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«Associations between physical fitness and blood pressure among primary schoolchildren in different disadvantaged neighbourhoods of Port Elizabeth, South Africa»

Masterarbeit

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Abstract

Background

Prevalence rates of cardiovascular diseases (CVDs) are increasing rapidly, especially in low-to-middle income countries and people from socioeconomically disadvantaged backgrounds are highly susceptible. There is large evidence that risk factors for CVD already develop in young ages through unfavourable changes in lifestyle habits. Furthermore, low cardiorespiratory fitness levels are associated with clustering of cardiovascular risk factors. Therefore, the aim of this master thesis is to provide evidence from primary schoolchildren data, deriving from a cross-sectional survey conducted in February to March 2019 in disadvantaged neighbourhoods in Port Elizabeth, South Africa. The aim included association analysis between cardiorespiratory fitness and blood pressure values as markers of cardiovascular health.

Methods

Baseline data was collected from a representative sample of 870 children, aged 9 to 13 years, within the framework of the *KaziBantu* study. Children's cardiorespiratory fitness was estimated through individual performance of a multistage fitness test, the 20-m shuttle run test, and resting blood pressure was assessed with the Omron M6® digital blood pressure monitor.

Results

Cardiorespiratory fitness (CRF) correlates significantly and negatively with blood pressure values. In addition, CRF differs significantly between gender and age, whereas boys in average have higher mean values of CRF than girls, and older children have lower CRF than their younger counterparts. A third of all the girls are classified in the low CRF level, with the majority of children assessed showing moderate CRF levels. Blood pressure values are relatively constant over gender, whereas age only influences systolic blood pressure. A high proportion of 8.6% of the total study population also shown blood pressure values in the pre-hypertensive stage (≥ 132/85 mmHg).

Conclusion

Children with physical fitness classified as «good» show lower blood pressure values and are therefore at a lower risk for developing cardiovascular diseases in adulthood. Children should be encouraged to improve their CRF to sustainably guarantee a satisfying cardiovascular health. Furthermore, regular tracking of the blood pressure is essential to detect children at an elevated risk for pre-hypertension and hypertension.

Zusammenfassung

Hintergrund

Die Prävalenzraten von Herz-Kreislauf-Erkrankungen (CVD) nehmen besonders in Entwicklungsländern rapide zu und Menschen aus sozioökonomisch benachteiligten Gesellschaften sind vermehrt exponiert. Wissenschaftliche Evidenz zeigt, dass sich Risikofaktoren für CVD bereits im jungen Alter durch ungünstige Lebensstilveränderungen entwickeln können. Eine ungenügende kardiorespiratorische Fitness (CRF) ist mit einer Häufung von kardiovaskulären Risikofaktoren verbunden. Ziel dieser Masterarbeit ist es, Daten aus einer Querschnittserhebung von Grundschulkindern aus benachteiligten Gegenden in Port Elizabeth, Südafrika, bereitzustellen und Zusammenhänge zwischen kardiorespiratorischer Fitness und Blutdruckwerten (BP), als Marker für die kardiovaskuläre Gesundheit, zu analysieren.

Methoden

Grundlagendaten wurden im Rahmen der *KaziBantu*-Studie aus einem Stichprobenumfang von 870 Grundschulkinder im Alter von 9 bis 13 Jahren erhoben. Die Querschnittserhebung wurde im Februar bis März 2019 in benachteiligten Gegenden von Port Elizabeth, Südafrika, durchgeführt. Die kardiorespiratorische Fitness der Kinder wurde durch die individuelle Leistung des mehrstufigen Fitnesstests, 20-m-Shuttle-Lauftest, geschätzt und der Ruheblutdruck mit dem digitalen Omron M6®-Blutdruckmessgerät gemessen.

Resultate

Zwischen der CRF und BP liegt eine signifikante inverse Korrelation vor. Die CRF unterscheidet sich signifikant zwischen Geschlecht und Alter, während Knaben im Durchschnitt höhere CRF-Mittelwerte als Mädchen und ältere Kinder eine niedrigere CRF als Jüngere aufweisen. Ein Drittel aller Mädchen wird in einem tiefen CRF Niveau eingestuft, die Mehrheit der Kinder hat ein moderates Fitnessniveau. Die Blutdruckwerte sind über die Geschlechter relativ konstant, während das Alter gemäss unseren Daten nur den systolischen Blutdruck beeinflusst. 8,6% der gesamten Studienpopulation werden in einem hypertonen Stadium klassifiziert (≥ 132/85 mmHg).

Schlussfolgerung

Kinder mit guter körperlicher Fitness weisen niedrigere Blutdruckwerte auf und sind daher einem geringeren Risiko für Herz-Kreislauf-Erkrankungen im Erwachsenenalter ausgesetzt. Kinder sollen ermutigt werden aktiv zu sein, um damit ihre CRF positiv zu beeinflussen und damit günstige Voraussetzungen für eine gute nachhaltige kardiovaskuläre Gesundheit zu schaffen. Eine regelmässige Überwachung des Blutdrucks ist relevant, um Kinder mit erhöhtem Risiko überhaupt identifizieren zu können.

Opsomming

Agtergrond

Die voorkomssyfer van kardiovaskulêre siektes (CVD) neem vinnig toe, veral in ontwikkelende lande, en mense uit sosio-ekonomies benadeelde gemeenskappe raak al hoe meer blootgestel. Wetenskaplike bewyse toon dat risikofaktore vir CVD op 'n vroeë ouderdom kan ontwikkel as gevolg van ongunstige lewenstylveranderings. Onvoldoende kardiorespiratoriese fiksheid (CRF) hou verband met 'n ophoping van kardiovaskulêre risikofaktore. Die doel van hierdie magistertesis is om inligting te verskaf uit 'n deursnee-opname van laerskoolkinders uit minderbevoorregte gebiede in Port Elizabeth, Suid-Afrika, en om korrelasies tussen kardiorespiratoriese fiksheid en bloeddrukwaardes (BP) te ontleed, as merkers vir kardiovaskulêre gesondheid.

Metodes

Basiese gegewens is versamel uit 'n steekproefgrootte van 870 laerskoolkinders van 9 tot 13 jaar, in die *KaziBantu*-studie. Die deursnee-opname is in Februarie-Maart 2019 in ontneemde gebiede van Port Elizabeth, Suid-Afrika, gedoen. Die skoolkinders se kardiorespiratoriese fiksheid is geskat deur die individuele uitvoering van die multivlak-fiksheidstoets, 20 m-pendeltoets en rustende bloeddruk gemeet met behulp van die Omron M6® digitale bloeddrukmonitor.

Resultate

Daar is 'n beduidende omgekeerde korrelasie tussen CRF en BP. Die CRF verskil aansienlik tussen geslag en ouderdom, terwyl seuns gemiddeld hoër CRF-gemiddeldes het as meisies en ouer kinders 'n laer CRF as jonger kinders. Een derde van alle meisies word in 'n lae CRF-vlak geklassifiseer; die meerderheid kinders het 'n matige mate van fiksheid getoon. Die bloeddrukwaardes is relatief konstant by die geslagte, terwyl die ouderdom volgens ons data slegs die sistoliese bloeddruk beïnvloed. 8,6% van die totale studiepopulasie word in 'n hipertoniese toestand geklassifiseer (≥ 132/85 mmHg).

Gevolgtrekking

Kinders met 'n goeie liggaamlike fiksheid het laer bloeddrukvlakke en hou dus 'n laer risiko vir kardiovaskulêre siektes by volwassenes. Kinders moet aangemoedig word om aktief te wees ten einde 'n positiewe invloed op hul CRF te hê en sodoende gunstige toestande te skep vir goeie, volhoubare kardiovaskulêre gesondheid. Gereelde monitering van bloeddruk is relevant om kinders in gevaar te identifiseer.

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BMI	Body Mass Index
BP	Blood Pressure
CAPS	Curriculum and Assessment Policy Statement
CRF	Cardiorespiratory Fitness
CVDs	Cardiovascular Diseases
DBP	Diastolic Blood Pressure
ESH	The European Society of Hypertension
HAKSA	The Healthy Active Kids South Africa
HTN	Hypertension
ICHCA	International Congress of Hypertension in Children and Adolescent
LMIC	Low- and Middle-Income Country
M	Statistical Mean Value
MMHG	Millimetres of Mercury
MVPA	Moderate to Vigorous Physical Activity
NA	Northern Areas
NC	Northern Area Control School
NAS	Northern Area Schools
NCDs	Non-Communicable Diseases
NI	Northern Area Intervention School
PA	Physical Activity
PE	Physical Education
SBP	Systolic Blood Pressure
SD	Standard Deviation
SES	Socio Economic Status
SSA	Sub-Sahara Africa
TA	Township Area
TC	Township Control School
TI	Township Intervention School
TSS	Township Schools
$\dot{V}O_2max$	Maximal Oxygen Uptake [mlO_2/min/kg bw]
20-m SRT	20-meter Shuttle Run Test

«Exercise is the key not only to physical health
but to peace of mind. »

Nelson Mandela (1918 – 2013)

1 Introduction

Low physical activity levels, raised sedentary behaviour, poor diet and other unhealthy lifestyle patterns are prevalent all over the world and human health is shaped by these trends. Cardiovascular diseases (CVDs) count globally as major causes of death and include diseases such as ischaemic heart diseases or strokes and vascular disorders such as atherosclerosis, coronary artery disease, peripheral arterial diseases and hypertension (Mendis, Puska, & Norrving, 2011). Hypertension (HTN) is furthermore responsible for 45% of heart diseases globally each year. HTN often stays undiagnosed over many years, with drastic damage only occurring much later in life (WHO, 2013). Low- and middle-income countries (LMICs) are heavily affected by the double burden of disease, since health care systems often are weak or only accessible to privileged citizens or at a very high cost. South Africa as an example, takes up more and more Western lifestyle habits and disease profiles (Steyn & Damasceno, 2006) and simultaneously it struggles with huge inequality in society's wealth and health that causes vast gaps in terms of health care management (Ataguba, Akazili, & McIntyre, 2011). It is necessary to gain a greater insight into the current state of health among South African youth, especially youth in lower socioeconomic areas, previously identified as of the most vulnerable groups (Walter, 2014). Furthermore, since unhealthy lifestyle habits predevelop in early childhood but can still be modifiable during these young ages, it is an ideal time to intervene (The NCD Alliance, 2011). Health parameters, such as cardiorespiratory fitness (CRF) and blood pressure (BP) can be taken as early indicators of future health profile (Lang, Larouche, & Tremblay, 2019).

The choice of South Africa for the *KaziBantu* project enlarges the state of knowledge in the field of physical health among children in sub-Saharan Africa (SSA) which concerningly counts globally as the region with one of the most rapid epidemiological changes (BeLue et al., 2009). Furthermore, there is a strong need for further evidence-based data in developing countries in SSA to justify the eligibility of health promotion programs and sustainable changes of national health care policies. Within the frame of the *KaziBantu* project, the current study is an approach to analyse current state of schoolchildren's health in disadvantaged neighbourhoods in Port Elizabeth, South Africa. This master thesis offers local data and can be used as baseline of CRF and blood pressure (BP) values for further research in longitudinal designs.

As a joint research project between the University of Basel in Switzerland (CH) and the Nelson Mandela University in Port Elizabeth South Africa (SA), the *KaziBantu* project aims to contribute positive impacts on schoolchildren's and teacher's health for sustainable healthy communities and therefor a healthy nation, independent of socioeconomic status (SES).

The aim of this study was to evaluate one perspective of current state of health and physical condition of the selected study population in a cross-sectional survey. This study evaluated whether CRF and BP correlate and how these parameters interact with other factors, including age, gender, location and ethnicity.

2 Theoretical framework and background

The following section provides an overview of health and healthcare policies, global and regional trends in epidemiology and focusses on the country South Africa, as the defined setting of the current study. Health related variables, on which is focussed in this paper, are furthermore illustrated and defined.

