.7)	454	140.2 (9.0)	0.237	−0.078
Weight (kg)	917	35.6 (10.1)	467	34.5 (9.1)	450	36.7 (11.0)	0.001 *	−0.221
BMI (kg/m^2)	917	18.0 (3.7)	467	17.5 (3.2)	450	18.4 (4.0)	<0.001 *	−0.250
Body fat (%)	922	23.64 (6.88)	471	21.00 (6.37)	451	26.41 (6.28)	<0.001 *	0.85
MVPA (min/day)	920	72.99 (28.25)	464	84.76 (28.80)	456	61.01 (21.96)	<0.001 *	−0.93

Notes. Statistical significance at * $p < 0.05$. The variation in the *n* values per variable results from missing data. The effect sizes (Cohen's d) are interpreted as: d < 0.2, no difference; d = 0.20–0.49, small difference; d = 0.50–0.79, medium difference; d ≥ 0.80, large difference. $\bar{x}$ = Mean; SD = standard deviation, BMI = body mass index.

Figure 1 shows the results of the differences in weight status in the compared groups. Weight status was determined using the age- and sex-specific international cut-off points for the relevant BMI categories [29]. Most children were of normal weight (340 boys, 290 girls), while 13% (63 boys, 52 girls) were underweight, 12% were overweight (43 boys, 63 girls) and 7% were obese (21 boys, 44 girls). The chi-squared test revealed highly significant differences between the distribution of the BMI categories of the girls and boys ($p < 0.001$; Cramer's V = 0.135). Cramer's V interpretation is as follows: small = 0.06, medium = 0.17

and large = 0.29. The odds of being overweight or obese were nearly twice as high for girls (OR = 1.97, 95% CI: 1.40–2.77) than for boys.

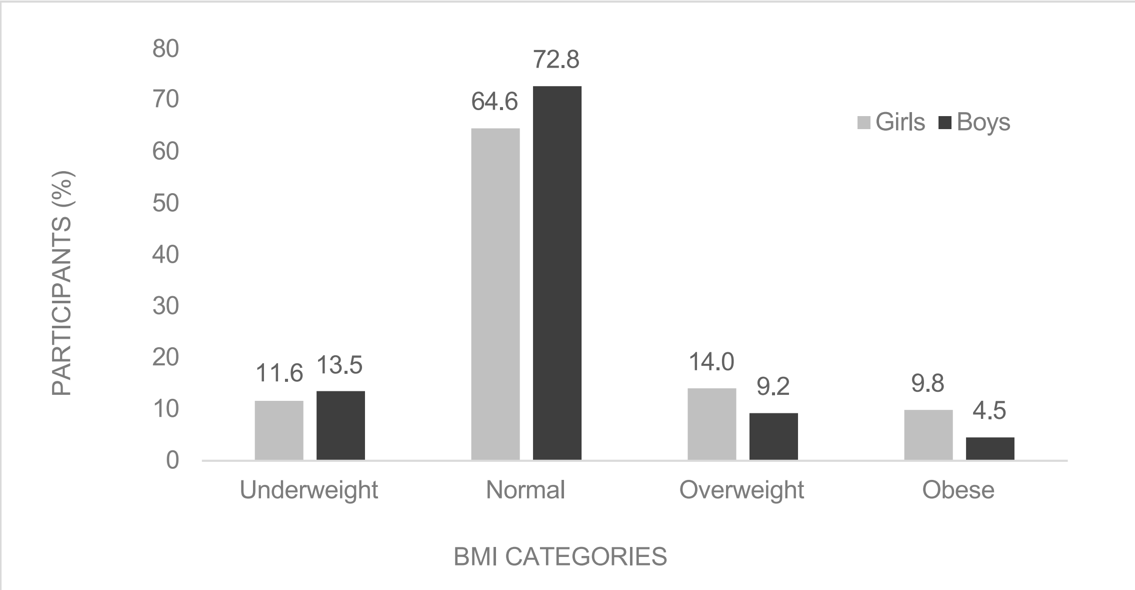

Figure 1. Prevalence of underweight, normal weight, overweight and obese, stratified by sex.

Figure 2 shows the difference between the unweighted mean total MVPA in minutes/day according to sex and BMI categories. The ANOVA revealed significant differences. The mean total MVPA of the boys was significantly different from that of the girls for the underweight (boys: 81.8 min/day, 95% CI: 74.5–89.1 vs. girls: 67.7 min/day, 95% CI: 61.2–74.2), normal weight (boys: 87.8 min/day, 95% CI: 84.8–90.9 vs. girls: 62.6 min/day, 95% CI: 59.9–65.2) and overweight (boys: 79 min/day, 95% CI: 69.6–88.4 vs. girls: 56.1 min/day, 95% CI: 51.4–60.8) categories, respectively. However, the mean total MVPA of the obese boys did not differ significantly from that of the obese girls (boys: 59.1 min/day, 95% CI: 48.1–70.1 vs. girls: 50.8 min/day, 95% CI: 45.2–56.3).

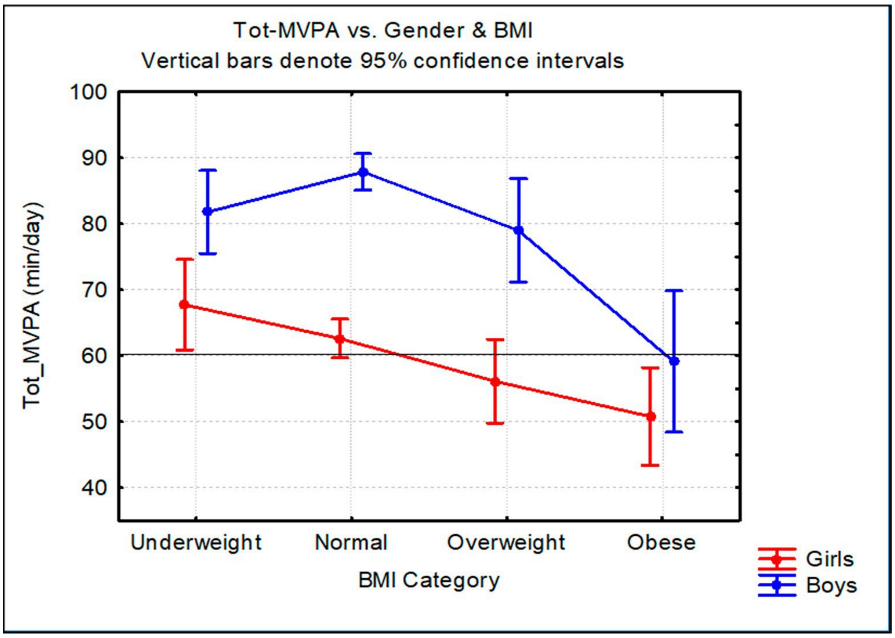

Figure 2. Mean total MVPA (min/day) stratified by sex and BMI categories.

Figure 3 shows the percentage of underweight, normal-weight, overweight and obese children who did and did not meet the ≥60 min MVPA/day. The highest count of children who achieved ≥60 min MVPA/day was (in descending order) normal-weight (*n* = 410, 47%) and underweight (*n* = 76, 9%) children, followed by overweight (*n* = 51, 6%) and obese (*n* = 22, 3%) children.

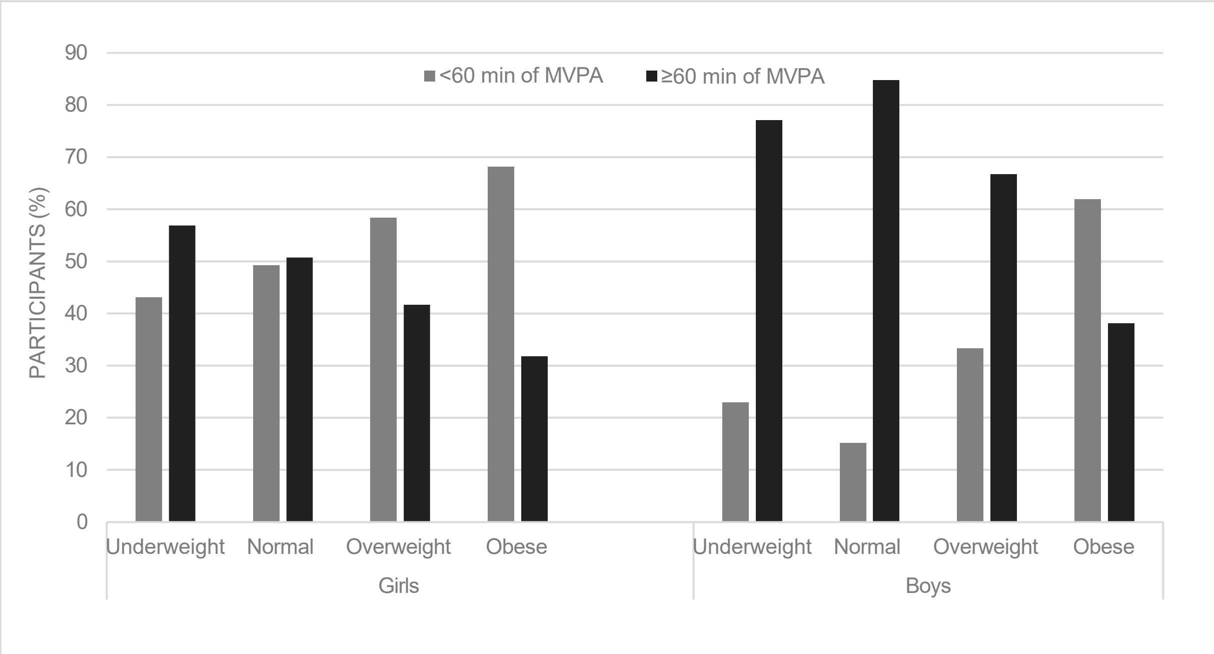

Figure 3. Percentage of children who did or did not meet ≥60 min MVPA, stratified by BMI categories and sex.

A higher percentage of boys achieved ≥60 min of MVPA/day than girls in the underweight (47 boys, 77% vs. 29 girls, 57%; $p = 0.029$, Cramer's V = 0.215), normal-weight (268 boys, 85% vs. 142 girls, 51%; $p < 0.0001$, Cramer's V = 0.378) and overweight (26 boys, 67% vs. 25 girls, 42%; $p = 0.021$, Cramer's V = 0.244) categories. In contrast, the difference between the percentages of obese boys and girls who achieved ≥60 min MVPA/day was not much different (8 boys, 38% vs. 14 girls, 32%; $p = 0.352$, Cramer's V = 0.062). Cramer's V interpretation is as follows: small = 0.1, medium = 0.3 and large = 0.5.

In the studied sample, obese girls were less likely to meet ≥60 min MVPA/day than overweight girls (OR = 1.53, 95% CI: 0.68–3.46). Moreover, the odds were much lower for obese boys to achieve ≥60 min of MVPA/day than for overweight boys (OR = 3.25, 95% CI: 1.08–9.80).

Table 2 presents the odds of being overweight or obese as a result of time spent in daily MVPA. Among the girls classified as overweight/obese, 62.5% (*n* = 65) engaged in <60 min of MVPA/day, while 37.5% (*n* = 39) engaged in ≥60 min of MVPA/day. The odds of engaging in ≥60 min/day are 1.78 times higher for underweight to normal-weight girls than overweight or obese girls (95% CI: 1.13–2.80, $p = 0.017$). Among the boys classified as overweight/obese, 43.3% (*n* = 26) engaged in <60 min of MVPA/day, whereas 56.7% (*n* = 34) participated in ≥60 min of MVPA/day. The odds of participating in ≥60 min/day are 3.89 times higher for underweight to normal-weight boys than overweight or obese boys (95% CI: 2.18–6.93, $p < 0.0001$).

Table 2. Prevalence of meeting MVPA criteria and the relevant odds ratios for girls and boys, respectively.

	Daily MVPA							
	<60 min		≥60 min		95% CI			
Sex	*n*	%	*n*	%	OR	LL	UL	*p*-value
Ov/Ob Girls	65	62.5	39	37.5	1.78	1.13	2.80	0.017 *
Ov/Ob Boys	26	43.3	34	56.7	3.89	2.18	6.93	<0.0001 *

Notes: Ov = Overweight. Ob = Obese. MVPA = Moderate-to-vigorous physical activity. CI = Confidence interval. OR = Odds ratio. LL = Lower limit. UP = Upper limit. Statistical significance at * $p < 0.05$.

3. Discussion

This study aimed to (1) establish the prevalence of underweight, overweight and obesity among 8–13-year-old children from selected quintile 3 (no-fee paying) schools in low-income peri-urban areas of Gqebeha in the Eastern Cape, South Africa and furthermore, (2) to establish whether children's BMI was associated with their PA behaviour.

The BMI prevalence rates from the current cohort (n = 916, $\bar{x}$ age = 10.4 ± 1.2 years: 13% underweight, 12% overweight and 7% obese) fall within the prevalence rates of a systematic review of South African children and youths (0–20 years) [5], which reported values that ranged from 4% to 19% for underweight (using the National Centre for Health Statistics/WHO z-scores), 5.4% to 32.4% for overweight and 2.5% to 17.3% for obesity using the Cole-IOTF age- and gender-specific cut-off points [5,28].

Studies conducted in different geographic regions in South Africa have reported conflicting results on the prevalence of weight status among children and adolescents. A systematic review by Monyeki, Awotidebe, Strydom et al. [5] found a higher incidence of being underweight in rural areas. In contrast, a later review by Mbogori, Kimmel, Zhang et al. [13] reported that the prevalence of underweight and overweight/obesity was similar in rural and urban regions of South Africa, with a ratio of 1.0. Pretorius, Neophytou and Watson [6] also reported significant differences in undernutrition (16.1% vs. 9.5%, $p < 0.001$) and overnutrition (9.7% vs. 41.2%, $p < 0.001$) between the peri-urban areas of Gqeberha in the Eastern Cape and the urban areas of Johannesburg in Gauteng.

The BMI profiles of the present study were compared to the anthropometric profiles of the Gqeberha sample (n = 791, $\bar{x}$ age = 9.7 ± 0.8 years) measured by Pretorius and colleagues in 2016 [6]. Pretorius, Neophytou and Watson [6] reported a mean BMI of 17.5 ± 3.1 kg/m^2, which was not much lower than the present study cohort's BMI (18.0 ± 3.7 kg/m^2) measured in 2019. Pretorius, Neophytou and Watson [6] reported similar prevalence rates for underweight (16.1%) and obesity (9.7%) compared to the current sample. However, the prevalence of overweight children (39.8%) was more than three times that of the current study, even though both cohorts were from peri-urban areas of Gqeberha and of similar SES.

Diet may explain the variations in weight status in different geographic areas. The study by Okeyo, Seekoe, de Villiers et al. [11] in the Eastern Cape found that compared to urban areas, the frequency of eating breakfast, sugary snacks and drinking cordial (a sweetened concentrate mixed with water) was higher among learners in rural areas, whereas those in urban areas consumed more boerewors (beef sausage), hamburgers and sugar-sweetened beverages. Wrottesley, Pedro, Fall et al. [10] found that factors such as irregular breakfast consumption, fewer meals with families and increased snacking were associated with increased weight and obesity among adolescents. It is also plausible that the differences in weight status could be due to different BMI reference charts used, which may underestimate or overestimate the incidence of underweight, overweight and obesity [5]. However, other factors such as ethnicity or culture could also play a role [4].

Adolescence is a life stage of significant anatomical and physiological changes with increased nutrient needs [7]. It is also a period where children and youths are highly susceptible to adopting unhealthy habits, which increase their risk of future NCDs. In the studied sample, the odds of being overweight or obese were nearly twice as high for girls (OR = 1.97, 95% CI: 1.40–2.77) than for boys (Figure 1). A plausible explanation is diet, since Okeyo, Seekoe, de Villiers et al. [11] found gender-related differences in eating habits as girls ate significantly more processed and sugary foods (hot dogs, fat cakes, candy and chips) than boys. The literature also suggests that gender-related discrepancies in weight status are likely due to differences in energy needs, the onset of sexual maturity and levels of PA [32]. Results from this study also showed that the girls (61.01 min of MVPA/day, 95% CI: 58.99–63.03) were significantly less active than boys (84.76 min of MVPA/day, 82.14–87.39) (Table 1). An Australian study conducted by Telford, Telford, Olive et al. [22] found that low PA levels among girls were associated with weak school, community and parental support, suggesting fewer opportunities for PA or less support for PA participation among girls. Telford, Telford, Olive et al. [22] also observed less favourable attributes (lower perceived competence in physical education (PE), lower cardiorespiratory fitness and higher body fat percentage) associated with PA among girls. Another study, conducted in the Western Cape (South Africa) among adolescents, found that programmes which do not meet the needs and interests of participants can severely discourage PA participation [33]. Other barriers reported to hinder PA participation among adolescent girls in South Africa include weather, safety, time constraints and fears of weight loss instead of having a fuller figure [10].

According to the new WHO 2020 guidelines on PA, "average of" 60 min MVPA is recommended for children and youths (5–17 years) [18]. Overall, 64% (n = 559) of the studied sample engaged in ≥60 min of total MVPA/day, of which more than half (62%) were boys. Findings from this study show that overweight to obese children were less likely to meet the 60 min of MVPA per day than underweight to normal-weight children (boys: OR = 3.89, 95% CI: 2.18–6.93; girls: OR = 1.78, 95% CI: 1.13–2.80) (Table 2). Moreover, obese children were less likely to meet ≥60 min MVPA/day than overweight children (Figure 3). Obese girls were 1.53 times less likely to meet ≥60 min MVPA/day than overweight girls (95% CI: 0.68–3.46), but obese boys were of particular concern as the odds (OR: 3.25 times, 95% CI: 1.08–9.80) were much lower for obese boys to meet the ≥60 min of MVPA/day than overweight boys. Our findings correlate with the literature, as research shows that children who are overweight or obese are typically less active as they display poorer physical competence as well as lower perceived physical competence [15]. PA's physical and psychological benefits are realised at an average of 60 min of MVPA per day [17,18]. Therefore, overweight and obese children should be encouraged to be more active and taught the value of a healthy and active lifestyle since regular MVPA is pertinent to correcting their body weight and modifying their metabolic disease risk [5].

Strengths and Limitations

Despite efforts, our study did have limitations. Previous studies have investigated body composition in relation to different ethnic groups; however, this was not the purpose of the current study, which only concentrated on sex comparisons among children attending low-income schools. The cross-sectional design of this study precludes inferences of causal associations. Furthermore, the study findings can not be generalised to all South African children as it was conducted in one metropolitan area in the Eastern Cape province (one of the nine South African provinces). Strengths of the study include a relatively large study sample focusing on a vulnerable community. The results are also based on the true measurements of height, weight and device-measured PA via accelerometers. An added strength of this study is quantifying the odds of children meeting the MVPA recommendations in relation to their BMI classifications. The findings from this study, a substudy of the larger *KaziBantu* project, also provide evidence of what may be required to achieve a 'Healthy Schools for Healthy Communities' environment in under-resourced settings.

4. Conclusions

We found a concerning incidence of underweight, overweight and obesity in the studied cohort of primary school children attending low-income schools in Gqeberha, South Africa. The profiling of malnutrition and physical inactivity is essential to determine disease risk and to define appropriate interventions. Findings showed that girls and overweight to obese children were less likely to be active than boys and underweight to normal-weight children. Furthermore, obese boys in particular were less likely to achieve the average 60 min MVPA/day than overweight boys. Girls were also identified as a vulnerable group requiring special attention in promoting and adhering to PA. PE at schools is crucial to children's all-round wellbeing and plays a vital role in developing an active lifestyle. PE educators are therefore encouraged to deliver equally engaging lessons for girls and children with excess weight to expose them to different modes of PA they may enjoy. In addition, the Department of Basic Education's role in this regard through the in-service training of PE teachers and other support is also recommended, especially within marginalised schools and communities. Promoting healthy and active lifestyles is important to curb future disease risk. Thus, future research intervention strategies addressing physical inactivity in South Africa should focus on sub-groups, such as girls and children with excess weight. Concerted efforts should also be made to inform children, parents and teachers alike about the role of PA and healthy eating as a preventative strategy to mitigate future NCD risk. Accompanying longitudinal research may also investigate the personal and social supportive roles of family members, peers and teachers for PA.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Nelson Mandela University Research Ethics Committee (Human) (H19-HEA-HMS-003; obtained on 4 June 2019), the Eastern Cape Department of Health (EC_201804_007; obtained on 5 June 2018)and the Eastern Cape Department of Education (obtained on 9 May 2018). The study was registered with the ethical review board of the Ethics Committee Northwest and Central Switzerland (R-2018-00047; registered on 1 March 2018).

Informed Consent Statement: The participant's parents/guardians provided written informed consent, and each participant gave oral assent to participate in this study.

Data Availability Statement: The data sets supporting the conclusions of this article are available from the corresponding author upon request.

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Chapter 6: *KaziBantu* School-based Health Intervention

Title: Effect of the KaziBantu school-based health intervention on non-communicable disease risk factors of children from low-income schools in Gqeberha, South Africa

Short running title: *KaziBantu* school-based health intervention

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Abstract

This study aimed to determine the effect of a 20-week school-based intervention programme on non-communicable disease (NCD) risk factors of children from low-income schools in Gqeberha, South Africa. A cluster randomised control trial was used to test the intervention, which included three components, namely the [1] *KaziKidz* toolkit, [2] a physical education (PE) coach and [3] two 90-min *KaziKidz* training workshops. The intervention was staggered across four schools which were differentiated by the level of intervention support, while another four schools formed the control group. A total of 961 children (491 boys, 10.88±1.19 years) from grade 4 to 6 were recruited from eight low-income schools. Measures included waist circumference, blood pressure, glycated haemoglobin, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol and accelerometer-based moderate to vigorous physical activity (MVPA). Analysis of covariance (ANCOVA) was used to test the effect of the intervention conditions, controlling for the children's pre-intervention results, age, height, and gender. The post-intervention comparison of the NCD risk factors of children who received interventions with external support showed positive outcomes. Improvements in children's NCD risk factors and MVPA levels were associated with the interventions, which included training workshops and, in some cases, a PE coach. (Meanwhile, the *KaziKidz* toolkit (on its own) showed little to no improvements in NCD risk factors and MVPA levels. School-based interventions providing teacher support may positively impact NCD risk factors and PA behaviours of children attending under-resourced schools. These findings add to our understanding of implementing interventions in resource-scarce schools where teachers are not sufficiently trained to teach PE.

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Keywords: children, low-income schools, school-based intervention, non-communicable disease, South Africa.

Introduction

Non-communicable diseases (NCDs) such as cardiovascular diseases, diabetes and hypertension are the leading causes of ill health, accounting for at least 74% of annual global mortalities (Bennett et al., 2018). Most NCDs share modifiable NCD risk factors which have become increasingly prevalent among children and youth (Long, Ngoc-Anh, Phuong, Tuyet-Hanh, Park, Takeuchi, Lam, Nga, Phuong-Anh & Bao, 2021). A recent study using data from the Global School-based Student Health Survey collected from 89 countries reported that one in three adolescents had lifestyle-related risk factors (Uddin et al., 2020). These behavioural risk factors, like poor dietary habits (increased calorie-dense foods and reduced fruit and vegetable intake), sedentariness and physical inactivity, are adopted in the early life years and are linked to NCDs in adulthood (Champion et al., 2019). Global estimates show that 80% of children fail to meet the recommended 60 minutes of moderate to vigorous physical activity (MVPA) per day (Guthold et al., 2018). Thus, concerted efforts are needed to promote healthy behaviours (such as healthy eating and regular physical activity (PA)), as these are cost-effective strategies for combating NCD risk factors among children and adolescents (Naik & Kaneda, 2014; Biswas et al., 2022).

Children spend a large part of their day at school, making this the ideal environment to cultivate healthy behaviours for an active and healthy lifestyle (Milton et al., 2021). Physical education (PE) offers a learning experience which deals exclusively with holistic and healthy living as children develop motor skills and positive attitudes towards PA that would persist across their lifespan with ongoing health benefits (Hills et al., 2015). Despite high-level advocacy at global forums, there remains a significant gap as action plans, policy intent and reports do not translate into the implementation of PE (Goslin, 2020). Thus, the status of PE worldwide is less than ideal (Hardman et al., 2013; Goslin, 2020). Hardman et al. (2013) highlighted concerns in The Final Report of the Worldwide Survey of School PE, which reported on concerns such as curriculum deficiencies and assessment practices, reductions in time allocation, inadequate facilities and equipment, poor teacher training and provision of professional development, and low perceived value of PE. These are challenges that are all too familiar in South Africa.

PE was often neglected and accorded a low status in the South African school curriculum, and it lost its stand-alone status when it was reintroduced in recent years as part of Life Skills (Gr R-6) and Life Orientation (Gr 7-12) in the South African Curriculum and

Assessment Policy Statement (CAPS) (Stroebel et al., 2016a). PE was allocated two hours a week in the Foundation Phase (Gr R-3) and one hour a week in the Intermediate (Gr 4-6) and Senior (Gr 7) Phases. However, despite CAPS guidelines, PE has often not been prioritised. In a recently published 12-country study, South Africa had the highest percentage of learners (32.1%) who were not participating in PE (Silva et al., 2018).