2.1 Health and diseases – a global approach

It is widely known that global modern lifestyles are responsible for changes in patterns of morbidity and mortality. Non-communicable diseases (NCDs), including CVDs, cancer, diabetes, and chronic respiratory diseases, are rising in all parts of the world and are affecting millions of people. Furthermore, NCDs lead to new strains of public health management and challenge local governments as well as global health institutions. The rising threat and burden of NCDs can even be seen as global crisis and cause annually 36.1 million of deaths per year (Beaglehole et al., 2011). HTN, as one of the major risk factors for CVDs, can lead to ischaemic heart disease and cerebrovascular accidents, which both annually cause around 17 Million deaths globally and are ranked as the two major causes of death worldwide (WHO, 2018, 24 May, #The top 10 causes of death) (Figure 1).

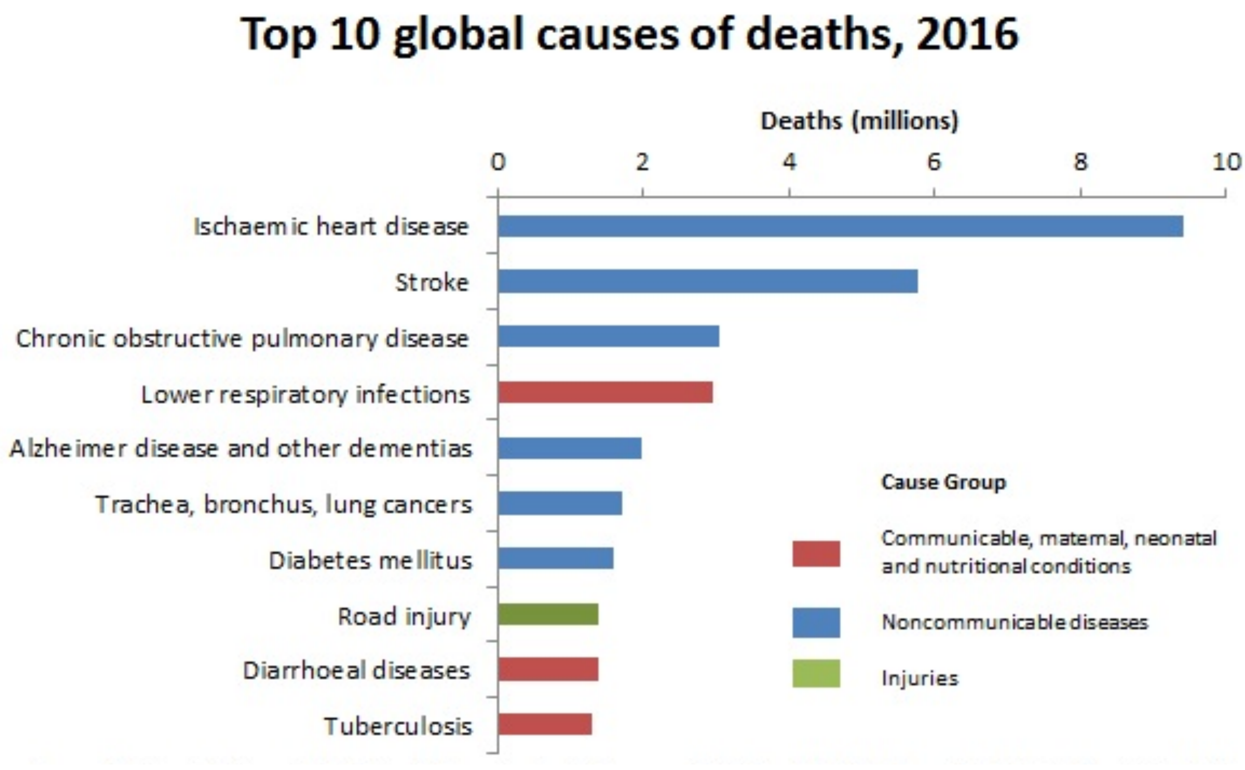


Figure 1: Top 10 global causes of death, 2016
Source: World Health Organization (2018)

The prevalence of NCDs is already high in developed regions but is increasing rapidly in LMICs due to malnutrition, disadvantaged lifestyle modifications and a lack of physical activity (PA) (Lachat et al., 2013). By examining the top 10 causes of mortality in LMICs, similar patterns to global trends are visible (Figure 2). In addition, LMICs are increasingly exposed to a double burden of disease, suffering from both communicable and NCDs (Müller et al., 2016).

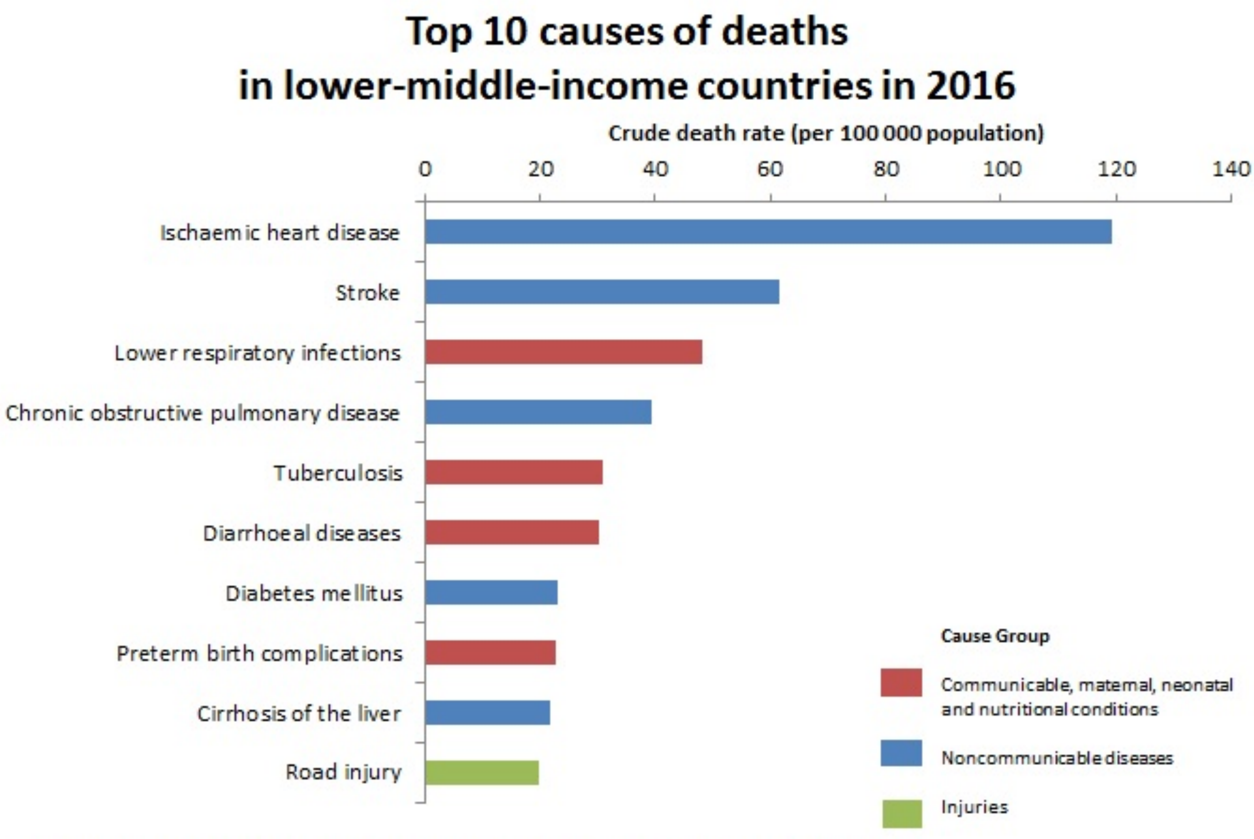


Figure 2: Top 10 causes of death in lower-middle-income countries in 2016
Source: World Health Organization (2018)

2.2 Epidemiologic transition in sub-Saharan Africa

SSA is not spared of negative global trends in public health profiles (Steyn & Damasceno, 2006) and is currently experiencing one of the most rapid epidemiological transitions in global history (BeLue et al., 2009). The incidence of NCD, especially CVDs, has rapidly increased over the past years and will have massive impacts on public health sectors and the country's health care systems (BeLue et al., 2009). NCD control is very challenging for local government in SSA then due to high poverty rates and inequality in these countries. This challenges accessibility and affordability of health care services, resulting in it is provision not always guaranteed for a large part of the society. This increases the threat of rising numbers of morbidity and mortality, with people from the lowest SES suffering the most (BeLue et al., 2009). South Africa, as a part of SSA, is faced with similar patterns of disease profiles, challenges within healthcare systems and a rising double disease burden, such as is found in its neighbouring countries. Due to large inequality rates and policies favouring inverse care law in South Africa, the lowest socio-economic groups have low access rates to good quality health care and suffer the most due to the dual burden of diseases. This is due to lack of monetary resources and insufficient accessibility to adequate healthcare services (Walter, 2014; Ataguba et al., 2011).

2.3 South Africa – a nation of inequality

South Africa still carries the aftermath of the apartheid regime, which was initiated in 1948 and ended in 1994. Under the apartheid legislation, several laws (Population Registration Act of 1950, The Group Areas Act of 1950, and many others) were introduced and discriminated against non-white citizens politically, educationally, socially and with regards to settlement rights. A drastic racial hierarchy was built, with white people favoured in all dimensions over coloured and black people[1]. Black people were under more restrictive laws and had lower rights than coloured people (South African History Online, 2019). Segregation policies of the apartheid regime introduced removal and forced relocation. Black and coloured people were displaced to the outskirts of cities, black people into designated locations and coloured people into municipal housing (Christopher, 1987; Schaefer, 2009). The apartheid legacy resulted in racial segregation in urban areas and unequally distributed wealth, which is still omnipresent to this day. These facts challenge the today's central as well the provincial government and its policies (Christopher, 2001; Coovadia, Jewkes, Barron, Sanders, & McIntyre, 2009). Segregation laws are repealed by now, but the legacy of apartheid still is preserved and visible in the social structure of urban space, whereas Port Elizabeth, as an example, counts as the most racially segregated city in South Africa (Statistics South Africa, 2016, 20 May).

Residential areas in the historical white districts, which counted as the most developed areas, are very expensive and for many people unaffordable (Christopher, 1987; Schaefer, 2009). The disadvantaged neighbourhoods (northern areas NA and townships or township areas TA) surrounding Port Elizabeth, South Africa, as an example of an apartheid city, were created under the segregation policies of apartheid laws and are one of the still visible legacies of this era (black urbanization, tightly controlled urban expansion). Township areas are predominantly inhabitant by black people, and include areas such New Brighton and Motherwell, while coloured people predominantly reside in the Northern areas of Port Elizabeth, which includes Korsten, for example. (Christopher, 1987).

Even though today South Africa officially is ranked as upper-middle-income country, (The World Bank, 2019) and has global economic growth since the transition to democracy in 1994, nearly 30% of the people are unemployed (2016) and over half of the population lives below the poverty line (less than R 992. 00 pm). Racial disparities are significant, whereas poverty levels are higher among black Africans, especially women and children (Statistics South Africa, 2017). In 2015, 0.4% of white people and nearly 50% of black people were affected by poverty. South Africa shows one of the highest inequality rates in the world, with a consumption expenditure Gini coefficient of 0.63 in 2015 and a Gini coefficient based on the income of 0.68 (Statistics South Africa, 2017). A Gini coefficient has values on a scale from 0 to 1, whereas an index of 0 would be "a state of total equality" (in such a society, everybody would share the same level of income). An index of 1 explains a status of complete inequality, which means wealth is concentrated on one single person while the rest of the society receive no share of the

[1] In this paper the major population groups are classified by the still common terminology used in South Africa: *Black people* (black African), *coloured people* (mixed race) and *others*, which include Indians, Whites, Mixed or other ethnic groups. All of these terms are used in a neutral way and do not entail any judgments or discrimination.

income (Statistics South Africa, 2017, p. 21). Again, Gini coefficients are higher among black people than other ethnic subgroups, such as coloured individuals or white people (Statistics South Africa, 2017).