South Africa is a country of significant inequality (0.63 Gini coefficient) (World Bank, 2022b), where most (two-thirds) school-going children attend quintile one to three (no-fee paying) public schools (South African Government, 2022). South African public schools are categorised into a quintile system (the poorest is quintile one to the least well-off quintile five groups), which allows the Department of Education to allocate funds to schools on a needs basis. Striking discrepancies in the delivery of PE have been reported as children attending lower-income schools are less likely to participate in PE than those of higher income (Micklesfield et al., 2014). Furthermore, the scarcity of PE equipment and functioning facilities as well as the lack of specialist PE teachers, also reduce the quality of the PE experience offered to most schoolchildren who attend lower-income schools (Stroebel, 2020; Burnett, 2021).

A national study conducted by the South African University PE Association (SAUPEA) and commissioned by the United Nations Children's Fund (UNICEF) in partnership with the South African Department of Basic Education investigated the state and status of PE across South African public schools. They reported that of the 175 PE teachers representing lower- and higher-income schools, only 51.3% were interested and 42% felt equipped to implement PE (Burnett, 2021). Moreover, 62.3% of PE teachers are non-specialists, and about 14.9% of PE lessons are outsourced to external service providers (Burnett, 2021).

Teachers play a crucial role in promoting PA in schools, and evidence shows that children appreciate and enjoy PE taught by their class teacher (Hills et al., 2014; Telford et al., 2021). The economic challenges highlighted in the South African context have a negative impact on the lack of PE delivery, especially in resource-scarce schools (Roux, 2020), where teachers are neither trained nor qualified to teach PE (Stroebel, Hay & Bloemhoff, 2016b).

In this context, a school-based intervention programme that includes training of generalist PE teachers and the provision of PE lesson materials to supplement the current CAPS curriculum may offer significant potential to improve the delivery of PE for health promotion in low-income settings. Therefore, the current study implemented a school-based health intervention (differentiated by the level of teacher support) targeting PA and NCD risk factors among children in low-income communities. To our knowledge, this is the first South African study to implement a school-based health intervention targeting PA and NCD risk factors among primary school children in low-income settings.

Materials and methods

Research design

The present study is a substudy of the larger *KaziBantu* project (Müller, Smith, Adams, Aerts, Damons, Degen, Gall, Gani, Gerber & Gresse, 2019b), which aims to improve the health conditions of both teachers and learners, thereby creating 'Healthy Schools for Healthy communities' in under-resourced settings. This study aimed to assess the effect of a school-based health intervention on NCD risk factors of Gr 4 - 6 primary schoolchildren attending low-resourced schools in Gqeberha, South Africa. We implemented a cluster-randomised control trial with a 20-week intervention and assessed the intervention outcomes by comparing the change in NCD risk factors from baseline to follow-up. Post-intervention, we compared the control group (four schools) to the four intervention conditions (one school for each intervention condition).

Intervention

The *KaziKidz* intervention (which formed part of the *KaziBantu* project), aimed to promote children's health by implementing three key components that were staggered across the four intervention schools (See Figure 1): [1] the *KaziKidz* toolkit (T) – 70 lessons per grade, basic equipment, and painted playground games, [2] a PE coach (C) - a graduate in the human movement science field to support non-specialist PE teachers, and [3] two 90-min *KaziKidz* training workshops (W). Each intervention school was randomly allocated to one of four intervention conditions: 1) *KaziKidz* toolkit + PE coach + *KaziKidz* workshop (T+C+W); 2) *KaziKidz* toolkit + PE coach (T+C); 3) *KaziKidz* toolkit + *KaziKidz* workshop (T+W) and 4) *KaziKidz* toolkit only (T).

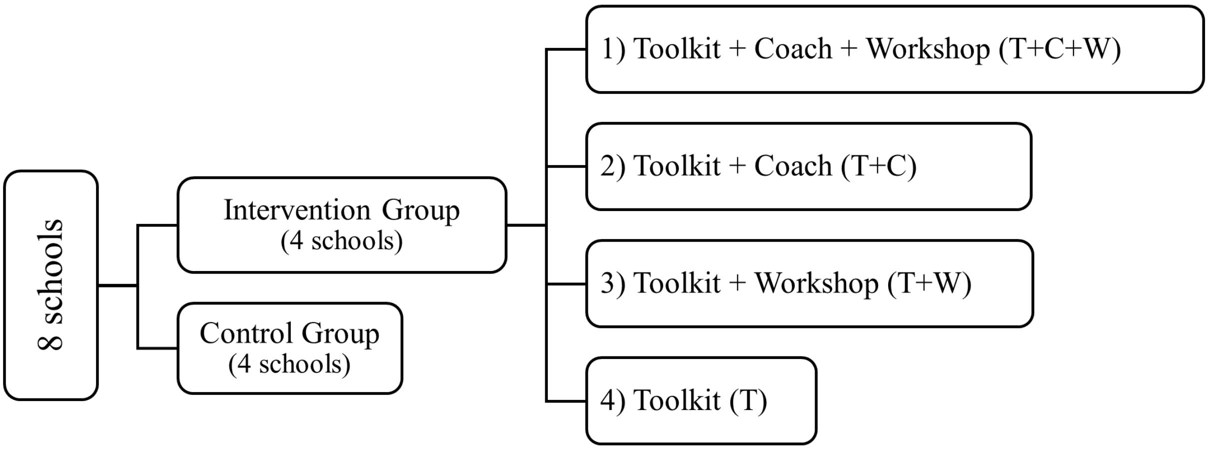

Figure 1: *KaziKidz* Intervention

The *KaziKidz* toolkit was developed in alignment with the South African Curriculum and Assessment Policy Statement (CAPS) and was piloted at two primary schools in Gqeberha in August 2018. Teachers who participated in the pilot testing completed feedback questionnaires and the materials were revised accordingly. All intervention schools received the *KaziKidz* toolkit, which consisted of 70 ready-to-use life skills lessons which covered three content pillars: (1) 32 PE lessons, (2) 32 moving-to-music lessons, and (3) three health, hygiene and nutrition education lessons which aimed to increase awareness of the importance of healthy nutrition. The *KaziKidz* lessons were delivered once a week as part of the Life Skills subject. Each intervention school also received basic sports equipment (a portable speaker, colour bands, bean bags, skipping ropes and a variety of sports balls) to conduct the PE and moving-to-music lessons. Playground games (hopscotch, 2-square, 4-square and mazes) were also painted on the school premises to encourage free play. These low-cost PA-friendly environments were found to be effective in increasing children's in-school MVPA (Walter, 2014).

The external support components (PE coach and the *KaziKidz* training workshops) were staggered across the intervention schools. The role of the PE coach was to assist the non-specialist PE teachers in a combined teaching approach while they presented their PE lessons. As previously mentioned, research on the state and status of PE in South African primary schools (Burnett, 2021) highlighted the need to support non-specialist PE teachers. Lastly, teachers participated in two 90-min *KaziKidz* training workshops, in which teachers received training on how to implement the *KaziKidz* lessons practically.

The interventions were offered to the whole school (grade 1 to 7), but only one class was selected per grade from the intermediate phase (grade 4 to 6) to assess the outcome of the four intervention conditions based on selected NCD risk factors. The control schools were treated as waiting-list control. They continued with their usual PE lessons during the intervention and received the *KaziKidz* toolkit, painted playground games and basic PE equipment at the end of the intervention period.

Ethics, consent and permissions

The following ethics committees reviewed and approved the study: the Nelson Mandela University Research Ethics Committee (Human) (H19-HEA-HMS-003), the Eastern Cape Department of Education (ECDoE) and the Eastern Cape Department of Health (EC_201804_007). The study was registered with the ethical review board of the Ethics Committee Northwest and Central Switzerland (R-2018-00047). All required procedures were adhered to, including good clinical practice guidelines and the ethical principles defined in the Declaration of Helsinki (World Medical Association, 2013). Oral assent was sought from each child, and their parent/guardian provided written informed consent for the child to participate in this study.

Study setting and participant recruitment

Principals of Quintile 3 primary schools situated in disadvantaged peri-urban areas were requested to attend a meeting at the ECDoE in October 2018. We received 64 responses, whereby 40 schools requested further project information. Eight schools matched the inclusion criteria and were purposively selected based on geographic location. Parents/guardians were informed about the study at meetings and through study information newsletters. Children were selected from the intermediate phase (grade 4 to 6). One class per grade was selected based on the highest consent return rate. Children were included if they met the following criteria: (i) written informed consent from parent/guardian, (ii) not being involved in other clinical trials during the study period, (iii) and not suffering from medical conditions that prevent participation in the study, as determined by medical personnel, and (iv) oral assent. Recruitment closed in January 2019.

Sample size and randomisation

A total of N=1020 children were enrolled in the study. The randomisation into intervention and control schools was done separately. Sequentially numbered, opaque, sealed envelopes were used to assign the four intervention arms (T+C+W, T+C, T+W or T only) to the intervention schools (see Figure 2). Data sets from 961 children (491 boys, 470 girls; M=10.88±1.19 years old) were available for analysis. The details on the power calculation for the intervention study are contained in the *KaziBantu* protocol (Müller, Walter, Du Randt, Aerts, Adams, Degen, Gall, Joubert, Nqweniso & Des Rosiers, 2020).

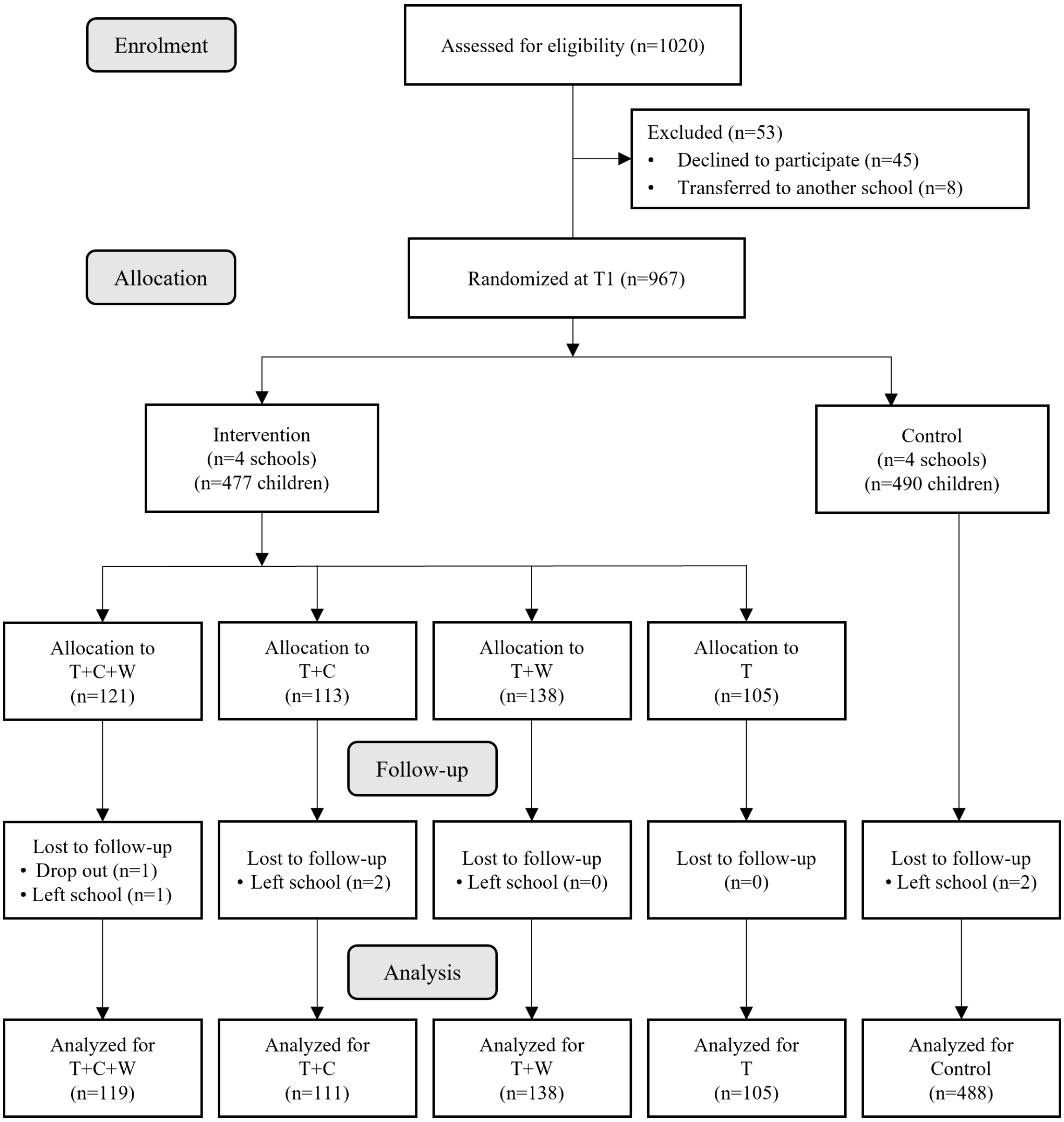

Figure 2: Participant flowchart

Data collection

Identical data assessments were conducted at T1 (January to February 2019) and T2 (August to September 2019), with a 20-week intervention[2] period in between to test the efficacy of the intervention conditions. The full measurement procedure has been published in

[2] The original study protocol indicated a 36-week intervention, however, due to practical reasons, a 20-week intervention was implemented which excluded data collection and subsequent administrative restrictions.

the *KaziBantu* study protocol (Müller et al., 2019b). Standardised anthropometric guidelines were used to measure: height, weight, and waist circumference (WC) (Norton, 2018). Blood pressure (BP) was measured using a validated oscillometric digital BP monitor (Omron® M6 AC; Hoofddorp, Netherlands). Capillary blood samples were assessed using the Alere Afinion AS100 analyser (Abbott Laboratories, Illinois, USA). Drops of blood were taken via finger prick to measure total cholesterol (Total-C), high-density lipoproteins (HDL-C), low-density lipoproteins (LDL-C), and glycated haemoglobin (HbA1c). Evidence of this finger-prick method's clinical utility and accuracy has been described previously (Parikh, Mochari & Mosca, 2009; Jain, Rao, Sharifi, Bhatt, Patel, Nirmal, Persaud & Nair, 2017).

Device-based PA was measured using a light triaxial ActiGraph® wGT3X-BT accelerometer (Actigraph LLC., Pensacola, USA), which has proven to measure daily activity for children accurately (Hills et al., 2014). The device was fitted around the child's hip with an elastic band and was worn for seven consecutive days, except during activities which involved water contact. A 30 Hz sampling rate was used, and data was stored as GT3X raw files. Analyses were performed with the ActiLife software (version 6.13.2; Actigraph LLC, Pensacola, USA) using 10-sec epoch lengths. Non-wear time was calculated using Troiano and colleagues (2008) algorithm. Cut points for children defined by Evenson, Catellier, Gill, Ondrak & McMurray (2008) were used to calculate an overall index for MVPA. During school (Monday to Friday, 08:00 to 14:00), wear time was used for the present study; the data was considered valid if the child wore the device for a minimum wear time of >180min per school day on ≥3 school days (Clemente, Nikolaidis, Martins & Mendes, 2016).

Data analysis

The collected data was double-entered and validated in EpiData version 3.1 (EpiData Association; Odense, Denmark). All statistical analyses were performed using Statistica® version 13 (TIBCO Software Inc, Palo Alto, USA) and Microsoft® Office Excel 2016 (Microsoft Corporation, Redmond, USA). Extreme outliers for which the absolute standard residuals were larger than three standard deviation units were removed from the data set. The pre-intervention (T1) descriptive data with the sample size (n), mean, and confidence intervals (CI) for all measured variables was presented. ANCOVA was used to test the effects of the four intervention conditions controlling for the T1 results. The model included age, gender, and height at T1 as covariates. The results of the ANCOVA analysis, where the mean values obtained at T2 of each intervention condition were compared to the mean values of the control group. The p-values relate to the T2 mean comparison of each respective intervention condition versus the control group. A p-value <0.05 indicates a statistically significant difference. Cohen's d was used to indicate the standardised difference between the mean of the control group and the mean of each of the four intervention conditions per NCD risk factor and in-school MVPA. Cohen's d effect sizes are interpreted as: d<0.2 no difference; d=0.20-0.49 small difference; d=0.50-0.79 medium difference; d≥0.80 large difference.

Results

Table 1 presents the descriptive statistics of the NCD risk factors, and in-school MVPA assessed at baseline for the whole group and for girls and boys separately. Apart from in-school MVPA (boys were 6.4 min/day more active than girls), the gender differences in the NCD risk factor averages were not significant before the intervention.

'Table 1 near here.'

Table 2 presents the post-intervention mean comparisons of each intervention condition to the control group per NCD risk factor and in-school MVPA, presented separately for girls and boys. The WC of the entire cohort increased from T1 to T2. At T2, the WC of the children who received intervention T+W (girls: -0.47 cm; p=0.0028; boys: -1.57 cm; p<0.001) increased at a slower rate and was significantly less than that of the control group.

The mean systolic BP (S-BP) of the children in all four intervention conditions (except the boys who received intervention T) had decreased between T1 and T2. Post-intervention, the mean S-BP of children from all intervention groups (except the boys who received intervention T) was significantly lower than that of the control group. At T2, the mean diastolic BP (D-BP) of the boys who received intervention T+C+W (64.16 mmHg, p=0.0563) was significantly lower than that of the control group (95% CI 65.66 - 67.96 mmHg). The mean D-BP of the children from the remaining intervention groups did not differ from the mean D-BP of the control group.

The HbA1c of the entire cohort decreased between T1 and T2. At T2, the mean HbA1c of the boys who received intervention T+C+W (33.80 mmol/mol, p=0.0086) and the children who received intervention T+C (girls: 33.72 mmol/mol, p=0.0002; boys: 34.00 mmol/mol, p=0.0137) was significantly lower than that of the control group (95% CI: girls: 34.38 - 34.88 mmol/mol; boys: 34.28 - 34.79 mmol/mol).

At T2, the mean total-C of the children from the intervention groups did not differ from the mean total-C of the control group. However, the mean total-C of the girls who received intervention T+W (3.83 mmol/L, p=0.0577) and the boys who received intervention T+C (3.92 mmol/L, p=0.0281) was significantly higher than that of the control group (95% CI: girls: 3.63 - 3.77 mmol/L; boys: 3.67 - 3.81 mmol/L).

At T2, the mean LDL-C of the girls who received interventions T+C+W (1.86 mmol/L, p=0.0049) and T+C (1.80 mmol/L, p<0.0001), was significantly lower than the mean LDL-C of the girls in the control group (95% CI 1.98 - 2.10 mmol/L). The mean LDL-C of the children who received interventions T+W and T did not differ from the mean LDL-C of the respective control groups.

The mean HDL-C of the whole cohort increased between T1 and T2. At T2, the mean HDL-C of the children who received the interventions with external support, i.e. PE coach and workshop (T+C+W: girls: 1.42 mmol/L, p=0.0582; boys: 1.45 mmol/L, p=0.0350; T+C: girls: 1.44 mmol/L, p=0.0140; boys: 1.46 mmol/L, p=0.0044; T+W: girls: 1.43 mmol/L, p=0.0311; boys: 1.45 mmol/L, p=0.0237) was significantly higher than that of the control group (95% CI: girls: 1.32 - 1.39 mmol/L; boys: 1.34 - 1.41 mmol/L). The mean HDL-C of the children who received intervention T did not differ from that of the children in the control group.

The in-school MVPA for all girls increased between T1 and T2. However, this was not the case for the boys. At T2, the in-school MVPA of the boys who received intervention T+C and intervention T was 5.56 min/day (p<0.0001) and 4.04 min/day (p<0.0001) lower than that of the control group (95% CI 21.15 - 23.18 min/day). On the other hand, the in-school MVPA of the boys who received interventions T+W and T+C+W was 3.56 min/day (p=0.0004) and 5.87 min/day (p<0.0001) higher than that of the boys in the control group (95% CI 21.15 - 23.18 min/day).

At T2, the in-school MVPA of the girls who received interventions T+W (3.45 min/day, p=0.0001) and T+C+W (5.76 min/day, p<0.0001) was significantly higher than that of the girls in the control group (95% CI 16.67 - 18.63 min/day). However, the in-school MVPA of the girls who received interventions T+C and T did not differ from the in-school MVPA of the girls in the control group.

‘Table 2 near here.’

Discussion

The objective of the present study was to assess the effect of four intervention conditions (differentiated by the level of implementation support) on NCD risk factors. This is the first known South African study to assess the impact of a school health intervention on the NCD risk factors of primary school children in low-income settings. Overall, the results from this study have shown some evidence that the interventions had positive effects. The T+C+W intervention condition was associated with a greater number of NCD improvements and increased MVPA compared to the control group. The T+W intervention was also associated with increased MVPA, though fewer positive changes in NCD risk factors were observed compared to the control group. Positive changes in NCD risk factors were associated with the T+C intervention, though no changes were observed for MVPA; in fact, MVPA had decreased among the boys. Lastly, the toolkit intervention showed no improvements in the NCD risk factors (apart from the girl's S-BP), and while MVPA showed no change among the girls, it worsened among the boys. These results should be interpreted with caution as changes in NCD risk factors may not necessarily have been associated with the change in MVPA. However, it does seem plausible that some external support offered in the intervention (i.e., the PE coach or the training workshop) may have been instrumental in bringing about health-related improvements.

The reduced MVPA among the boys who received the T+C and T intervention was unexpected; according to the literature, girls are less likely to be physically active than boys (Mlangeni et al., 2018). The decrease in the boys' MVPA may be attributed to gender binary beliefs in PE; as a result, these boys may not have emersed themselves in the dancing (moving to music) lessons like the girls. These findings are supported by Cárcamo, Moreno & Del Barrio (2021), who qualitatively assessed the gender beliefs of 8-10-year-old Colombian children. They found that both boys and girls view dance as a feminine activity, and boys perceive themselves to be more skilful in PE than girls (Cárcamo et al., 2021). The nuance of the *KaziKidz* toolkit is a consolidated practice of PE through games and dance activities. Still, to maximise participation in PE, teachers should be conscious of gender equality to reduce gender binary stereotypes in PE.

This study also found that interventions with the workshops (T+C+W and T+W) were associated with increased MVPA from baseline to post-intervention, and at T2, MVPA was significantly higher than in the control groups. A possible explanation is that the workshops may have provided a theoretical base for teachers to better understand how to implement the lessons in the toolkit, which, therefore, emphasises the need for training of generalist PE teachers in order to improve the delivery of PE. These findings also broadly support the conclusions of the national study (jointly conducted by UNICEF, DBE, and SAUPEA), highlighting the correlation between poor teaching and inadequate teacher training. The professional development of generalist classroom teachers is one of the many ongoing challenges requiring attention in order to implement quality PE.

Prior South African studies have also reported on the positive impact of low-cost school-based interventions on children's PA levels. Tian et al. (2017) found positive effects on PA levels and sedentary behaviours after implementing a 12-week intervention delivered as a 60-minute once-a-week CAPS-based PE lesson, including trained PE teachers, improvised PE equipment made from upcycled materials and homework activities accompanied by a reward system. Another study by Naidoo & Coopoo (2012) implemented an 18-month nutrition and PA intervention integrated into the school curriculum with cost-effective classroom-based materials and implemented by the school staff with minimal external support. Overall, the intervention schools demonstrated improvements in fitness and increased sports participation compared to the control group. This study also found that classroom teachers (who were not PE specialists) could deliver effective PA lessons with the training they received, underscoring the need for in-service training of PE teachers to equip them to deliver this specialised learning area.

Findings from these studies confirm the importance of trained PE teachers, as PE taught by well-trained teachers is likely to generate increased time spent in PA (Lonsdale, Rosenkranz, Peralta, Bennie, Fahey & Lubans, 2013), as children may be more motivated and confident in their physical and motor abilities (Telford et al., 2021). Well-trained PE teachers could also deliver PE lessons that are inclusive of all learners, where the focus is on promoting holistic and healthy living, and emphasis is placed on individual success rather than athletic ability. Furthermore, children without well-trained PE teachers may have reduced opportunities to learn about health-promoting strategies targeting PA to prevent NCD risk factors.

Strengths and limitations

Strengths of the study include the cluster randomised design, the high-priority study population, and the assessment of a range of clinical markers. Furthermore, the novelty of the *KaziKidz* materials facilitates the implementation of these ready-to-use lessons, which were specially developed for resource-scarce schools. The lessons can also be tailored and adapted for other school settings as the materials have already been scaled up and disseminated in selected schools in other African countries like Senegal, Ivory Coast, and Tanzania.

Despite these strengths, the study should be interpreted in light of some limitations. Firstly, caution should be exercised in terms of generalising these results to other contexts, cultures and demographic groups. Secondly, we acknowledge the untested potential of pre-existing differences between schools, such as differences between school contexts, the teacher's experience and attitude toward PE, or the learner's motivation for PE. However, these pre-existing differences should have played less of a role by controlling for T1 results and focusing on the change of quantitative outcomes from baseline (T1) to post-intervention (T2). Finally, the intervention was comprised of a staggered design as each of the intervention schools received different levels of intervention support with the PE coach and/or the training workshops. Consequently, it was not possible to determine the extent of each intervention component's contribution, especially given the exploratory nature of the study.

Conclusion

The *KaziKidz* toolkit (on its own) did not yield positive changes in children's PA, with little to no improvements in NCD risk factors. Meanwhile, improvements in children's NCD risk factors and increased MVPA levels were observed when the intervention included the training workshops and, in some cases, the PE coach. These findings highlight the need for in-service training of PE teachers. Specialist PE coaches' continued support to generalist PE teachers may not be financially feasible. Therefore, further research is needed on the sustainability of school-based PA interventions to determine the long-term effectiveness and the factors that may negatively affect compliance with the proposed interventions. School-based health interventions, which include external support for generalist PE teachers, may improve the NCD risk factors of children attending low-income schools in Gqeberha, South Africa.