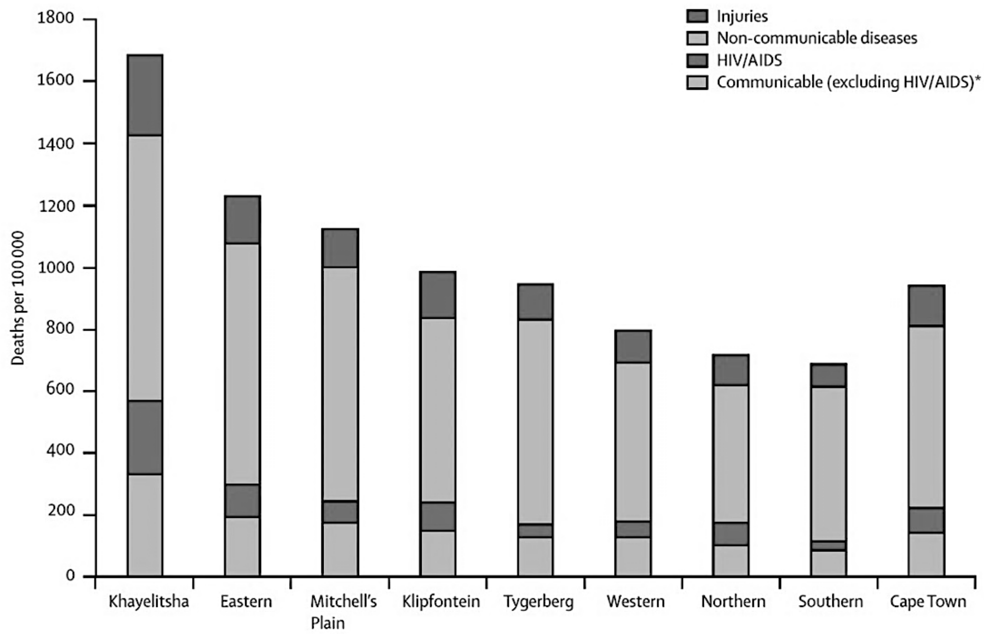
These facts contribute to a high crime rate especially in urban areas, favour the propensity to violence and violent attacks, as well as political unrest. Experts assess South Africa as a dangerous place and caution must be exercised while residing in South Africa (EDA, 2019).

2.4 Public physical health in South Africa

South Africa and the large problem of inequality is also present in public health management. Poverty is still strongly associated with the creation of large disparities in health care access and affordability and therefore general health conditions of the population (Harris et al., 2011). The burden of diseases, including communicable and noncommunicable diseases, are greater among lower socio-economic groups compared to higher groups, and the poorest of the poor are the worst off (Ataguba et al., 2011). Health care services in South Africa are geared toward the rich, whereas 20% of the richest population received 36% of the total benefits of using services (measured in monetary value), while the poorest only received 12.5% (Ataguba & McIntyre, 2009). Furthermore, the rich are favoured using most facilities such as hospitals across all private sector services (Ataguba & McIntyre, 2009). About 84% of South African's population do not have private health insurance, and rely on the national public health sector, which is understaffed (only approximately 30% of national doctors are employed by the public sector). Only a minority (16%) of South Africans do have private healthcare insurance, which employs about 70% of the country's doctors. Up to a fourth of people who are not insured pay out of their pocket for private-sector care (Mayosi & Benatar, 2014). Combining the fact that lower SES, which historically is linked to non-white ethnicities, and resulting in lower accessibility and affordability to health care services, it is obvious that poor health (ill-health) is more prevalent among black people (Williams & Mohammed, 2009).

By having a closer look at numbers and figures of mortality rates and diseases, drastic racial disparities can be observed. Prevalence rates of HIV/AIDS (human immunodeficiency virus and acquired immunodeficiency syndrome), for example, are seven times higher among black people than among white men and women. Infant mortality rates are also much higher among black people (67 per 1000) than among the white population (7 per 1000). Life expectancy differs drastically between races: in 2002 white females had a 50% longer life expectancy than black women (Coovadia et al., 2009). Not only the unequal access to health-care services but also the differences in quality between private and public health-care sectors leads to large inequality in the society's state of health (Mayosi et al., 2009).

The South African society is faced with communicable diseases such as HIV/AIDS but increasingly by NCDs, such as hypertensive disease, strokes, ischaemic heart diseases, obesity and diabetes (Mayosi et al., 2009). Outcomes about South African's risk profile are comparable with the results of the global investigation of the WHO (2018, #The top 10 causes of death): The risk factor "high blood pressure" closes at second-ranking position and consequently "ischaemic heart diseases" are second most causes of annual death, right after HIV/AIDS (Norman et al., 2007). The poor communities (such as townships and the northern areas), mostly in an urban and suburban setting, are therefore predominantly facing a growing double burden of diseases (Mayosi et al., 2009). A study that investigated age-standardized mortality rates in Cape Town (Figure 3) has shown that people living in disadvantaged neighbourhoods have general higher mortality rates than people living in more advantaged areas, where NCDs are the leading cause of death (Groenewald et al., 2008).



	Khayelitsha	Eastern	Mitchell's Plain	Klipfontein	Tygerberg	Western	Northern	Southern	Cape Town
Injuries	259·6	152·7	126·1	150·6	113·3	150·6	98·2	70·5	128·9
Non-communicable diseases	856·4	781·1	755·7	594·9	662·1	512·7	445·8	501·3	590·2
HIV/AIDS	238·5	103·2	69·3	90·2	43·0	50·2	69·6	25·6	76·1
Communicable (excluding HIV/AIDS)*	330·3	193·8	174·2	149·4	125·5	127·4	103·2	87·7	144·3

Figure 3: Age-standardised mortality rates for broad cause groups by subdistrict, Cape Town
Source: Mayosi et al. (2009)

Considering the demographic change and the concerned risk-factor profile of South African's population the number of cardiovascular deaths will be doubled by 2040 (Mayosi et al., 2009). South African's district-based primary health-care system is urged to establish cost-effective interventions in primary and secondary prevention of chronic and non-communicable diseases to achieve successful management of the double burden of diseases and a long-term decrease of risk factors in population (Mayosi et al., 2009).

These are clear facts which lead to the need of health promotion and low-threshold interventions in specially disadvantaged areas to empower the poor communities in terms of health strategies. Children are an important target group and schools seem to be a convenient frame for interventions (Mayosi et al., 2009).

Considering the demographic change and the concerned risk-factor profile of South African's population, the number of cardiovascular deaths is expected to be doubled by 2040 (Mayosi et al., 2009). South African's district-based primary health-care system is urged to establish cost-effective interventions in primary and secondary prevention of chronic and non-communicable diseases to achieve successful management of the double burden of diseases and a long-term decrease of risk factors in the population of South Africa (Mayosi et al., 2009).

These are clear facts that lead to the need for health promotion and low-threshold interventions, in specially disadvantaged areas, to empower poor communities in terms of health strategies. Children, who are still developing individual lifestyle habits and are receptive to behavioural change (Ortega, Ruiz, Castillo & Sjöström, 2008), are an important target group for primary prevention and schools seem to be a convenient frame for interventions (Mayosi et al., 2009). Schools as community institutions are embedded in communities, are close to the needs of local population and could offer a suitable access to the most vulnerable groups and pupils through promotion of healthy and active lifestyles (Mayosi et al., 2009).

2.5 Cardiovascular risk factors

The prevalence of NCDs is rapidly growing and CVDs are closing at first ranking in global, but also national cause of death (Lachat et al., 2013). It is therefore important to have a closer look at the general causes of CVDs. Major risk factors underlie the demographic change and modern lifestyle behaviour, such as tobacco and alcohol abuse, low physical activity patterns, unhealthy diet, and raised stress levels, favoured by urbanisation and the economic structural change towards a service society, which predestines the development of cardiovascular risk factors (McVeigh, Norris, & De Wet, 2004; BeLue et al., 2009; Mayosi et al., 2009). CVDs include diseases of the cardiovascular systems such as coronary heart diseases, stroke, HTN, heart failure, diseases of the arteries, congenital cardiovascular defects and rheumatic heart diseases (Plowman & Smith, 2014, p. 454).

LMIC are faced by a large demographic change and high urbanisation rates (Mayosi et al., 2009). Additionally, large sections of the population of SSA take up modern risk factor behaviour such as smoking, sedentary lifestyle, lower energy expenditure in everyday life and malnutrition stays ever present which increases the risk of CVD. These factors shift the disease profile in SSA from communicable to non-communicable disease profile (BeLue et al., 2009). Nutrition transition, access to Western/fast food through globalization and accompanied overweight or obesity occurs more frequent, whereas overweight often coexists with malnutrition due to excess intake of high-calorie content and nutrient-poor diet (BeLue et al., 2009). In South Africa, the shift towards a cash-based economy, away from agriculturally based economies, increases the rates of sedentary or less physically active work (McVeigh et al., 2004).

2.5.1 Cardiovascular risk factors in global children

Children barely experience cardiovascular events, but research has shown that atherosclerotic disease can predevelop in childhood (Anderssen et al., 2007; Plowman & Smith, 2014). Youth is a crucial period in life since lifestyle habits are formed and large changes in the physiological and psychological systems can take place. All of these influences and shape behavioural patterns and health status in adulthood (Ortega et al., 2008). At this time children worldwide adopt more and more unfavourable lifestyle patterns which have long-term impacts on their health and the rising chance of CVDs in a later stage of life (Steyn & Damasceno, 2006; Bucher et al., 2013). High rates of childhood obesity, poor diet, dyslipidaemia, diabetes mellitus (Type 1 and increasingly Type 2), elevated BP values, cigarette smoking, and inactive lifestyle are concerning facts which need to be addressed by public health institutions and health promotion programs to prevent and treat NCDs (Plowman & Smith, 2014). Taking South Africa as an example, a large number of children do not reach the national and global recommended physical activity (PA) guidelines of 60 minutes of moderate to vigorous PA (MVPA) daily. Only half of the South African children get enough PA and simultaneously increased inactive and sedentary time is recognized among children, which was shown in the results of the South Africa's 2014 Report Card on Physical Activity for Children and Youth, where MVPA was either self-reported and/or objectively measured through accelerometery (Draper, Basset, De Villiers, Lambert, & the HAKSA Writing Group, 2014). Vulnerable groups are pupils from disadvantaged neighbourhoods who are learners at low SES state schools with limited financial resources which is emerged in insufficient sports facilities and a lack of sports equipment (Walter, 2014).

Schools in South Africa do not contribute to change the fact of increasing inactive lifestyle in childhood since physical education (PE) is not a stand-alone subject and is included in the "Life Skills" subject. Per week, four lessons of Life Skills are included in the Curriculum Assessment Policy Statements (CAPS) prescribed by the South African Department of Education (DoE). PE is further downgraded, as only one hour per week is allocated to PE. PE is not regulated through a separate curriculum and has as a non-academic subject lower priority compared to academic subjects (Hardman, 2008). This is evident by comparing the number of subject hours per week, while for example six hours are referred to mathematics and only one hour to PE (Department of Basic Education, 2011).

In black African communities, only about 30% of black African schoolchildren were offered formal PE. Governmental schools with higher SES are not as much affected because of higher financial recourses for the availability of equipment and sports infrastructure (Armstrong, Lambert, & Lambert, 2011).