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Authors' contributions: DD, CW, RdR UP, MG, IM, LA, NJ, PA, SN, HS, PS and JU designed the research. DD, LA, NJ, IM, and SN collected and curated the data. JB supported with statistical analysis. DD conceptualised the study and interpretation of data and wrote the manuscript. All authors contributed to the revision process and have approved the final version.

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Table 1: Demographics of children attending eight under-resourced schools in Gqeberha, SA, assessed pre-intervention in February/March 2019

	Total			Girls			Boys		
	n	M1±SD	95% CI	n	M1±SD	95% CI	n	M1±SD	95% CI
WC (cm)	917	58.4±7.9	57.9 - 58.9	451	58.8±8.3	58.0 - 59.6	466	58.1±7.5	57.4 - 58.8
S-BP (mmHg)	943	108.9±13.4	108.1 - 109.8	465	109.3±13.8	108.0 - 110.5	478	108.6±13.2	107.4 - 109.7
D-BP (mmHg)	943	67.2±11.0	66.5 - 67.9	465	67.9±10.9	66.9 - 68.8	478	66.5±11.0	65.5 - 67.5
HbA1c (mmol/mol)	765	35.7±2.6	35.5 - 35.9	383	35.7±2.8	35.4 - 36.0	382	35.7±2.7	35.4 - 36.0
Total-C (mmol/L)	756	3.7±0.7	3.7 - 3.8	378	3.8±0.6	3.7 - 3.9	378	3.7±0.7	3.6 - 3.8
LDL-C (mmol/L)	747	2.0±0.5	2.0 - 2.1	374	2.1±0.5	2.0 - 2.2	373	2.0±0.6	1.9 - 2.06
HDL-C (mmol/L)	756	1.3±0.3	1.3 - 1.3	378	1.3±0.3	1.3 - 1.3	378	1.3±0.3	1.3 - 1.4
MVPA (min/day)	919	17.9±8.2	17.4 - 18.5	455	14.7±5.7	14.2 - 15.3	464	21.1±9.0	20.3 - 21.9

Notes. The variation in the n values per variable results from missing data. M1= Mean at T1; SD=Standard deviation; CI=Confidence interval; WC=Waist Circumference; S-BP=Systolic blood pressure; D-BP=Diastolic blood pressure; HbA1c=Glycated haemoglobin; Total-C=Total Cholesterol; LDL-C=Low-density lipoprotein; HDL-C=High-density lipoprotein; MVPA=Moderate to vigorous physical activity.

Table 2: Post-intervention comparison of each intervention condition to the control group, for girls and boys separately.

	Girls	n	M2 (SD)	95% CI	p	Cohen's d	Boys	n	M2 (SD)	95% CI	p	Cohen's d
WC (cm)	Control	218	62.20 (3.73)	61.70 - 62.69			Control	225	62.32 (3.67)	61.84 - 62.80		
	T+C+W	57	63.94 (3.69)	62.98 - 64.90	0.0018*	0.47	T+C+W	55	62.55 (3.74)	61.56 - 63.55	0.6692	0.06
	T+C	47	63.20 (3.65)	62.15 - 64.24	0.2528	0.27	T+C	59	62.59 (3.65)	61.66 - 63.53	0.9847	0.08
	T+W	73	61.73 (3.62)	60.90 - 62.56	0.0028*	-0.13	T+W	55	60.75 (3.69)	59.78 - 61.73	<0.0001*	-0.43
	T	47	62.91 (3.72)	61.85 - 63.98	0.7985	0.19	T	52	62.71 (3.74)	61.69 - 63.73	0.5099	0.11
S-BP (mmHg)	Control	218	111.97 (11.41)	110.45 - 113.49			Control	220	111.72 (11.34)	110.22 - 113.22		
	T+C+W	56	104.32 (11.27)	101.36 - 107.28	<0.0001*	-0.67	T+C+W	47	105.54 (11.40)	102.28 - 108.81	0.0007*	-0.54
	T+C	46	108.32 (11.34)	105.04 - 111.61	0.0396*	-0.32	T+C	58	105.17 (11.26)	102.26 - 108.07	<0.0001*	-0.58
	T+W	75	108.57 (11.04)	106.07 - 111.07	0.0465*	-0.30	T+W	60	105.73 (11.18)	102.90 - 108.57	0.0005*	-0.53
	T	48	106.56 (11.20)	103.38 - 109.73	0.0034*	-0.48	T	53	109.65 (11.25)	106.62 - 112.68	0.2473	-0.18
D-BP (mmHg)	Control	217	66.94 (8.69)	65.78 - 68.10			Control	216	66.81 (8.60)	65.66 - 67.96		
	T+C+W	56	66.18 (8.54)	63.94 - 68.42	0.5542	-0.09	T+C+W	47	64.16 (8.65)	61.68 - 66.64	0.0563*	-0.31
	T+C	46	69.11 (8.56)	66.63 - 71.59	0.1340	0.25	T+C	58	64.87 (8.49)	62.68 - 67.06	0.1267	-0.23
	T+W	75	68.83 (8.10)	66.99 - 70.67	0.0693	0.22	T+W	60	65.99 (8.23)	63.91 - 68.08	0.5023	-0.10
	T	48	69.06 (8.54)	66.64 - 71.48	0.1156	0.24	T	53	67.24 (8.57)	64.93 - 69.55	0.6980	0.05
HbA1c (mmol/mol)	Control	184	34.63 (1.72)	34.38 - 34.88			Control	175	34.54 (1.71)	34.28 - 34.79		
	T+C+W	48	34.29 (1.71)	33.81 - 34.77	0.2259	-0.19	T+C+W	50	33.80 (1.74)	33.32 - 34.29	0.0086*	-0.43
	T+C	45	33.72 (1.78)	33.20 - 34.24	0.0002*	-0.52	T+C	47	34.00 (1.78)	33.49 - 34.52	0.0137*	-0.31
	T+W	49	34.88 (1.73)	34.39 - 35.36	0.4891	0.15	T+W	45	34.63 (1.74)	34.12 - 35.14	0.9833	0.06
	T	48	34.88 (1.75)	34.38 - 35.37	0.2775	0.15	T	49	34.30 (1.76)	33.81 - 34.80	0.4880	-0.13
Total-C (mmol/L)	Control	180	3.70 (0.47)	3.63 - 3.77			Control	173	3.74 (0.47)	3.67 - 3.81		
	T+C+W	48	3.82 (0.47)	3.69 - 3.96	0.1094	0.26	T+C+W	50	3.81 (0.47)	3.68 - 3.95	0.3534	0.15
	T+C	44	3.69 (0.47)	3.55 - 3.83	0.7757	-0.02	T+C	49	3.92 (0.47)	3.79 - 4.05	0.0281*	0.38
	T+W	50	3.83 (0.46)	3.70 - 3.95	0.0577*	0.26	T+W	45	3.73 (0.47)	3.59 - 3.86	0.9523	-0.04
	T	48	3.90 (0.46)	3.77 - 4.03	0.0655	0.41	T	49	3.90 (0.47)	3.77 - 4.04	0.1853	0.34
LDL-C (mmol/L)	Control	175	2.04 (0.39)	1.98 - 2.10			Control	165	2.02 (0.39)	1.96 - 2.08		
	T+C+W	46	1.86 (0.39)	1.74 - 1.97	0.0049*	-0.47	T+C+W	48	1.93 (0.39)	1.82 - 2.04	0.1588	-0.23
	T+C	43	1.80 (0.38)	1.69 - 1.92	<0.0001*	-0.61	T+C	46	2.01 (0.38)	1.90 - 2.12	0.5054	-0.02
	T+W	49	2.02 (0.37)	1.91 - 2.12	0.9786	-0.05	T+W	44	1.90 (0.38)	1.79 - 2.02	0.1184	-0.29
	T	47	1.98 (0.38)	1.87 - 2.09	0.2261	-0.14	T	50	2.03 (0.38)	1.93 - 2.14	0.8280	0.04
HDL-C (mmol/L)	Control	181	1.36 (0.22)	1.32 - 1.39			Control	173	1.37 (0.22)	1.34 - 1.41		
	T+C+W	47	1.42 (0.22)	1.36 - 1.49	0.0582*	0.31	T+C+W	50	1.45 (0.22)	1.39 - 1.51	0.0350*	0.34
	T+C	44	1.44 (0.22)	1.38 - 1.51	0.0140*	0.40	T+C	49	1.46 (0.22)	1.40 - 1.52	0.0044*	0.40
	T+W	50	1.43 (0.21)	1.37 - 1.49	0.0311*	0.35	T+W	45	1.45 (0.22)	1.39 - 1.52	0.0237*	0.36
	T	48	1.44 (0.22)	1.38 - 1.50	0.2436	0.38	T	49	1.43 (0.22)	1.37 - 1.49	0.5845	0.25
In-school MVPA (min/day)	Control	213	17.65 (7.30)	16.67 - 18.63			Control	200	22.17 (7.32)	21.15 - 23.18		
	T+C+W	54	23.42 (7.03)	21.54 - 25.30	<0.0001*	0.80	T+C+W	47	28.04 (7.11)	26.00 - 30.08	<0.0001*	0.81
	T+C	44	17.83 (7.23)	15.69 - 19.97	0.9878	0.02	T+C	58	16.61 (7.36)	14.71 - 18.51	<0.0001*	-0.76
	T+W	72	21.10 (7.11)	19.45 - 22.74	0.0001*	0.48	T+W	56	25.76 (7.16)	23.88 - 27.64	0.0004*	0.49
	T	44	17.53 (6.82)	15.50 - 19.55	0.6012	-0.02	T	49	18.12 (7.03)	16.15 - 20.09	<0.0001*	-0.56

*Notes. Statistical significance at *p<0.05. The variation in the n values per variable results from missing data. The effect sizes (Cohen's d) are interpreted as follows: d<0.2 no difference: d=0.20-0.49 small difference; d=0.50-0.79 medium difference; d≥0.80 large difference. M2= Mean at T2; SD=Standard deviation; CI=Confidence interval; WC=Waist Circumference; S-BP=Systolic blood pressure; D-BP=Diastolic blood pressure; HbA1c=Glycated haemoglobin; Total-C=Total Cholesterol; LDL-C=Low-density lipoprotein; HDL-C=High-density lipoprotein; MVPA=Moderate to vigorous physical activity.*

Chapter 7: Discussion, Recommendations and Conclusions

7.1 Introduction

NCDs represent a leading public health threat, especially in LMICs, where the urban poor are left vulnerable with limited access to primary healthcare and a general lack of knowledge on healthy behaviour change and NCD awareness. Moreover, increased exposure to unhealthy diets and physical inactivity has amplified the incidence of overweight and obesity among children despite the prevalence of undernutrition, giving rise to the dual burden of malnutrition in many African countries, including South Africa. Thus, lifestyle modifications should be addressed within the supportive school environment where children (while young and amenable to behaviour change) can learn to adopt healthy habits and, in time, break the intergenerational cycle of malnutrition and diet-related NCDs. While schools may be uniquely positioned to serve as a health hub to promote PA and reinforce healthy eating behaviours, generalist PE teachers may need additional support in conveying the message. Since the introduction of LS/LO in the South African CAPS curriculum, PE has often been overlooked and inadequately taught by generalist PE teachers, especially given the lack of understanding around content and pedagogical concepts. Against this background, the *KaziKidz* toolkit was developed and implemented as part of a multi-component intervention to improve the health and wellbeing of children attending under-resourced schools. This intervention package included three main components, which were staggered across the intervention schools: (1) the *KaziKidz* toolkit (T) comprised 70 lessons per grade, basic equipment to facilitate the teaching of PE, and painted playground games, [2] a PE coach (C) HMS graduate to support non-specialist PE teachers, and [3] two 90-min *KaziKidz* training workshops (W) for teachers.

As discussed in Chapter 1, this PhD thesis represents a sub-study of the overarching *KaziBantu* study, which aimed to investigate the effect of the school-based health intervention by comparing the four intervention conditions differing in level of support (experimental groups) with the control group. The intervention was tested with a cluster RCT, including baseline and follow-up testing. This chapter builds on the key findings presented in Chapters 4 to 6 by returning to and addressing the aim and objectives of this thesis. This PhD thesis sought to address four objectives. The first objective was to describe baseline NCD risk factors (blood lipids, cholesterol, HbA1c, BP, height, weight, BMI, waist circumference and BF%), PA and CRF. The second objective was to determine the prevalence of a CRS and its associations with PA and CRF. The third objective sought to determine the prevalence of BMI categories (underweight, overweight and obesity) and each of these categories relationship with MVPA respective per gender. The fourth and final objective was to determine the effect of the school-based health intervention on NCD risk factors (WC, BP, blood lipids, cholesterol and HbA1c) and PA levels by comparing the experimental groups (four intervention conditions differentiated by level of support) with the control group. These objectives guided the overarching aim of the present study, which sought to investigate the effect of a school-based health intervention on the NCD risk status of Gr 4 - 6 school children from selected schools situated in disadvantaged communities in Gqeberha, South Africa. The present chapter concludes with an overview of the strengths and limitations of the research and provides conclusions, recommendations for future research and practical implications for improving children’s health in under-resourced settings.

7.2 Clustered Cardiovascular Disease Risk

The article presented in Chapter 4 (Clustered Cardiovascular Disease Risk among Children aged 8-13 years from Lower Socio-economic Schools in Gqeberha, South Africa) sought to address objective 1 (to describe baseline NCD risk factors, PA and CRF) and objective 2 (to determine the prevalence of a CRS and its associations with PA and CRF). The findings showed that 43.1% of the cohort presented with at least one elevated NCD risk factor, with most at-risk children presenting with elevated cholesterol levels (raised TG=27.7%, depressed HDL-C=20.7% and raised total-C=15.9%), followed by elevated HbA1c (13.7%), elevated BP (raised S-BP=12.5% and raised D-BP=11.4%) and excess weight (elevated BMI=11.5% and high WC=10.4%) (see Table 3 in Chapter 4).

The overall prevalence of TG and total-C was higher in the present cohort than in previous South African studies (Negash et al., 2017; Oldewage-Theron et al., 2017), where the prevalence did not exceed 8%. Although, these studies reported much higher incidences of depressed HDL-C (42.5% - 67.2%) compared to the present cohort. The samples measured by Oldewage-Theron et al. (2017) and Negash et al. (2017) were from different regions (rural and peri-urban) in South Africa, but they were of similar age, spanning from 6 to 18 years. Since the present cohort (8 - 13 years) did not include older adolescent learners, it is probable that age (Gooding et al., 2015) and hormonal changes experienced during puberty (Lee, 1980; Eissa et al., 2016) might explain the observed lipid differences in the present cohort.

Age-related developmental differences are also known to impact the diagnostic criteria of MetS among children and adolescents; hence, why literature urges researchers not to use MetS definitions in children younger than ten years old (Zimmet et al., 2007). Since more than half (55.2%) of the present cohort were younger than the age of ten years, the clustering of NCD risk factors was therefore determined by calculating a CRS. The clustering of NCD risk factors has proved to be a better measure of cardiovascular health in children rather than single NCD risk factors, as the risk score provides a 'physiological' variable that accounts for gradual changes, which better reflects the continuum between an unhealthy and healthy metabolic profile (Andersen et al., 2003; Bugge, El-Naaman, McMurray, Froberg & Andersen, 2013). In addition, children with an elevated CRS present with poorer cardiometabolic health than those with only one abnormally high risk factor (Anderssen, Cooper, Riddoch, Sardinha, Harro, Brage & Andersen, 2007). The results of the present study showed that 17% of the sample had an elevated CRS, where girls presented with a significantly higher CRS than boys (χ^2=4.39, p=0.036, which is consistent with existing literature (Müller et al., 2020; Nqweniso et al., 2021). In addition, the incidence of CRS in the present cohort was higher than in most previously reported studies due to the variability in the methodology. The need for further research in this regard utilising standardised methodology is certainly evident.

There is extensive evidence which confirms the negative association between CRF, PA and the clustering of NCD risk factors among children and adolescents (Andersen et al., 2006; Anderssen et al., 2007; Müller et al., 2020; Nqweniso et al., 2021). However, few studies have quantified the protective function of CRF and PA in reducing the probability of an elevated CRS. Based on the findings presented in Figures 1 and 2 in Chapter 4, the results showed a halving of an elevated CRS for every 49 min increase in MVPA (95% CI 27 to 224 min/day) or every 2.17 ml/kg/min increase in VO_2 max (95% CI 1.66 to 3.12 ml/kg/min), providing a strong argument for the promotion of PA and CRF in children. According to normative values by Ruiz, Cavero-Redondo, Ortega, Welk, Andersen & Martinez-Vizcaino (2016), the average VO_2 max of the present cohort (girls: 45.48 ml/kg/min; boys: 48.46 ml/kg/min) was associated with low CVD risk. In addition, the average MVPA per day for the whole group was relatively high, with 72.99 min per day (girls: 61.01 min/day; boys: 84.76 min/day). Results from this study also showed that girls presented with significantly lower CRF (<0.0001) and total-MVPA (<0.0001) per day than boys.

In a global context, declines in PA and increased overweight and obesity are expected to affect CRF and cause a decrease in VO_2 max, which may lead to increased CVD risk (Kemper et al., 2001; Rowland, 2007). Thus, necessary action should be implemented to increase PA participation, especially among vulnerable sub-groups such as girls, who are known to be less active than boys. Findings from this study identified a large percentage (43.1%) of the cohort that presented with at least one NCD risk factor. Moreover, 17% of the cohort presented with an elevated CRS, which raises concern given the evidence of CRS tracking into adulthood and the potential decline in the life expectancy of future generations. Greater attention should, therefore, be focused on reducing NCD risk factors by intervening early enough among children and adolescents. The results from the present study also quantified the importance of PA and CRF as preventative measures in reducing NCD risk. This is pivotal given the financial strain of these debilitating lifestyle diseases later in life. However, extensive evidence shows that PA levels decline with age; in addition, many school-aged children do not engage in the recommended amount of PA needed to protect against NCDs and CVDs. Thus, further research is needed to identify children at risk of physical inactivity, which is a leading risk factor for NCDs and to lobby for appropriate action with evidence-based research.

7.3 Relationship between Body Mass Index and Physical Activity

The article in Chapter 5 (Relationship between Body Mass Index and Physical Activity among Children from Low-income Communities in Gqeberha, South Africa: A Cross-sectional Study) addressed objective 3, which aimed to determine the prevalence of BMI categories (underweight, overweight and obesity) and the relationship between MVPA and the respective BMI categories. Results from the present study identified a dual burden of malnutrition as 13% of the cohort were underweight, and 19% were overweight/obese (12% were overweight and 7% were obese) (see Figure 1, Chapter 5).

Findings from the DASH study (Smith et al., 2020) on the prevalence of overweight/obese children (18.8%) were similar to the current cohort. However, the incidence of underweight children in the present cohort (13%) was relatively higher than the 4.5% of underweight children identified in the DASH cohort. Meanwhile, Pretorius, Neophytou & Watson (2019) reported that of the Gqeberha cohort in their sample, 16.1% were underweight, 9.7% were obese, but 39.8% were overweight, which is more than 3 times the prevalence of the current cohort. These findings show a coexistence of undernutrition and overweight/obesity, with a greater incidence of the latter, which contributes to NCD risk factors. Unfortunately, countries like South Africa experience pervasive poverty and a widening economic gap, reducing the quality of life of those who are poverty-stricken and marginalised. Children and youth, in particular, are vulnerable as they are exposed to unhealthy lifestyle practices that critically affect their growth and development. Furthermore, poor diets and physical inactivity expose children to serious health risks, which may impact their current and future health status.

Findings of the present study also identified that a fairly high percentage of the cohort (64%) engaged in the recommended ≥60 min of MVPA per day, of which more than half were boys (40%). Thus, as expected, our results showed that a higher count of boys met the daily target of ≥60 min of MVPA compared to girls (24%). Further analysis revealed a significantly higher percentage of boys that were categorised as underweight (77%), normal weight (85%), and overweight (67%) met the recommended ≥60 min MVPA per day, whereas those categorised as obese (38%) failed to meet the target. Meanwhile, only underweight (57%) and normal-weight (51%) girls met the daily MVPA recommendation, whereas those categorised as however, overweight (42%) and obese (32%) failed to meet the daily MVPA target. These results show that underweight to normal-weight children are more likely to be active than overweight to obese children. Thus, our findings demonstrate an inverse association between BMI categories and the duration of total-MVPA achieved per day as children with excess weight were less likely to engage in the PA, or meet the recommended duration of ≥60 min MVPA per day. Figure 2 (Chapter 5) confirms the relationship between BMI and total-MVPA, stratified by sex.

In the context of this study, profiling malnutrition and physical inactivity is necessary for determining disease risk and defining appropriate interventions for vulnerable sub-groups. In particular, girls and children with excess weight were identified as vulnerable sub-groups requiring tailored intervention strategies to increase their PA participation. These intervention strategies should also be aimed at increasing awareness of the importance of healthy nutrition, given the well-established link between dietary patterns and the occurrence of NCDs. Given the regression of PA levels as children transition into adolescence and the tracking of NCDs from childhood to adulthood, school-based health interventions may effectively intercept to promote healthy behaviours to curb the rise of NCDs. Although, in the South African context, generalist PE teachers may require additional support to adequately deliver PE, especially given the 'lack of PE training and professional development'.

7.4 *KaziKidz* School-based Health Intervention

This intervention aimed to promote children's health by implementing three key components (*KaziKidz* toolkit, PE coach, and training workshops) across four intervention groups, differing by the level of implementation support. There is a paucity of South African studies that have investigated the effectiveness of school-based health interventions by measuring post-intervention change in NCD risk factors. Thus, in Chapter 6, the article 'Effect of the *KaziBantu* school-based health intervention on non-communicable disease risk factors of children from low-income schools in Gqeberha, South Africa', sought to address objective 4, 'To determine the effect of the *KaziKidz* intervention on NCD risk factors (WC, BP, blood lipids, cholesterol and HbA1c) and PA levels by comparing the experimental groups (four intervention conditions differing in level of support) with the control group'. A summary of significant intervention findings is presented in Table 2 below.

Table 2: Summary of significant intervention findings

Intervention condition	Total group	Girls only	Boys only
Toolkit + Coach + Workshop	• ↑ MVPA • ↑ HDL-C • ↓ S-BP	• ↓ LDL-C	• ↓ D-BP • ↓ HbA1c
Toolkit + Coach	• ↓ MVPA • ↓ HbA1c • ↓ S-BP • ↑ HDL-C	• ↓ LDL-C	• ↓ Total-C
Toolkit + Workshop	• ↑ MVPA • ↓ S-BP • ↑ HDL-C	• ↓ Total-C	
Toolkit only	• ↓ MVPA		

Findings from this study have shown some evidence that the interventions had positive effects. Although, the intervention effect on MVPA among children who received the T+C and T intervention was unexpected. As a result, the changes in NCD risk factors may not necessarily be associated with the change in MVPA alone. The changes in NCD risk factors may also be attributed to dietary changes due to increased awareness of healthy nutritional practices. In addition, these results do not rule out the influence of other factors, such as hormonal changes during puberty; therefore, these results should be interpreted with caution. Nevertheless, the post-intervention comparison of the NCD risk factors of children who received interventions with external support showed positive outcomes. Furthermore, the improvements in children's NCD risk factors and MVPA levels were generally associated with the interventions, which included training workshops and, in some cases, a PE coach. Meanwhile, the *KaziKidz* toolkit (on its own) showed little to no improvements in NCD risk factors and MVPA levels.

The *KaziKidz* toolkit is a consolidated practice of CAPS-based pre-prepared lesson plans incorporating PE (games and dance activities) and health, hygiene and nutrition lesson content. This toolkit also included basic equipment and painted playground games to address concerns regarding poorly resourced schools. However, results and observations from this study suggest that a toolkit alone may not be sufficient for generalist PE teachers to deliver PE adequately. While some teachers may be motivated to use the toolkit without the additional external support, it may also seem like an additional workload for other teachers who lack the foundational knowledge needed to interpret and implement the teaching resource.

The support of a PE coach was generally associated with positive post-intervention NCD changes. Although in some cases, the T+C intervention condition was associated with a decrease in boys' in-school MVPA levels, which may be attributed to a lack of interest in the dancing activities presented, as reported by Cárcamo et al. (2021). In this case, the lessons could have been adapted to suit the learners' interests (Klaasen, Noorbhai & van Gent, 2022). Thus, while the PE coach may have the foundational human movement, sport and exercise knowledge, they may have required further pedagogical understanding to adapt the lessons accordingly. A team-teaching approach was intended, whereby the coach and the teacher worked together to implement the lesson. The PE coach may not have had the skill set to cope with disciplinary issues, manage large classroom sizes, or know how to maximise participation during the lesson (Hollander, 2017). That said, a team-teaching approach may not be economical or realistic in a real-world setting and, therefore, may not be a long-term and solution.

The two intervention conditions incorporating a workshop component were associated with increased in-school MVPA and positive post-intervention changes, thus confirming the need for trained PE teachers. Besides disseminating pre-prepared lesson plans, teachers should still be trained to interpret the lesson plans, improvise when needed, and be able to deliver the content practically. According to Van Deventer (2012), educators should be trained in 'content, programme planning and presentation skills', all crucial topics, especially when teaching in low-income settings where under-resourced schools have limited access to the appropriate equipment and learning materials. Thus, children taught by generalist PE teachers who do not have the content understanding or the practical skills to improvise and adapt their lessons according to available resources may have reduced opportunities to engage in lessons targeting PA, nutrition, and all-around healthy behaviours to prevent NCD risk factors.