2.6 Physical activity

PA is very important throughout one's lifetime and contributes maintaining a healthy lifestyle and preventing CVD. PA patterns decrease often from youth, into adolescents and ultimately into adulthood, while sedentary behaviour increases (WHO, 2019, #Physical Activity). Many studies have shown that children and youth leading sedentary lifestyles, are more likely to continue leading an inactive lifestyle into adulthood, whereas physical active children and adolescents more likely to stay physically active (Vanreusel et al., 1997). Furthermore, PA goes hand in hand with physical fitness and consequently CRF. Regular vigorous activity is strongly associated with high CRF levels. The more time children spent in MVPA, the better their CRF level and hence their health profile (Ortega et al., 2008). Globally recognized and valid recommendations for long-lasting health benefits highlight the importance of the everyday physical activity (WHO, 2019, #Physical activity; #Physical activity and young people).

Around 30 minutes of PA, obtained once or accumulated in bouts of at least moderate intensity should be performed every day in adulthood, whereas in children at least 60 minutes, predominantly aerobic, are recommended to improve CRF, muscular fitness, bone density, and cardiovascular, and metabolic systems (WHO, 2019, #Physical activity and young people). For additional health and fitness benefits, vigorous intensity should be integrated into PA sessions, at least three to five days a week. Activity in any form is better for health and wellbeing than a lifestyle in the absence thereof (Plowman & Smith, 2008).

3 Definitions and current state of research

The following chapter provides an overview of the selected parameters and provides definitions of the investigated parameters. Additionally, parameters are embedded in the current state of research by providing an overview of the vast literature body.

3.1 Defining cardiorespiratory fitness

The CRF describes the ability of a person to perform physical endurance activity and depends on the performance of the cardiorespiratory system and the ability to provide oxygen to the body and remove waste products produced (Plowman & Smith, 2014). The cardiorespiratory system includes the respiratory system, which oxygenates the body, and the cardiovascular system, including the ability of the heart and artery system to transport oxygen to the body cells and remove waste (Plowman & Smith, 2014, chap. 9). Plowman and Smith (2014, p. 710) define CRF as the following:

> "The ability to deliver and use oxygen under the demands of intensive, prolonged exercise or work."

3.1.1 Defining $\dot{V}O_2max$

Maximal oxygen uptake ($\dot{V}O_2max$) can be defined as the maximum amount of oxygen which can be used in physiological mechanisms to provide energy to metabolically active body cells at a maximum level of performance (Aus der Fünten, Faude, Skorski, & Meyer, 2013). It can be specified as absolute $\dot{V}O_2max$ (ml/min) as well as relative $\dot{V}O_2max$, referring to body weight (ml/min/kg body mass). Due to standardisation for body weight, which is highly variable in individuals, relative $\dot{V}O_2max$ is more suitable to compare $\dot{V}O_2max$ of different individuals (Aus der Fünten et al., 2013). Since fat cells are mainly metabolically inert, body composition influences $\dot{V}O_2$max levels. A lean individual has general higher $\dot{V}O_2max$ values than his or her obese counterpart, even though not differ in weight is present (Rowland, 2007). $\dot{V}O_2max$ is used as a classical indicator to define physical fitness and endurance power, since it is an expression of maximal capacity. Furthermore, $\dot{V}O_2max$ declines over age and differs between gender, whereas male have naturally higher values of $\dot{V}O_2max$ than females (Aus der Fünten et al., 2013).

$\dot{V}O_2max$ can be estimated through several testing methods in the field but also in a laboratory setting. The spiro-ergometry on a treadmill in a laboratory provides the most reliable data because inspiratory and expiratory gasses are directly measured, and all larger muscle groups are involved in the maximal physical activity (Aus der Fünten et al., 2013). Nevertheless, this method is a very recourse-intense process and therefore not suitable for measuring large numbers of individuals in a short period, or during field assessment. If testing includes large sample sizes or restricted timeframes, distance runs, such as the 20-m shuttle run test (20- SRT) from Léger, Mercier, Gadoury and Lambert (1988) would be more suitable than direct oxygen assessment. $\dot{V}O_2max$ values then are estimated and not directly measured. All $\dot{V}O_2max$ assessment methods have the following in common: adequate data acquiring, and maximal loading is necessary, participation further requires enough volition to push themselves to a maximal aerobic performance (Plowman & Smith, 2008).

3.1.2 Influences of growth on the cardiorespiratory system

Physical growth in children influences the cardiorespiratory physiology and therefor physical performance. In children, $\dot{V}O_2max$ levels increase with the development of lungs, heart and skeletal muscle – which all are determinants of aerobic maximal capacity. Male lung volume grows between the ages of 6 to 16, from a total average capacity of 1.937 ml to 5.685 ml. The weight of the heart increases almost three times during the same period. These anatomic changes are influencing physiological mechanisms. Between the age of five to 16 years, a boy's absolute $\dot{V}O_2max$ is tripled and therefore also his aerobic capacity increased (Rowland, 2005, p. 23). Nevertheless, $\dot{V}O_2max$ cannot be taken as the only indicator to describe the development of endurance performance in absolute terms during the period of growth. Despite the fact that aerobic endurance capacity progressively increases, relative $\dot{V}O_2max$ does not, it rather stays stable (in boys) or even decreases (in girls) (Rowland, 2005, p. 98). Absolute $\dot{V}O_2max$ in contrast increases from childhood into adolescence to adulthood, by almost tripling in both genders, due to the growth of system components, which are responsible for $\dot{V}O_2max$. Increase rates differ between gender, with higher rates observed in males than in the female. In adolescence, the process in boys are even accelerated due to hormonal change. In the course of adulthood, and after the age of 30, $\dot{V}O_2max$ levels decrease again if no active action is taken (Shvartz & Reibold, 1990; Rowland, 2005). Interestingly to consider is the fact, that while absolute $\dot{V}O_2max$ increases over the maturing process, relative $\dot{V}O_2max$ stays steady for boys (at around 52 ml/min/kg on average) throughout growing years, whereas relative $\dot{V}O_2max$ in girls slightly declines from about 50ml/min/kg at the age of 8 to 40ml/min/kg at the age of 15 (Rowland, 2005, p. 109).

3.2 The 20-m shuttle run test as a valid CRF assessment tool

The 20-m SRT count as one of the most frequently utilized tools to assess CRF among a large study population and in a feasible frame (Tomkinson, Lang, Blanchard, Léger, & Tremblay, 2019). The 20-m SRT is internationally recognized and highly valid and reliable to assess CRF in children (Castro-Piñero et al., 2009; Tomkinson et al., 2019). Test results are converted in relative $\dot{V}O_2max$ values (or peak $\dot{V}O_2$ relative to body mass) through the application of the formula of Léger *et al*. (1988). Fat mass could influence test performance since it is metabolically inert and an extra load to carry. Test performance (cumulative laps) have a moderate-to-high criterion-related validity for estimating $\dot{V}O_2max$ (mean correlation coefficient of criterion-related validity was *r* = .84 according to Léger et al., 1984, 1988) (Mayorga-Vega, Aguilar-Soto, & Viciana, 2015). Methodological variability can be minimized, and testing reliability can be guaranteed through accurate application of the standardized testing protocol of Léger *et al*. (1988) adequate reporting of affective factors on testing performance such as internal and external motivation, environmental conditions (ground conditions, weather conditions, temperature) and reporting of results in metric scale (number of completed laps, running speed) (Tomkinson et al., 2019).

3.3 Research on cardiorespiratory fitness among children

Shvartz and Reibold released an extensive literature review in 1990, where they included studies which measured $\dot{V}O_2$max from Canadian, American and European children to elderly people (with ages ranging from six to 75 year) through direct measurement (Shvartz & Reibold, 1990). On the basis of this vast $\dot{V}O_2$max data, directly measured in both gender, international comparable normative values from poor to excellent CRF levels were defined. Values for nine to 13 years old boys range from 33 ml/min/kg (classified as poor fitness) to 46 ml/min/kg (average fitness) to 53 ml/min/kg (good fitness) up to 60-66 ml/min/kg (very good or excellent fitness). In girls, values are slightly lower and range from 30 ml/min/kg (classified as poor fitness) to 40 ml/min/kg (average fitness) to 46 ml/min/kg (good fitness) up to 50-58 ml/min/kg (very good or excellent fitness) (Shvartz & Reibold, 1990). Any exercise, which involves large muscle groups and is sustained for prolonged periods can potentially increase CRF (Plowman & Smith, 2008).

Tomkinson *et al.* (2016) published a large systematic review which included 177 studies from 50 countries, incorporating 1’142’026 children between the age nine to 17 years, which examined CRF through the 20-m SRT, to developed age- and gender-specific international norms, ranging from poor to healthy CRF levels. Boys had consistently higher 20-m SRT performance than girls. CRF and CRF related health decreased systematically over age in boys and girls (Tomkinson et al., 2016; Castro-Piñero et al., 2017), which is controversial to anatomical and physiological theory (Rowland, 2005). Findings that support the theory of growth were shown among boys in the Muscatine Study (Janz, Dwason, & Mahoney, 2002). CRF was measured through direct expired gas analysis in a maximal cycle ergometer test and was shown as $\dot{V}O_2$max values adjusted for body weight ($kg^{-2/3}$) [ml x $kg^{-2/3}$ / min]. The five-year longitudinal study showed improved CRF levels for boys, while $\dot{V}O_2$max values in boys raised from 162±21 to 176±24 from pre- to post-puberty, and during the age from 10 to 15. Findings of CRF patterns among girls within the Muscatine Study were lower than among boys throughout all age groups, whereas, in contrast to the boys, mean values of relative $\dot{V}O_2$max in girls decreased over age from 130±20 to 127±16 [ml x $kg^{-2/3}$ / min]. $\dot{V}O_2$max values within the Muscatine Study are expressed as millilitre oxygen consumption with a theoretically derived mass exponent of $kg^{-2/3}$ of body weight each minute [ml x $kg^{-2/3}$ / min], make a comparison to other studies, which are estimating CRF through indirect methods (e.g. 20-m SRT) and provide information of $\dot{V}O_2$max values in relation to body weight [ml/min/kg] difficult.

Moreover, CRF also has a genetic component, which contributes to individual $\dot{V}O_2$max and therefore some children are predisposed to higher CRF. Heritability estimates for relative $\dot{V}O_2$max account for 55%, for absolute even up to 60% (Schutte, Nederend, Hudziak, Bartels, & de Geus, 2016).

3.3.1 Research on cardiorespiratory fitness among children from SSA

A large, national based study of South Africa was carried out by several research groups from five South African Provinces (Western Cape, Eastern Cape, Gauteng, Free State, KwaZulu Natal), who evolved the basic physical fitness of 10’295 South African school children aged six to 13 years (Armstrong et al., 2011). The EUROFIT testing battery, as an internationally recognized testing tool, was applied to collect data (Van Mechelen, Van Lier, Hlobil, Crolla, & Kemper, 1991). The main aim of the national study of Armstrong *et al.* (2011) was to create a national baseline for health-related physical fitness measurements according to different ethnic groups and provide reference values for further longitudinal research. CRF was part of the physical fitness test battery and was assessed through a 5-m shuttle run test, according to the EUROFIT test protocol. Overal results showed dropping test results (shuttle run times) over age among boys and girls. Highest test scores were achieved by white children whereas black boys were consistently slower than their white or coloured male counterparts. Test performance of the 5-m shuttle run test was measured in seconds and not converted in $\dot{V}O_2$max values, which makes the comparison to the 20-m SRT test and standardized cut-off values of CRF difficult. In conclusion, Armstrong *et al.* (2011) highlighted the need for the reintroduction of PE in schools as a standalone subject especially in previously disadvantaged public schools where the learners are predominantly black African children.

Another South African specific study investigated levels of PA in nine-year old children associated with different levels of SES and ethnicity (McVeigh et al., 2004). Children were classified in quartiles of SES, which were based on individual statements about housing conditions, property information, education degree of parents, income and health status. A high quartile is associated with higher status of SES. White children were represented only in the highest quartile of SES, whereas black children were categorized predominantly in the lower quartile of SES. Significant ethical differences were found in terms of activity patterns. Black African children were less active than their white counterparts, recorded higher rates of television watching and had a lower likelihood to participate in PE classes at school (McVeigh et al., 2004).

Data from the South Africa’s 2016 Report Card showed poor to fair CRF levels for children (n = 1200) and adolescents (n = 300) and assigned the national physical fitness state for children and youth in South Africa with grade D (succeeded with less than half but some children and youth 21% to 40%). CRF levels of 1300 primary school children were estimated in a cross-sectional survey in Mpumalanga and Limpopo provinces, and defined as poor, despite of prevalent high levels of PA. High prevalence of underweight (74%) was mentioned as possible explanation (Uys et al., 2016). Results from South Africa’s 2014 and 2018 “Healthy Active Kids South Africa” (HAKSA) Report Card showed no reported data for physical fitness levels among children and adolescents in South Africa (Draper et al., 2014; Draper et al., 2018; HAKSA, 2018).

A vast systematic review about physical activity, sedentary behaviour, and physical fitness among school-aged children in SSA was released in 2014 from the authorship Muthuri *et al.* (2014). Results specifically for aerobic fitness (CRF) showed generally lower rates on CRF for girls than boys. Two studies showed trends of higher CRF for children with lower SES, living in rural settings, whereas another study found higher CRF level for girls in towns (higher SES) than girls from townships (lower SES). It was highlighted that urbanization and associated higher rates of sedentary behaviour in SSA was major cause for decreasing levels of CRF (Muthuri et al., 2014).

3.4 Research on cardiorespiratory fitness as a powerful marker of health

CRF counts as one of the most important variables in terms of cardio-protective factors and is significantly associated with health, consistently overall all PA levels (Blair, Cheng, & Scott Holder, 2001; Schmid, Romann, Kriemler, & Zahner, 2007; Lee, Artero, Sui, & Blair, 2010; Lang et al., 2019; Tomkinson et al. 2019). Improved CRF is strongly associated with several biological mechanisms such as improved insulin sensitivity, blood lipid profile, body composition, reduced inflammation, and blood pressure (Lee et al., 2010). The change of CRF stands in inverse association with mortality risk (Lee et al., 2010) and a good CRF in childhood and adolescence is in close relation to good cardiovascular health in a later stage of life, based on longitudinal studies (Castro-Piñero et al., 2017). Several studies from all over the world have found similar effects (Carnethon, Gulati, & Greenland, 2005; Ortega et al., 2008; Castro-Piñero et al., 2017).

The review of Ortega *et al.* (2008) summarizes several publications regarding physical fitness (PF) and health outcomes in global youth, independent of origin. A good physical fitness at a young age has positive effects on long term health, concerning cardiovascular risk factors, adiposity, skeletal health, certain types of cancer, and mental health and wellbeing. There is strong evidence that CRF in combination with muscular fitness is favourable for the cardiovascular profile at any young age. In terms of health promotion policies, schools can play an important role as they can on the one side encourage children in being physically active by promoting positive health behaviours, and on the other side by helping to detect children with low CRF who might be potential risk taker for later CVDs (Ortega et al., 2008).

A study among American youth and adolescents presented findings of the direct negative association between physical fitness and the prevalence of CVD risk factors and emphasized the current situation of high prevalence rates of low CRF among American youth. 33.6% of the included adolescent study population was categorized in the low CRF category, with similar prevalence rates in males (32.9%) and females (34.4%) (Carnethon et al., 2005).

3.4.1 CRF cut-off values

Castro-Piñero *et al.* (2017) published health-related cut-off points of CRF within a Spanish population, aged between six and ten years. In a two-year follow-up study, data of CRF

($\dot{V}O_2max$) were taken to determine the present and future risk for CVDs. They defined $\dot{V}O_2max$ values of 39.0 ml/kg/min for boys and 37.5 ml/kg/min for girls as health-related cut-off values. The fact was highlighted that CRF in childhood count as a substantial early predictor for identifying children at risk for adult CVD and supported the urge for effective primary prevention integrated into health policies. Children with persistently high levels of $\dot{V}O_2max$ (≥ 39.0 ml/min/kg in boys and ≥ 37.5 ml/min/kg in girls) had lower CVD risk scores at follow-up as their counterparts of persistent low and decreased CRF levels. A change of CRF from a low level to a high level had significant positive effects on CVD risk score and therefor a healthier cardiovascular profile with general lower blood pressure (BP) values, lower blood lipid levels, more favourable insulin sensitivity and lower skinfold thickness. Despite the positive facts of good and improved CRF, levels of CRF tend to stay consistent or even decline from childhood to adolescence and longitudinal results showed high probabilities of low CRF at baseline and at follow-up (Castro-Piñero et al., 2017).

Broad international literature work from Ruiz *et al.* (2016) also defined cut-off values for healthy CRF in boys and girls. The meta-analysis included data from 9’280 children and adolescents, aged between eight and 19 years, from 14 countries (Europe and USA), and cut-off values therefor can be taken as international standards. Ruiz *et al.* (2016) defined cut-off values for boys at a level of ≤ 42 ml/kg/min and girls at a level of ≤ 35 ml/min/kg for increased CVD risk. These cut-off values are slightly lower than health related cut-off values defined by Castro-Piñero *et al.* (2017).

Health related cut-off values from both authorship, Ruiz *et al.* (2016) and Castro-Piñero *et al.* (2017), correspond to “poor” (30 to 33 ml/kg/min) to “average” (40 to 46 ml/kg/min) fitness levels in both, boys and girls (Shvartz & Reibold, 1990).

3.5 Defining blood pressure

BP values describe the pressure of blood within blood vessels and directly depended on cardiac output and vascular resistance (Klabunde, 2012). BP is controlled through different, short- to long-term body regulation systems, such as mechanical and pressure-sensitive receptors (arterial baroreceptors and receptors for expansion) integrated with the vascular system, endocrine regulations and renal regulation of total fluid volume. Systolic blood pressure (SBP) is defined as the peak pressure of the arterial pulse as a result of blood ejection by the left ventricle (Klabunde, 2012). Whereas diastolic blood pressure (DBP) results as the lowest value of the falling pressure during ventricular relaxation (during the filling phase) (Klabunde, 2012).

3.5.1 Blood pressure in children

In children, BP is additionally depended on other factors such as height, gender, and age, which need to be taken into account with its interpretation, due to high variability in height within gender and age groups (Gupta-Malhotra et al., 2015). Height-sensitive BP charts for children aged three to 20 years are shown in Appendix 1.

BP values in children compared to adult BP values, are lower on average and increase as age increases. BP values correlate positively with height, more than with age or weight (Licht &

Büscher, 2018; Ploier, 2013). Mean arterial pressure in infant children may only amount 70 mmHg whereas adult means arterial pressure is 100 mmHg. SBP generally increases more over age than DBP (Klabunde, 2012). After the onset of puberty, BP values align with adult BP values (Mohrman & Heller, 2018). Female normally have slightly lower BP values than male after the onset of puberty at the same age due to metabolic, anatomical and physiological differences, which favour lower BP among the female gender (Klabunde, 2012).

3.5.2 Reference values for childhood blood pressure

Since height is one of the most important factors influencing the variability of BP in children, it is very difficult to establish suitable reference values. Banker *et al.* (2016) developed height-specific BP percentile charts for children based on the United States' (US) population, with a 100% sensitivity and specificity above 94% for screening. These charts are internationally used and widely recognized. The chart has a similar structure to the CDC growth charts and shows curves for boys and girls respectively (see Appendix 1). Other reference values (height and age-adjusted) are shown by Neuhauser, Thamm, Ellert, Hense and Schaffrath Rosario (2011) for a German baseline study. The KiGGS 2003-2006 study, can be used due to the fact, that the US reference values may not comply with the global paediatric population. It is for this reason that it is important to evolve reference values from populations with other origins. Neuhauser *et al.* used a national sample in Germany, collected BP data with oscillometric methods validated in children and improved statistical application. Baseline results were provided from normal-weight children so that not to distort results, whereas the US reference values were influenced by the prevalence of childhood overweightness and obesity. For this reason, results based on the KiGGS study, show lower values for most of the subgroups, compared to the US reference values.

3.6 Defining hypertension

HTN in adulthood is defined as high BP values above the cut-off value of 140/90 mmHg, whereas systolic values from 120 to 139 mmHg and diastolic values from 80 to 89 mmHg count as pre-hypertensive (Klabunde, 2012).

3.6.1 Primary (essential) hypertension

About 90% to 95% of patients are diagnosed with primary (essential) HTN. Causes of primary HTN are unidentifiable and it is diagnosed by exclusion criteria. Systemic vascular resistance and blood volume are both increased, which elevates pressure in the cardiovascular system and lead to hypertensive states. Primary HTN is strongly associated with family history of high BP, age, race, SES, exposure to stress, obesity as well as diabetes (Klabunde, 2012).

3.6.2 Secondary hypertension

5% to 10% of HTN patients suffer from secondary HTN which is indirectly caused by another condition. Renal disorders or disfunctions, tumours, aortic coarctation or other diseases or disorders, as well as pregnancy or sleep apnea can cause secondary HTN (Klabunde, 2012).

3.6.3 Defining paediatric hypertension

HTN in children is defined as long-term elevated systolic and/or diastolic BP values, relative to an individual, gender-and height-adjusted values above the 95th percentile (Licht & Büscher, 2018). Furthermore, the prevalence of essential and secondary HTN among screened children is between 4.5% and 13% (Gupta-Malhotra et al., 2015). The prevalence of essential HTN is ever increasing and is strongly linked to obesity (Lurbe et al., 2016).

Roughly general HTN can be differentiated between acute and chronic arterial HTN. Acute HTN is mostly caused by acute kidney inflammation (glomerulonephritis) or kidney failure and therefor of secondary source, whereas causes for chronic HTN are very diverse and depend on many factors. HTN in children has therefore to be analysed very differentiated, as causes can vary from harmless to severe. HTN can furthermore occur through examination situation (white-coat-effect[2]), resulting in BP having the possibility to be essential or secondary, temporary or persisted (Licht & Büscher, 2018).

The diagnosis of infantile HTN depends on several factors and diagnosis often is inaccurate. Many variables need to be considered, such as height, sex, and age of the child. Measurements must be performed according to a protocol and need to be repeated over time before any referrals for further evaluation occur. It is very important that children stay calm and in a resting position over a sufficient period before and between measurements to measure accurate resting BP values (Gupta-Malhotra et al., 2015). According to Licht and Büscher (2018), it is even proposed to measure BP at all four extremities to obtain adequate results and preclude the diagnosis of congenital stenosis (stenosis of the aortic isthmus). The choice of the suitable size of the cuff is crucial and needs to cover two-thirds of the upper arm of the child. To finally diagnose HTN, pathological values need to appear at different days with repeated measurements. For further differential diagnosis a 24-hours BP registration is recommended (Licht & Büscher, 2018).

3.7 Research on paediatric hypertension

Investigations on children's BP has become a growing field in pathophysiological and clinical research. In May 2019 the second "International Congress of HTN in Children and Adolescent" (ICHCA) was held in Warsaw, Poland, and proclaimed the vast relevance on early assessment of BP, not only epidemiologically but also for clinical purposes. The congress was endorsed by the Southern African Hypertension Society, the International Society of Hypertension, the European Society of Hypertension (ESH) and the World Hypertension League (ICHCA, 2019). The European Society of Hypertension (ESH) defined BP cut-off values, and stated that children's BP categories, whether normotensive, pre-hypertensive and hypertensive, should be determined by the reference group of the population itself. Children with values under the 90th percentile are then classified as normotensive, children between the 90th and the 95th percentile

[2] White-coat effect: "White-coat HTN (*hypertension*) is defined as elevated BP in office, yet normal being elsewhere. The reported frequency of white-coat HTN varies, perhaps as a result of the criteria used to establish the diagnosis, ranging from 1% to 44% (Lurbe et al., 2016, p. 1896).

as pre-hypertensive and children with values over the 95th percentile are classified as hypertensive (Lurbe et al., 2009).