Therefore, the findings from this study highlight the immediate need for in-service training of PE teachers.

7.5 Strengths and Limitations

Strengths of this study include the cluster-randomised design that was used to test the effect of the multi-component intervention. The wide range of clinical markers (height, weight, WC, BMI, BF%, HbA1c, total-C, TG, HDL-C, LDL-C, VO_2 max and PA) included in the assessment battery allowed researchers to have an overall impression of NCD risk and also allowed researchers to determine the effectiveness of the intervention over a broad range of clinical markers such as body composition, blood glucose, blood lipids, cholesterol and PA. In addition, our relatively large sample of 961 children is also identified as a strength and a high-priority study population. Despite these strengths, the study should be interpreted in light of some limitations. The findings of this study should be interpreted with caution as some of the findings are not based on causality but only on association. In addition, these findings cannot be generalised to all South African children, as the study was conducted in one metropolitan area in the Eastern Cape province. In the context of methodological limitations, PA intensity was only measured during the testing periods at baseline and follow-up and not during the PE lessons. Given the sample size, it was not feasible to objectively measure the intensity of PA during PE lessons. It is recommended that future studies select a small sample of children to wear heart rate monitors during PE lessons in order to monitor PA intensity during the intervention. Dietary intake was not part of the scope of the study protocol, and this could also be considered a limitation due to its relationship to overweight and obesity. Finally, qualitative feedback in the form of focus group discussions from a select group of learners and teachers is recommended as this would provide invaluable information with regard to the compliance and sustainability of such interventions.

7.6 Conclusions

Together, the studies presented in this PhD thesis endeavoured to broaden the understanding of schoolchildren’s health in under-served communities in Gqeberha in the Eastern Cape, South Africa. Overall, this study identified a prevalence of NCD risk factors and clustered CVD risk. Additionally, it confirmed the independent and inverse association of the CRS with PA and CRF. Furthermore, the coexistence of under and overnutrition was found in conjunction with an inverse association between BMI categories and the duration of MVPA achieved per day. Finally, the school-based health intervention results revealed improvements in children's NCD risk factors and increased MVPA levels when the intervention conditions included the workshops and, in some cases, the PE coach. The *KaziKidz* toolkit (on its own) showed little to no improvements in NCD risk factors and MVPA levels.

This thesis contributes to the body of knowledge by highlighting the importance of PA and CRF and emphasising their separate pathways in reducing the clustering of NCD risk factors in children. Special attention should be given to increasing the PA participation of vulnerable sub-groups, such as girls and children with excess weight, especially since PA levels are likely to decline as children get older. Concerted efforts should be made to expose children to a variety of fun PA, as enjoyable PE activities are key to children's participation and play a vital role in nurturing an active and healthy lifestyle. In addition, there is an urgent need to address the theoretical understanding and practical application of PE for in-service generalist PE teachers. Therefore, it is without question that PE should be re-introduced as a stand-alone subject in the school curriculum, which may ensure quality pre-service training of qualified and enthusiastic PE teachers.

Given the shortage of literature on NCD risk factors among children, this study is the first known study, as far as could be ascertained, where both the individual and clustered NCD risk factor prevalence was determined for primary schoolchildren from underprivileged settings. Therefore, this study is fulfilling a research gap. The novelty of this PhD thesis is the design of the intervention, which quantitatively investigated the effectiveness of the school-based health intervention by measuring the change in NCD risk factors and establishing the external assistance needed by non-specialist PE teachers to implement a school-based health intervention. In addition, the rise of NCD risk factors among schoolchildren and the tracking of NCDs into adulthood make school-based health interventions an invaluable opportunity to alleviate NCD risk factors and shape future generations with healthy and active lifestyles.

7.7 Recommendations for Further Research

Following are recommendations for future research to be considered:

- Determine the long-term sustainability of school-based health interventions, including the factors that may affect compliance.
- Assess the long-term post-intervention impact of school-based health interventions on NCD risk factors.
- Longitudinally investigate the prevalence of NCD risk factors to allow for a broader understanding of these lifestyle-related NCDs.
- Determine the influence of social support networks such as peers, family members, and the community in behaviour modification of physical inactivity and unhealthy dietary habits.
- BMI reference charts are often not representative of the African population. Thus establishing reference charts based on a nationally representative sample of South African children should be a priority.
- Given this cohort's relatively high prevalence of under and overnutrition, greater attention should be focused on dietary intake, specifically in low-income settings. A broader analysis of dietary patterns, household influences, and environmental factors is needed to guide public health strategies.
- Future research intervention strategies addressing physical inactivity should focus on vulnerable sub-groups, such as girls and children with excess weight. These studies should investigate perceived barriers to PA, personal motivations and strategies to get these sub-groups to be more active. Accompanying longitudinal research may also investigate the personal and social supportive roles of family members, peers and teachers for PA.
- Extensive evidence shows a decline in PA as children transition into adolescence; therefore, research interventions should investigate innovative ways to increase PA in the school environment during the relevant transition period.
- Finally, given the necessity for in-service training of generalist PE teachers, future research interventions should focus on best practices for ‘continued professional teacher development'.

7.8 Practical Implications

In view of the current evidence on NCD risk among children and adolescents and considering the findings from the current study, a list of practical implications arise for implementation to promote schoolchildren's health in low-income communities.

- There is a need to reduce the NCD risk in future generations. Therefore, screening of NCD risk factors between the ages of nine and eleven years is recommended and should be led by interdepartmental collaborations between government departments such as the Department of Education and the Department of Health.
- School policies should address modifiable risk factors (PA, diet, substance abuse and mental health) that typically lead to NCDs. These strategies should increase awareness of these unhealthy behaviours, increasing the risk of lifestyle-related NCDs.
- Support from the Department of Basic Education in re-skilling generalist PE teachers and other support is recommended, especially within marginalised schools and communities. It is further recommended that continued professional development short learning programmes for teachers include sections on healthy nutrition and the importance of healthy active living to increase knowledge and awareness of NCDs.
- Considering the coexistence of under and overnutrition in the present cohort, it is recommended that government regularly monitor the national school nutrition programme. This should ensure that children from disadvantaged settings are provided with nutritionally appropriate and portion-controlled meals.
- Lastly, policymakers must continue to recognise the school environment as a vehicle for addressing healthy and active lifestyles. Thus it is recommended that schools involve the schoolchildren's families and the surrounding community to support and facilitate PA-enhancing opportunities for the children and therebystrive towards achieving '*Healthy Schools for Healthy Communities*' in under-resourced settings.

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Appendices

Appendix A: Permission from Journals

A1: Permission from BMJ Open Sports and Exercise Medicine

Verhagen, E.A.L.M. (Evert) <e.verhagen@amsterdamumc.nl>
To: Dolley, Danielle (Ms) (Summerstrand Campus South)

Thu 12/01/2023 17:25

Of course, Danielle!

Regards
Evert

On 11 Jan 2023, at 08:52, Dolley, Danielle (Ms) (Summerstrand Campus South) <danielle.dolley@mandela.ac.za> wrote:

Dear Evert,

I hope this message finds you well.

I am currently pursuing my PhD thesis by publication format, and I would like to include the published paper "***Clustered cardiovascular disease risk among children aged 8–13 years from lower socioeconomic schools in Gqeberha, South Africa***" https://bmjopensem.bmj.com/content/8/2/e001336 as part of my PhD thesis submission for 31 January 2023. I would, therefore, like to confirm that this is in order with the BMJ Open SEM policies.

With thanks and kind regards,
Danielle

From: Verhagen, E.A.L.M. (Evert) <e.verhagen@amsterdamumc.nl>
Sent: 14 August 2022 10:50
To: Dolley, Danielle (Ms) (Summerstrand Campus South) <Danielle.Dolley@mandela.ac.za>
Subject: Re: BOSEM BLOG - A Peek Behind your Study

Wonderful Danielle . I have now just posted it and we will make it known through our Social Media in the coming week.
You can find the blog here .. https://blogs.bmj.com/bmjopensem/2022/08/14/ap-eek-behind-the-study-with-danielle-dolley/

Thank you again. Both for a great paper and for this contribution.

Regards

Evert
<Screenshot 2022-07-26 at 09.05.14.png>

Professor | Department of Public and Occupational Health & Amsterdam Movement Sciences

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A2: Permission from IJERPH

Vinnie.He <vinnie.he@mdpi.com>
To: Dolley, Danielle (Ms) (Summerstrand Campus South)
Cc: IJERPH Editorial Office <ijerph@mdpi.com>

Tue 17/01/2023 14:06

Dear Dr. Danielle,

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Best luck with your Ph.D. defense, and look forward to publishing your next papers.

Kind regards,
Vinnie He
Assistant Editor
E-Mail: vinnie.he@mdpi.com

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On 2023/1/16 18:17, Dolley, Danielle (Ms) (Summerstrand Campus South) wrote:
> CAUTION - EXTERNAL: This email originated from outside of MDPI
> organisation. BE CAUTIOUS especially to click links or open attachments.
>
> Dear Vinnie He,
>
> I hope this message finds you well.
>
> I am currently pursuing my PhD thesis by publication format, and I would
> like to include the published paper "*/Relationship between Body Mass
> Index and Physical Activity among Children from Low-Income Communities
> in Gqeberha, South Africa: A Cross-Sectional Study/*"
> https://www.mdpi.com/1660-4601/20/2/1428
> <https://www.mdpi.com/1660-4601/20/2/1428> as part of my PhD thesis
> submission for 31 January 2023.
>
> I would, therefore, like to confirm that this is in order with the
> IJERPH policies.
>
> With thanks and regards, Danielle

A3: Permission from AJPHES

Abel Toriola <abel.toriola2015@gmail.com>
To: Dolley, Danielle (Ms) (Summerstrand Campus South)
Thu 19/01/2023 17:46

Dear Ms Dolley,

Thank you for your submission to AJPHES entitled, "**Effect of the KaziBantu school-based health intervention on non-communicable disease risk factors of children from low-income schools in Gqeberha, South Africa**." Your manuscript has been assigned the following tracking code and will be forwarded to our reviewers for technical evaluation. AJPHES/MS/R/19.1.2023. Note that AJPHES' review process takes about 8 weeks and you will be notified once feedback is received. Expect to hear from us soon.

Regards,

Prof Toriola

Abel Toriola <abel.toriola2015@gmail.com>
To: Dolley, Danielle (Ms) (Summerstrand Campus South)
Thu 23/03/2023 15:51

Dear Dr Dolley,

We have received feedback from AJPHES' reviewer regarding your paper submitted to the journal for publication. I am pleased to inform you that our reviewer has recommended that your paper may be accepted for publication subject to satisfactory minor revisions. In revising your manuscript, you are required to do the following:

1. Carry out the suggested revisions meticulously, otherwise, the paper will be rejected or returned for further revision and this will delay its processing considerably.
2. Colour the changes made for the editor's attention.
3. Submit a rebuttal or list of corrections indicating all the revisions made word-for-word and line by line. Also react to each of the reviewers' comments as appropriate.
4. Subject your manuscript to originality assessment via *turnitin* software and submit the report together with your revised paper. This should be done again after your revision, regardless of whether or not it was submitted in the first instance.
5. Language edit your manuscript and submit the proof of language editing.
6. Ensure that your references are quality checked such that none of the citations is missing from the reference list. Similarly, references listed at the end of your manuscript should have been cited in the body of your paper.
7. Include DOI nos or in its absence, URL for all the references listed at the end of your manuscript. This is a new requirement. Papers published in AJPHES are now assigned DOI numbers by CrossRef (USA based organisation). This is meant to improve their citation index and visibility internationally.
8. You will be advised in due course if any other revision is required or when a final decision is taken regarding your manuscript.
9. I suggest that you do not rush to do the revision, but ensure that it is thoroughly done. Be advised that you have only two opportunities to carry out the revision satisfactorily and this is the **FIRST** opportunity.
10. Deadline for re-submission: Thursday 30 March 2023.

I look forward to receiving your revised manuscript as scheduled.

Thank you.
Regards,
Prof Toriola
Editor, AJPHES

Appendix B: Ethics Approval

B1: KaziBantu Project REC-H Approval

NELSON MANDELA
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Chairperson: Research Ethics Committee (Human)
Tel: +27 (0)41 504 2235
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Ref: [H18-HEA-HMS-001 / Approval]

26 March 2018

Prof R du Randt and Prof C
Walter Faculty of Health
Sciences
South Campus

Dear Profs Du Randt and Walter

EFFECTS OF A SCHOOL-BASED HEALTH INTERVENTION PROGRAMME IN MARGINALISED COMMUNITIES IN PORT ELIZABETH, SOUTH AFRICA: THE KAZIBANTU PROJECT

PRP: Prof R du Randt / Prof C
Walter PI: Prof R du Randt / Prof
C Walter

Your above-entitled application served at the Research Ethics Committee (Human) for approval.