Most of the research in paediatric BP is still done in Western countries and refers to American or European youth population (Musa & Williams, 2012). Data on BP in children from SSA setting is barely available and it is unclear whether increasing prevalence on HTN is reflected in children (Agyemang et al., 2005; Kagura, Adair, Musa, Pettifor, & Norris, 2015).

In the current epidemic of CVD, experts and specialists emphasise the need of global public health policies for improving diagnosis and treatment of paediatric HTN worldwide. There is growing evidence that not only prevalence of childhood HTN is on the increase, but concerningly also the rise of mild elevation in BP values among children, which more often stays asymptomatic and undetected and longtermly seen entails tremendous burdens. But broad screening processes are rarely done in children (Banker, Bell, Gupta-Malhotra, & Samuels, 2016; Ewald & Haldeman, 2016).

The ESH published 2009 the first international guidelines for management of paediatric HTN (modified and complemented in 2016) and concluded with a list of areas, in which urgently greater knowledge must be gained. Areas of future research like the development of accurate blood pressure monitor devices for oscillometric BP measurements, the generation of robust office, home and ambulatory reference values in paediatric population and long-term clinical research about later organ damage based on proper risk stratification in young age were mentioned. Furthermore, the need of further long-term, randomized clinical control trials was highlighted to enlarge the data-pool of cause-and-effect relation of childhood HTN with high evidence. As an essential cause of elevated HTN rates among children, lifestyle modifications were mentioned and detailed recommendation were given by the ESH, relevant for physicians, nurses but also private environment such as families and educational institutions (Lurbe et al., 2009).

The literature review of Ewald and Haldeman (2016) shows the complex context of paediatric HTN by summarizing several factors which contribute to HTN in youth, such as genetic disposition, lifestyle behaviour, dietary habits and SES. The need of early detection of HTN was emphasised preventing drastic organ damage in later. In many health screenings, assessment of BP is not included, due to lack of reference values, large variability in measurement outcomes and complex and multidimensional occurrence of childhood HTN. Only 13 to 26% of children with HTN are properly diagnosed with prevalence rates from 2 to 5%. Most of the cases are asymptomatic or symptoms are mild and not directly referred to HTN. Overweight and obesity are strongly associated with paediatric HTN, whereas obese children have significant higher prevalence (11-30%) of HTN than normal-weight children (3-14%) (Ewald & Haldeman, 2016). Obesity often was claimed as one of the major risk factors for essential HTN but the fact that prevalence also increased in normal-weight individuals, results in simple cause-effect relations not possible. Changes in family structure with a shift to unhealthy diets in children, including increased highly proceed food and increases in general salt intake among in these groups, which increases the risk to develop HTN. Other modifiable risk factors such as PA levels, second-hand smoke and poor sleep quality ca also contribute. As non-modifiable risk factors, Ewald and Haldeman (2016) identified low birth weight, family history of HTN, gender, race, genetic inheritance, excess adiposity and SES. Especially children with low SES should be additionally screened for HTN, due to general lower access to health care services and higher exposure to risk factors such as obesity. Screening interventions can be integrated in school settings to address all target groups. Furthermore, for sustainable prevention, family structures and family support must be integrated while family playing a big part in psychosocial dimension of behavioural change and role modelling. The authorship formulated a call to action by realising more research in the multifaceted character of HTN in youth.

Prospective, randomised BP studies are barely conducted and therefor specified causes of chronic HTN in children are rare (Licht & Büscher, 2018). Large studies with a focus on genetic modification as cause of HTN in children haven't been conducted yet (Licht & Büscher, 2018).

3.7.1 Tracking BP from childhood to adulthood

HTN count as major cause for ischaemic diseases, cerebrovascular accidents and renal disease, with a global prevalence rate of around 30% (Gillespie & Hurvitz, 2013). The prevalence of raised BP (SBP ≥ 140 and/or DBP ≥ 90) in adulthood in South Africa is up to 30% (WHO, 2018, #Prevalence of raised blood pressure) and rates of HTN is SSA increased 67% between 1990 and 2010 (Southern African Hypertension Society, 2019, #About us). Elevated BP often stays undiscovered over a long period of time, because it is usually asymptomatic until damage to organs or cardiovascular events occurs. It has been shown that both systolic and diastolic HTN can cause cardiovascular disorders (Klabunde, 2012).

The potential risk of adult HTN and accompanying burdens could already start in young ages by developing elevated BP or pre-hypertension in childhood. The negative long-term effects of elevated BP from a young age, were shown by several authors and research teams, and the need for regular screening and BP management could prevent adult HTN (Bao, Threefoot, Srinivasan, & Berenson, 1995; Janz et al., 2002; WHO, 2004; U. S. Department of Health and Human Services, 2005; Chen & Wang, 2008; Lurbe et al., 2009; Bucher et al., 2013; Lurbe et al., 2016; Noubiap et al., 2017). Further longitudinal cohort studies investigating BP values over time, from childhood into adulthood, are requested to provide further evidence for relationships of later cardiovascular events and childhood BP and detect early CVD risk factors (Flynn, 2019).

Koskinen *et al.* (2019) investigated the behaviour of adult carotid intima-media thickness (cIMT), which count as relevant risk factor for CVDs. Elevated BP in younger ages can be taken as strong indicator of adult's CVD profile. This was shown through a representative international sample of almost 6'000 participants by a mean follow-up period of 25 years. A strong correlation of elevated adult cIMT and long-term elevated BP values was found. cIMT can be taken as a strong marker of atherosclerosis and therefor cardiovascular events, including ischaemic heart disease and strokes. Lower risk could have been shown in participants with elevated BP in childhood and normotensive BP in adulthood, which shows again the importance of early tracking of BP and regulated health intervention (Chen & Wang, 2008; Flynn, 2019).

3.7.2 Hypertension among children in SSA

Trends in rising paediatric HTN could also have been found in the setting of SSA; such as among Nigerian (Ejike, Ugwu, Ezeanyika, & Olayemi, 2008) and South African youth (Monyeki & Kemper, 2008; Kagura et al., 2015). The need for further research in SSA has been highlighted and the claim for cost-effective interventions to prevent the rising double burden of diseases in SSA was formulated (Agyemang et al., 2005). As a major risk factor the reduction of regular PA was highlighted. The focus should be set on primary prevention at a community level, by promoting healthy lifestyles and avoiding other cardiovascular risk factors such as overweight and obesity (Noubiap et al., 2017).

3.7.3 Differences in BP values between ethnicities

Associations between BP values and ethnicity have widely been investigated among Americans whereas higher prevalence rates for black people (African American) compared to white (Caucasian ancestry) could have been found (Lackland, 2014). Black African children were at higher risk for general CVD than their non-black counterparts. Exposure to environmental and psychosocial stressors, such as low SES, family HTN history, obesity, influencing childhood BP was greater among black African children (Bucher et al., 2013; Fuller-Rowell, Curtis, Klebanov, Brooks-Gunn, & Evans, 2016).

The longitudinal study of Fuller-Rowell *et al.* (2016) has shown racial disparities in the average change of systolic and diastolic BP among African American (black) and European-/Caucasian American (white) preterm children over five years. Family history and neighbourhood SES were examined, whereas significant influences were only found in neighbourhood SES. Gupta-Malhotra *et al.* (2015) were evolving etiological factors among 423 American children (mean age of 11.7 ± 3.7 years), diagnosed with HTN and referred to a tertiary paediatric HTN clinic. Race was one of the investigated parameters to evaluate differences among the study-eligible population and significant differences were found. A higher proportion of black children had essential HTN in comparison with non-Hispanic white children (43% vs. 18%; $p = 0.01$). Results of race distribution in secondary HTN were similar.

Disparities in racial differences are not only based on genetic disposition. Research showed, that disparities are very often based on discrimination against non-white people in terms of health care accessibility and quality (James, 2017). Racial disparities in HTN prevalence and CVDs as well as mortality and morbidity should be reduced by equal access to health care services and must be integrated in health care policies. Focus for management and control programs should be set on vulnerable subgroups and public health strategies must bridge the gap (Gillespie & Hurvitz, 2013; Lackland, 2014).

3.8 Associations between CRF and BP

As in above chapters already shown, CRF and CVD markers are in strong relation to determine health status in adulthood with its roots in childhood. The analysis of associations between BP and CRF in youth is very often conducted in a clustered design, where other CVD risk factors such as body composition and blood lipid profile are included (Janz et al., 2002; Klasson-Heggebø et al., 2004; Eisenmann, Welk, Ihmels, & Dollman, 2007; Musa & Williams, 2012).

By focussing on the marker BP in association to CRF, affirmative findings can be presented. A good CRF stays in close relation to better BP profiles, which was shown among Nigerian youth (3234 participants, aged 9-15 years) (Musa & Williams, 2012). Low levels of CRF are associated with high levels of SBP, whereas positive changes in CRF levels lead to favourable cardiovascular health profile. An adequate CRF during youth contributes to positive BP profile and might delay the development of HTN in later life (Agostinis-Sobrinho et al., 2018; Lang et al., 2019). These findings are consistent with other cross-sectional studies showing significant associations between CRF and BP (Klasson-Heggebø et al., 2004). Other findings have shown, that body composition and body mass index (BMI) is strongly associated with the interaction of CRF and BP and even can be seen as mediator. Apart from the importance of promoting good levels of CRF, maintaining a healthy body weight during childhood is additionally highly important to control BP values in children (Pozuelo-Carrascosa et al., 2017; Agostinis-Sobrinho et al., 2018).

4 Purpose of the study and research questions

According to the current situation in LMICs in SSA and the importance of a good physical fitness in young age as a protective factor of CVDs in adulthood, the *KaziBantu* project could have an important role on future national health profiles in South Africa's population. Concerning the fact, that especially adult HTN causes large health hazards, it is interesting to focus on the current situation of children's BP and related CRF to evaluate current state of health for the eventual need of continuously highlighting the importance of early tracking for effective primary prevention (Daniels, Pratt, & Hayman, 2011).

On the basis of the situation of ethnic line in South Africa and the fact that in today's residential situation in Port Elizabeth ethnical segregation is still current and TA are predominantly inhabited by black African people and the NA are predominantly inhabited by coloured, both related to lower SES, it can be assumed, that TA are even more vulnerable than NA.

The purpose of this master thesis was to focus on two of the numerous health parameters (CRF and BP) assessed during the baseline testing of the *KaziBantu* study and to gain a greater insight about the overall health conditions of schoolchildren in different disadvantaged neighbourhoods in Port Elizabeth, South Africa.

Considering this theoretical framework and the background of the chosen parameters (CRF and BP), the following research questions were formulated:

- Are there indicators of **low CRF** levels among children in disadvantaged neighbourhoods in Port Elizabeth, South Africa? (R1)
- Are there indicators of elevated mean BP **among children** in disadvantaged neighbourhoods in Port Elizabeth, South Africa? (R2)
- Are there potential **negative correlations** of BP values and CRF among children in disadvantaged neighbourhoods in Port Elizabeth, South Africa? (R3)

- Are there differences in CRF and BP values among children from different **school locations** in Port Elizabeth, South Africa? (R4)
- Are there differences in CRF and BP values among children from different **ethnicities** in Port Elizabeth, South Africa? (R5)

The investigations within the frame of this master thesis might be important to enlarge the baseline data-pool of local schoolchildren's BP and CRF levels in Port Elizabeth, South Africa. Potential differences between gender, age groups, schools, locations and ethnicities might serve as indicator to prioritize and define target groups receiving sustainable health intervention and long-term implementation of health promotion programs.

5 Hypotheses

The following hypotheses were derived from the above formulated purpose of the study.

Hypothesis 1: Characteristics of CRF

H1a CRF ($\dot{V}O_2max$) differs between gender (male/female) and age

H1b Weather conditions' influence on performance of the 20-m SRT

Hypothesis 2: Associations of CRF and BP

H2a SBP and DBP correlate negatively with CRF ($\dot{V}O_2max$)

H2b: CRF has a direct influence on SBP and DBP

H2c: Height has an influence on SBP and DBP values

Hypothesis 3: Spatial and ethnical differences of CRF and BP

H3a: SBP, DBP and CRF differ between children from the NA and TA

H3b: SBP, DBP and CRF differ between the schools within areas

H3c: SBP, DBP and CRF differ between ethnicities (black African and coloured)

6 Methods

The following paragraph describes the methodological design of the *KaziBantu* project. The purpose of the *KaziBantu* project was to promote health and wellbeing in primary school settings, by empowering schoolchildren and their teachers.

The current master thesis used data of the baseline assessment of the *KaziBantu* study, which was collected during testing period one (T1), from January to March 2019. From this data, a cross-sectional survey was conducted.

6.1 *KaziBantu* study design

The *KaziBantu* study is a randomised controlled trial implemented in eight primary schools in Port Elizabeth, in the Eastern Cape Province of South Africa. The study was conducted for 32 weeks and contained a baseline assessment, an intervention period and a post assessment. Figure 4 shows the timeline of the *KaziBantu* project in 2019.

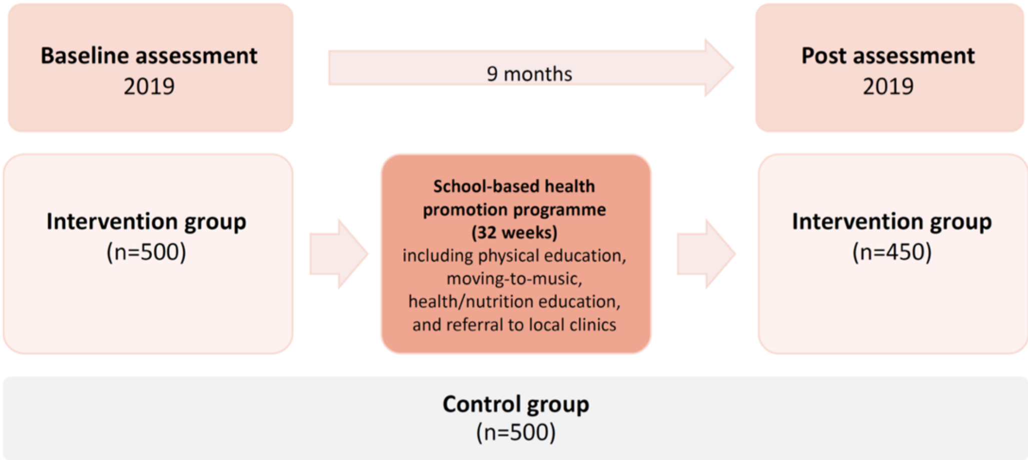


Figure 4: The study design of the *KaziBantu* study
Source: Müller et al. (2019)

The baseline assessment and the post assessment were conducted in all of the eight participating schools. The intervention was implemented in four schools only, while four schools served as control schools (see Figure 5). Three intervention conditions were randomized assigned, and included a toolkit, workshops and coaching units.

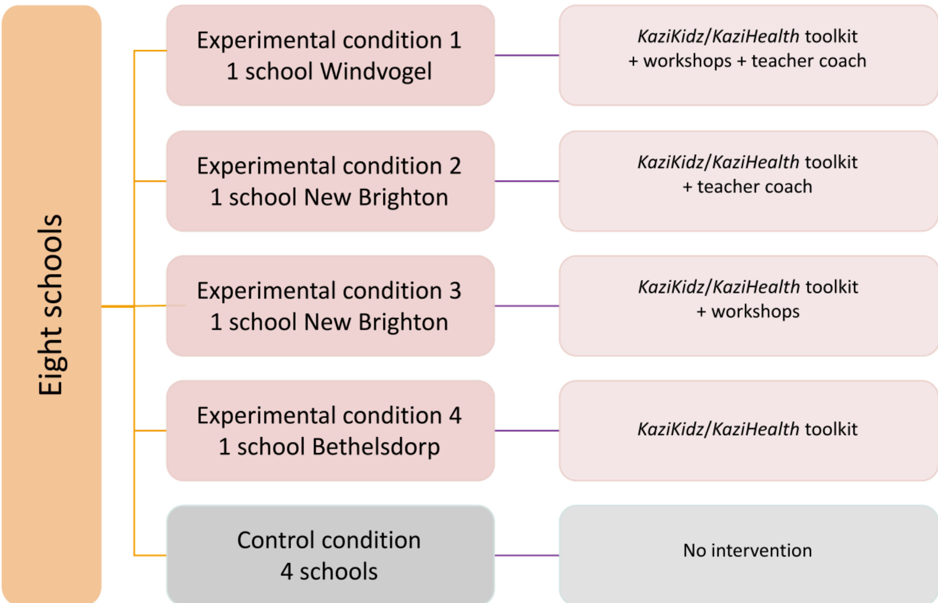


Figure 5: KaziBantu study design – experimental and control conditions
Source: Müller et al. (2019)

As stated in the study protocol, the intervention lasted nine month (from April to September 2019) and functioned as a school-based health promotion program. The intervention included a PE program, health, hygiene and nutritional education as well as "*Moving to Music*" dance lessons. Furthermore, the intervention programs were led by '*KaziCoaches'*, graduate students from the Human Movement Science and Biokinetics department at the Nelson Mandela University in Port Elizabeth.

All the content of the intervention was integrated in the *KaziKidz* toolkit, teaching material which was developed and designed by a group of master's students from the University of Basel in Switzerland. Furthermore, the *KaziKidz* toolkit was provided to all schools after the intervention period was completed (Müller et al., 2019). The toolkit was aligned with the Curriculum Assessment Policy Statements (CAPS) of the Department of Education in South Africa and the content can be readily integrated into the teaching and learning on a daily basis.

For further information on the study design and intervention program, consider the *KaziBantu* study protocol (Müller et al., 2019).

6.2 Ethical clearance

All procedures and methods of the *KaziBantu* project are consistent with the Declaration of Helsinki. Local ethics committees of Switzerland and South Africa (Ethical committee of Northwestern and Central Switzerland (EKNZ), Nelson Mandela University Human Ethics Committee (NMU REC-H), Eastern Cape Department of Health (ECDoH), Eastern Cape Department of Education (ECDoE) has approved the study.

The participation was on voluntary agreement and at any time participants could withdraw from the study without any further consequences. The participants were comprehensively informed about the process, the objectives and the potential risks of the study in advance. The participants were only assessed if the schoolchildren and their parent/guardian have given written informed consent.

Collected data of the study participants was treated confidentially throughout all duration of the study. The data will be stored for 10 years at the Department of Human Movement Science at the Nelson Mandela University, Port Elizabeth, South Africa, and will be deleted irreversibly after this period.

All the detailed information about the study can be found in the study protocol (Müller et al., 2019).

6.3 Study procedure

Data was collected during school times at each of the respective school settings. The assessment was carried out through an interdisciplinary, Swiss and South African research team consisting of researchers, project employees, medical nurses and university students.

The assessment protocol included standardized testing methods:

- Anthropometric measurements (body weight, height, hip-to-waist-ratio, body compositions)

- Questionnaires (social and demographic background, SES questionnaire, KIDSCREEN-10, Health Behaviour in School-aged Children HBSC survey, Physical Activity Questionnaire for Children (PAQ-C))
- Clinical examination (physical examination, self-reported health status, BP, capillary blood sampling)
- Physical fitness tests (20-m SRT, a handgrip resistance test)
- Actigraphy (accelerometers worn over seven consecutive days to evaluate children's activity pattern)

Data from anthropometric measurements, clinical examination, physical fitness level and accelerometery were taken as CVD markers and are seen as important indicators of the general health profile.

6.4 Study area

The schools who participated in the study were located in disadvantaged neighbourhoods in Port Elizabeth, South Africa, which are described as marginalized areas. Low SES, high unemployment rate, lack of education, employment and leisure opportunities, high crime rate and unfavourable schooling conditions such as big class sizes, neglection of PE and other non-academic subjects as well as insufficient sports facilities and generally poorly resourced, characterize these marginalized areas (Müller et al., 2019). Furthermore, as a result of poverty, people have a lack of accessibility to proper health care and adequate nutrition and hence a vast percentage of children within these areas are suffering under the double burden diseases (Walter, 2014). This results in their physical development and academic performance being negatively affected (Müller et al., 2016).

The disadvantaged neighbourhoods in Port Elizabeth, South Africa, are called TA and NA. TA or the *locations* are characterized by being populated by either predominantly black African people (largely Xhosa speaking) and therefor also called *the black suburbs*. NA are predominantly inhabited by coloured people, also referred to as mixed race (Afrikaans speaking) and are called coloured areas. The clustering of ethnicity is the result of resettlement actions under the apartheid laws. Desegregation since that time has not really taken place (Christopher, 1987).

These areas are embedded in an urban region and are therefore in terms of population density clearly declared as urban areas (Statistics South Africa, 2003).

The study area, showing the eight schools, as well as which schools were assigned to intervention and control condition, are marked on the following Figure 6. Control schools will be abbreviated as TC (township control school; TC1 and TC2) and NC (northern area control school; NC1 and NC2), intervention schools as TI (township intervention school; TI1 and TI2) and NI (northern area intervention school; NI1 and NI2). These abbreviations are used to avoid linking back to the participants, and therefor to ensure anonymity.

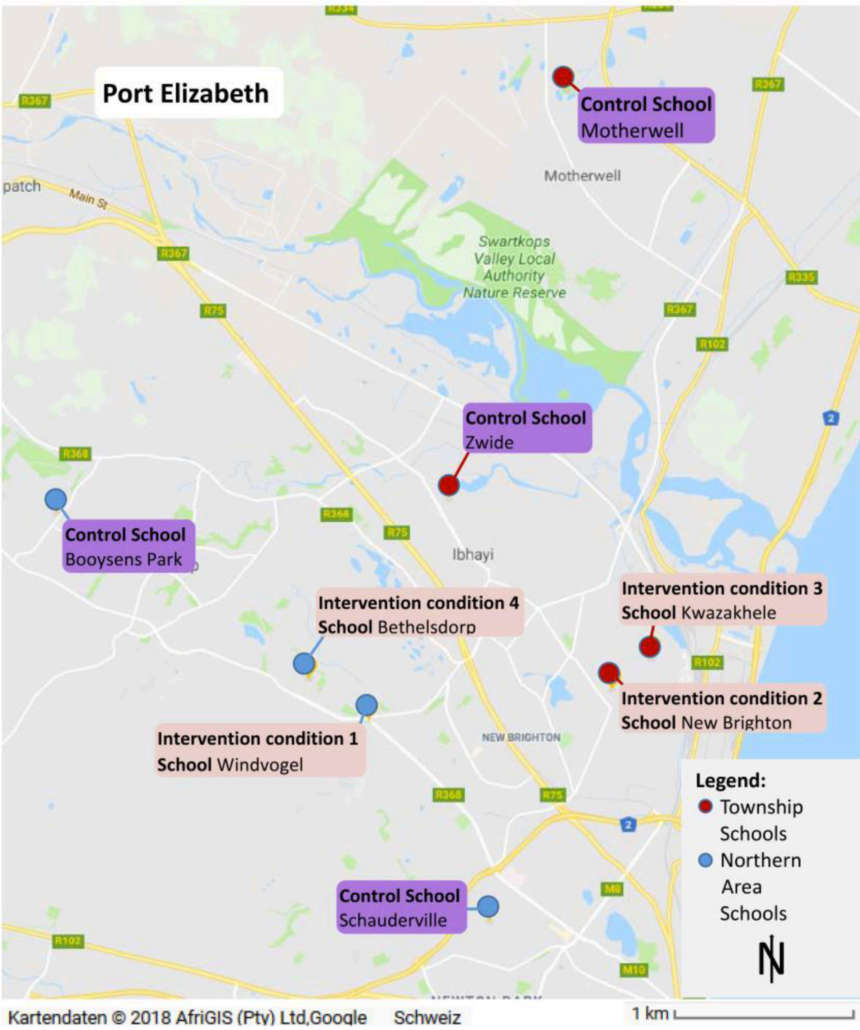


Figure 6: The study area, Port Elizabeth, South Africa

Source: Müller et al. (2019)

6.5 Participants

A representative sample of 1,080 grade four to six schoolchildren were recruited for the *KaziBantu* study. Data of 984 children (466 girls and 478 boys, 40 no information for gender) was collected during the baseline testing phase from January to March 2019.