The ethics clearance reference number is **H18-HEA-HMS-001** and is valid for three years. Please inform the REC-H, via your faculty representative, if any changes (particularly in the methodology) occur during this time. An annual affirmation to the effect that the protocols in use are still those for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.

We wish you well with the project.

Yours sincerely

CB Cilliers

Prof C Cilliers
Chairperson: Research Ethics Committee (Human)

Cc: Department of Research Capacity
Development Faculty Officer: Health Sciences

B2: PhD thesis REC-H Approval

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Ref: [H19-HEA-HMS-003] / Approval]

6 June 2020

Professor C Walter and Professor R du Randt
Faculty: Health Sciences

Dear Professor Walter and Professor du Randt

EFFECT OF A SCHOOL-BASED HEALTH INTERVENTION ON THE NON-COMMUNICABLE DISEASE RISK STATUS AMONG SCHOOL CHILDREN FROM DISADVANTAGED COMMUNITIES

PRP: Professor C Walter and Professor R du
Randt PI: Ms D Smith

Your above-entitled annual progress report (APR) was reviewed by REC-H EXCO for approval. The procedure regarding the referral of participants for treatment where necessary has been noted. We take pleasure in informing you that the Research Ethics Committee (Human) has approved your report. Please note the following as you continue your study to its completion:

1. In the event of a requirement to extend the period of data collection (i.e. for a period in excess of 1 calendar year from date of original approval of study), completion of an extension request is required (form RECH-005 available on Research Ethics Committee (Human) portal)
2. In the event of any changes made to the study (excluding extension of the study), completion of an amendments form is required (form RECH-006).
3. Immediate submission (and possible discontinuation of the study in the case of serious events) of the relevant report to RECH (form RECH-007) in the event of any unanticipated problems, serious incidents or adverse events observed during the course of the study.
4. Immediate submission of a Study Termination Report to RECH (form RECH-008) upon expected or unexpected closure/termination of study.
5. Immediate submission of a Study Exception Report of RECH (form RECH-009) in the event of any study deviations, violations and/or exceptions.
6. Acknowledgement that the study could be subjected to passive and/or active monitoring without prior notice at the discretion of Research Ethics Committee (Human).

Please inform the REC-H, via your faculty representative, if any changes (particularly in the methodology) occur during this time (forms as above). An annual affirmation to the effect that the protocols in use are still those for which approval was granted, will be required from you. Please quote the ethics clearance reference number in all correspondence and enquiries related to the study. For speedy processing of email queries (to be directed to Imtiaz.Khan@mandela.ac.za), it is recommended that the ethics clearance reference number together with an indication of the query appear in the subject line of the email.

We wish you well with the continuation of your study.

Yours sincerely

Dr S Govender

Chairperson: Research Ethics Committee (Human)

Cc: The Office of Research Development
Faculty Officer: Health Sciences

B3: Eastern Cape Department of Education Approval

Province of the

EASTERN CAPE

EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES

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Enquiries: B Pamla Email: babalwa.pamla@ecdoe.gov.za Date: 09 May 2018

Professor Cheryl Walter

Department of Human Movement Science
Nelson Mandela University
Port Elizabeth
77000

Dear Prof. Walter

PERMISSION TO UNDERTAKE A RESEARCH PROJECT: EFFECTS OF A SCHOOL-BASED HEALTH INTERVENTION PROGRAMME IN MARGINALISED COMMUNITIES OF PORT ELIZABETH, SOUTH AFRICA - THE KAZIBANTU PROJECT

1. Thank you for your application to conduct research.
2. Your application to conduct the abovementioned research involving 800 participants from four Primary Schools of Nelson Mandela Bay District under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:
    a. there will be no financial implications for the Department.
    b. consent will be sought from parents of minor children.
    c. institutions and respondents must not be identifiable in any way from the results of the investigation;
    d. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;
    e. you will make all the arrangements concerning your research.
    f. the research may not be conducted during official contact time.

g. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Strategic Management Monitoring and Evaluation;

h. your research will be limited to those institutions for which approval has been granted, should changes be effected written permission must be obtained from the Chief Director: Strategic Management Monitoring and Evaluation;

i. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 - 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis.

j. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary.

k. you are requested to provide the above to the Chief Director: Strategic Management Monitoring and Evaluation upon completion of your research.

l. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you.

m. you comply with your ethical undertaking (commitment form).

n. you submit on a six-monthly basis, from the date of permission of the research, concise reports to the Chief Director: Strategic Management Monitoring and Evaluation

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

4. The Department will publish the completed Research on its website.

5. The Department wishes you well in your undertaking. You can contact the Director, Ms. NY Kanjana on the numbers indicated in the letterhead or email nelisa.kanjana@ecdoe.gov.za should you need any assistance.

NY KANJANA

DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH & SECRETARIAT SERVICES FOR SUPERINTENDENT-GENERAL: EDUCATION

B4: Eastern Cape Department of Health Approval

Province of the
EASTERN CAPE
HEALTH

Enquiries Zonwabele Merile Tel no: 083 378 1202

Email: Zonwabele.Merile@echealth.gov.za Fax no: 043 642 1409

Date: 05 JUNE 2018

RE: EFFECTS OF A SCHOOL-BASED HEALTH INTERVENTION PROGRAMME IN MARGINALISED COMMUNITIES IN PORT ELIZABETH, SOUTH AFRICA: THE KAZIBANTU PROJECT. (EC_201804_007)

Dear Prof C. Walter and Prof R. Du Randt

The department would like to inform you that your application for the abovementioned research topic has been approved based on the following conditions:

1. During your study, you will follow the submitted amended protocol with ethical approval and can only deviate from it after having a written approval from the Department of Health in writing.

2. You are advised to ensure, observe and respect the rights and culture of your research participants and maintain confidentiality of their identities and shall remove or not collect any information which can be used to link the participants.

3. The Department of Health expects you to provide a progress on your study every 3 months (from date you received this letter) in writing.

4. At the end of your study, you will be expected to send a full written report with your findings and implementable recommendations to the Eastern Cape Health Research Committee secretariat. You may also be invited to the department to come and present your research findings with your implementable recommendations.

5. Your results on the Eastern Cape will not be presented anywhere unless you have shared them with the Department of Health as indicated above.

Your compliance in this regard will be highly appreciated.

SECRETARIAT: EASTERN CAPE HEALTH RESEARCH COMMITTEE

Appendix C: *KaziBantu* Project

C1: *KaziBantu* Information Sheet

KaziBantu
Healthy Schools for Healthy Communities

Information Sheet for Parents/Guardians

Identity of researchers and sponsoring institution: This study will be carried out in collaboration with Prof. Cheryl Walter, Prof. Rosa du Randt from the Nelson Mandela University, Port Elizabeth, South Africa and Prof. Pühse from the University of Basel, Switzerland. The following institutions will be part of the research team, namely the Swiss Tropical and Public Health Institute (Swiss TPH) and the Department of Sport, Exercise and Health, University of Basel, Switzerland. The study is funded by the Novartis Foundation, a non-profit organization located in Basel, Switzerland.

Study objectives: To assess the efficacy of a school-based health promotion program on risk factors for non-communicable chronic diseases (e.g., type 2 diabetes, obesity, hypertension) and health behaviours (e.g., physical activity) in grade 4 to 6 primary schoolchildren from selected communities in Port Elizabeth. This study will further our knowledge about the potential of school health interventions to improve children's health and wellbeing.

Research procedures: This research project takes place over 12 months (1 school year). Approximately 1080 children from 8 different schools in Township and/or Northern Areas of Port Elizabeth will take part in this study. Official authorities (Eastern Cape Department of Education, Eastern Cape Department of Health) have approved the study, and the school principals have agreed to participate in the study. Out of the 8 schools, 6 schools are randomly assigned to an intervention condition and 2 schools to a control condition. From each school only one class per grade will be randomly selected for testing. Each child will be assessed twice. The first assessment will be during January 2019 before the intervention, and the second assessment during October 2019 after the intervention. Each data assessment period will take up to 3 school days per school. However, each tested class will be involved for no longer than ±3 hours during each assessment period.

Consent: Permission for your child's participation in the project is sought, but due to a cap on the number of participants that can be assessed in the given time for the research, not all children with signed consent from their parents/ legal guardian will be selected for testing. If your child attends a school that is randomly identified as an intervention school, your child will receive the intervention program irrespective of whether he/she has been tested. If your child attends a school that is identified as a control school, your child can also receive the intervention program, but only from 2020. The contents of the intervention program (physical activity and health lessons) is taught during regular school hours. The intervention schools will implement an intervention program consisting of one weekly Physical Education lesson (40 min), one weekly Moving-to-Music lesson (40 min), 3 Health Education lessons, and 3 Nutritional Education lessons for each grade per year.

Voluntary participation: It is your choice whether to have your child participate or not. If you choose not to consent, all school services for your child will continue, and nothing will change. Should you decide to withdraw your consent before the project commences in January, kindly inform your child's class teacher or contact the researchers (see contact details on page 2). You may also choose to change your mind later and stop participating, even if you agreed earlier. However, we would like to inform you that the data gathered before withdrawal can be used for reports and publications.

Confidentiality: All information collected in this study will be coded with a unique personal identification number and stored in a safe place. Only members of the study will have access to the data. The officials of the national committee of ethics and research can ask for access to the collected information for the monitoring of good clinical practice. We will publish the key findings of this study, but names and personal identities will not be revealed.

Sharing of the Results: Confidential information will not be shared. Research results will be published.

NOVARTIS | The Novartis Foundation   NELSON MANDELA UNIVERSITY   University of Basel   DSBG   Swiss TPH Swiss Tropical and Public Health Institute

Risks: There are no specific risks associated with this study. Risks for capillary blood sampling are minimal and present a frequently used procedure. Nevertheless, finger prick might be a slightly uncomfortable procedure. A qualified professional nurse will examine your child before he/she engages in the maximal fitness test (20m shuttle run). The project nurse will determine whether a child suffers from a medical condition, which prevents participation in such a maximal physical fitness test.

Benefits

If your child participates in this research, it will have the following benefits:

- Clinical Examination: All children receive a free clinical examination by a registered nurse. In case of detection of severe medical conditions, children will be referred to a local clinic.
- Health and Nutritional Education: All children receive two health and nutritional education lessons per term.
- Food and Drinks: Refreshments will be served after blood testing and the physical fitness testing.

Data Assessment: The two measuring occasions will involve the following tests:

Clinical Examination  	The clinical examination involves anthropometric indicators (e.g. height, weight), body composition and blood pressure, which are all non-invasive. To assess blood lipids, a small amount of capillary blood is needed (a few blood drops). Therefore, the finger will be pricked with a small lancet. This is a slightly uncomfortable procedure but does not cause any long-lasting pain. Blood tests will be done fasting (meaning not eating or drinking). More information about the fasting will be provided to all study participants before testing. HIV/AIDS testing will **NOT** be done.
Physical Fitness 	Children's physical fitness will be assessed with the 20m shuttle-run test.
Physical Activity 	Physical activity levels will be assessed via accelerometry. Therefore, we will ask your child to wear an accelerometer device for 7 days around the hip.

Who to Contact: If you have any questions, you may ask our present research assistant(s) now or later, even after the study has started. If you wish to ask questions later, you may contact any of the following:

Professor Cheryl Walter (SA principal investigator)
Tel.: +27 41 504-2499/7
E-Mail: Cheryl.Walter@mandela.ac.za

Danielle Dolley (local coordinator)
Tel.: +27 41 504-4692
E-Mail: Danielle.Dolley@mandela.ac.za

C2: Informed Consent Form

KaziBantu
Healthy Schools for Healthy Communities

I have read the foregoing information regarding the planned study or it has been read to me in a language that I understand. I have also had the opportunity to ask questions about the study and these have been answered to my satisfaction. I am aware of the purpose, objectives and procedures, risks and benefits of the study. I understand that I can withdraw my child from the study at any time without further consequences.

I hereby consent for my child to participate in the research which will include the relevant assessments and where applicable the interventions indicated. I also acknowledge and accept that:

- Only one class per grade in my child's school will be included in the assessment/testing involved in this research process.
- The class to be tested per grade will be randomly selected in January 2019 when class lists have been finalised.
- My child may therefore not form part of the relevant class.

Statement by the parent/legal guardian

I, as the parent/legal guardian, I consent voluntarily for my child to participate in the *KaziBantu* study.

Name of child:

Surname of child:

Name of parent/legal guardian:

Surname of parent/legal guardian:

Signature of parent/legal guardian: ______________________ Date:______________________________

If parent/legal guardian is illiterate: A literate witness must sign. Participants who are illiterate should include their thumbprint as well.

I have witnessed the accurate reading of the consent form to the parent of the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness:

Surname of witness:

Signature of witness: _____________________________ AND Thumbprint of parent/legal guardian

Date: _____________________________