In the further analysis of this study, 870 children (427 girls; 49.1% and 443 boys; 50.9%) were finally included (see flow chart of including criteria in Figure 7). Of these 870 children 62.4% were of black African ethnicity (n = 543), 23.4% of coloured ethnicity (n = 204) and 10.8% of other ethnicity groups (mixed 8.5% (n = 74), white 1.6% (n = 14), Indian 0.1% (n = 1), other

0.6% (n = 5)). The geographic location wherein the project schools were located, largely influenced the ethnic composition of the study sample, and were responsible for the two main ethnic group being black African and coloured. Furthermore, 65.9% of the study sample spoke Xhosa (n = 573), 21.5% Afrikaans (n = 187), 9.2% English (n = 80) and 0.7% (n = 6) spoke other languages at home. The average age of the study sample was 10.9 years (SD ± 1.07).

6.6 Data assessment

The variables selected to answer the research aim are *cardiorespiratory fitness* (CRF), from which maximal oxygen uptake ($\dot{V}O_2$max in ml/min/kg) was estimated, and *blood pressure* (BP, in mmHg). Additionally, demographic background information was collected with the "survey on schoolchildren's social and demographic background, physical fitness and psychosocial health in Port Elizabeth, South Africa" and the "clinical assessment questionnaire".

6.6.1 Assessment of CRF

To evaluate the physical fitness level of the participants the "Maximal Multistage 20 Meter Shuttle Run Test" (20-m SRT) by Léger and Lambert (1984) was chosen, as a valid instrument to estimate maximal aerobic power of children ($\dot{V}O_2$max) (Castro-Piñero et al., 2009; Mayorga-Vega et al., 2015; Tomkinson et al., 2019). The 20-m SRT protocol, applied in the baseline testing of the *KaziBantu* T1 is provided in Appendix 5. The 20-m SRT is a progressive maximal endurance test to estimate the maximal aerobic capacity by multiplying reached speed (X) and the rounded lower age (A) with defined constants with following formula: $Y = 31.025 + 3.238 * X - 3.248 * A + 0.1536 * A * X$ (Léger et al., 1988). The sound signal of the multistage fitness test starts at a speed of 8.5 km/h, whereas the frequency of the audio signal is continuously increasing by 0.5 km/h every minute. Children were asked to run back and forth on a flat course and touch the 20 m line after each run. A test instructor was running with the children to ensure the required pace is maintained and motivation to continue running stays high. Children were running in groups of ten to 15 and test supervisors recorded the cumulative laps each child on the fitness score sheet (see Appendix 3).

Before completing the maximal exercise test, all children were assessed by a registered nursing team. Only the children with no health risks were permitted to participate in the 20-SRT. Data from the clinical examination were recorded on each participant's information sheet for monitoring (see Appendix 3).

The cumulative shuttles as individual test performance were transformed into speed values by using the table of test protocol summery (Léger et al., 1988) (Table 1).

Table 1: 20-m SRT Test protocol summery
Source: Léger et al. (1988)

Levels	Shuttles	Cumulative Shuttles	Speed (km/h)	Shuttle Time (s)	Total level time (s)	Dis-tance (m)	Cumulative Distance (m)	Cumulative Time (mm:ss)
1	7	7	8.5	9.00	63.00	140	140	01:03
2	8	15	9.0	8.00	64.00	160	300	02:07
3	8	23	9.5	7.58	60.63	160	460	03:08
4	9	32	10.0	7.20	64.80	180	640	04:12
5	9	41	10.5	6.86	61.71	180	820	05:14
6	10	51	11.0	6.55	65.50	200	1020	06:20
7	10	61	11.5	6.26	62.61	200	1220	07:22
8	11	72	12.0	6.00	66.00	220	1440	08:28
9	11	83	12.5	5.76	63.36	220	1660	09:31
10	11	94	13.0	5.54	60.92	220	1880	10:32
11	12	106	13.5	5.33	64.00	240	2120	11:36
12	12	118	14.0	5.14	61.71	240	2360	12:38
13	13	131	14.5	4.97	64.55	260	2620	13:43
14	13	144	15.0	4.80	62.40	260	2880	14:45
15	13	157	15.5	4.65	60.39	260	3140	15:46

CRF ($\dot{V}O_2max$) is calculated by using Léger et al. (1988) formula:

$$Y = 31.025 + 3.238 * X - 3.248 * A + 0.1536 * A * X$$

Y = $\dot{V}O_2max$ Value [ml O_2/min/kg]
X = reached speed [km/h]
A = rounded lower age [years]

CRF levels, based on the subject's $\dot{V}O_2max$ values, were categorized in three different stages (Salvini et al., 2018):

1. low CRF (children in the lowest quartile)
2. moderate CRF (second and third quartiles)
3. high CRF (fourth quartile)

6.6.2 Assessment of BP

BP was measured as one out of nine testing stations integrated in the test battery to evaluate CVD markers. Resting BP was measured to generate valid data. Participants were instructed to be seated and relax for five minutes. BP was then measured three times, with a one-minute interval between each measure. For the assessment the Omron M6® digital BP monitor was used (Omron® AC model; Hoofddorp, The Netherlands), and the suitable cuff-size (Omron®

CS2 Small Cuff; Hoofddorp, The Netherlands) was used on the children's left arm. Average values from the second and third measurement were used because the first measurement often results in higher values. BP values have been reported on the clinical examination sheet (see Appendix 3).

For the grouping of BP values within the study population, European classification of defining reference values (ESH) have been used, due to no reference values of BP in children in SSA (Agyemang et al., 2005). The 90^{th} and 95^{th} percentile served as cut-off points and classified the subjects in normotensive ($<90^{th}$ percentile), pre-hypertensive ($\geq 90^{th}$ to $<95^{th}$ percentile) and hypertensive ($\geq 95^{th}$ percentile). Internationally recommended and established office application protocol of diagnostic evaluation of elevated BP has been partially met: For proper detection of elevated BP values, oscillometric measurements should be confirmed with auscultatory methods, due to the fact that in oscillometric methods results are considerably higher (Lurbe et al., 2016).

6.6.3 Assessment of demographic background information

Demographic information, such as age and ethnicity, and information about the SES was collected from the "Survey on schoolchildren's social and demographic background, physical fitness and psychosocial health in Port Elizabeth, South Africa". The questionnaire was designed by the *KaziBantu* study project team and involved researchers from the Human Movement Science (HMS) department in Port Elizabeth, South Africa and the department of sports, movement and health (DSBG) in Basel, Switzerland. Information about gender was collected from the clinical examination survey (clinical examination – individual sheet for monitoring, Appendix 3), which was conducted by the fieldwork team during the field testing. The study protocol of the 20-m SRT (participant evaluation – fitness score sheet) provided details about testing day environmental conditions (weather: hot, overcast, drizzling, extremely windy, cold) (see Appendix 3).

6.7 Statistical analysis

Statistical analysis was conducted with the SPSS statistic program for Mac (IBM SPSS Statistics, version 26). Values of the descriptive statistics are shown as means (*M*) and standard deviation (SD) unless otherwise indicated. Data is visualized in tables and graphs.

In this analysis, the variables CRF ($\dot{V}O_2max$) and BP (SBP and DBP) were investigated, in relation to other variables such as gender, age, schools and ethnicity. For all analyses an alpha level of $p < .05$ is defined to indicate statistical significance.

The two main variables both show continuous characters. Assumption of normal distribution of the data was made through visual control (consider histograms in Appendix 9).

Additional to the raw data pool and available variables, several further variables were created, which were needed for the analyses (maximum speed during 20-m SRT (km/h), $\dot{V}O_2max$, mean SBP and DBP, School Location (NA and TA)).

Analysis of CRF

Test performance of the 20-m SRT (cumulative laps) was converted in $\dot{V}O_2$max values according to the formula of Léger *et al.* (1988). According to the lowest, second, third and fourth quartile of $\dot{V}O_2$max values, cut-off points for CRF were calculated. Frequency tables and cross-tables according to gender and age were conducted to analyse the data. Diagrams show distribution of CRF levels for different schools.

Analysis of BP

Average values of the second and the third measurements were used in the statistical analyses, first measurement was excluded due to considerably higher values. Values for SBP and DBP are shown in millimetre of mercury (mmHg). Frequency tables and cross-tables according to gender, age and height were constructed to analyse the data.

BP values were compared within the subjects by calculating cut-off values for determining the status of normotension, pre-hypertension or HTN.

The relative cut-off values of the present study sample have been defined as the follow:

1. Normotensive: >126/79 mmHg
2. Pre-hypertensive: ≥ 126/79 < 132/85 mmHg
3. Hypertensive: ≥ 132/85 mmHg

Diagrams show distribution of BP categories for different schools.

Analysis of demographic background information

Demographic background information was analysed in frequency tables and cross-tables.

Hypothesis 1: Characteristics of CRF

To evaluate differences of CRF among the study population in age- and gender-groups (cross-sectional), a univariate analysis of variance (ANOVA) was conducted. It was decided to adjust the test results of the 20-m SRT with weather condition to evaluate if weather condition had an influence on test performance. Additional variable (weather condition) was integrated as co-variate by using an analysis of covariate (ANCOVA). Partial eta-squared (η^2) values were reported to evaluate effect size of the model. According to Cohen (1988), a partial eta-squared of .01 refers to a small effect, .06 a medium effect and .14 a large effect. Games-Howell post-hoc analysis was used to determine differences within the age groups, and 95% CI were calculated. Variance homogeneity of CRF data was not assumed. To analyse inter-subject differences on CRF in different weather conditions, an ANCOVA was conducted with weather condition as covariate.

Hypothesis 2: Associations of CRF and BP

To evaluate relations between CRF and BP (cross-sectional), a bivariate correlation was performed. Correlation coefficients of Bravais-Pearson were used to evaluate effect size (Bravais' *r*: small effect $r = .1$; medium effect $r = .3$; large effect $r = .5$) (Cohen, 1988; 1992).

A regression model was additionally conducted for formulation prediction on the behaviour of SBP and DBP with CRF as predictor. R^2 was used to assess effect sizes ($R^2 = .02$ = weak effect; $R^2 = .13$ = moderate effect; $R^2 = .26$ = strong effect; according to Cohen, 1988). Additional univariate analyses were performed (ANCOVA) to evaluate tendencies among groups of BP and CRF. BP categories (normotensive, pre-hypertensive, hypertensive) were analysed with regards to CRF values and reverse CRF levels (low CRF, moderate CRF, high CRF) were analysed based on BP values. Partial eta-squared (η^2) values were reported to evaluate effect size of the variables. Gender was included as a covariate for adjustment. It was additionally decided to include height in the analysis of BP values. The effect of height on BP was evaluated through a bivariate correlation. Correlation coefficients of Bravais-Pearson ® were used to evaluate the effect size. A linear regression model was performed to formulate prediction on trends in BP by increasing height and R^2 was used to assess effect size.

Hypothesis 3: Spatial and ethnical differences of CRF and BP

To investigate differences of CRF and BP values, in dependence of school location independent, simple t-test was performed for all three variables (CRF, SBP, DBP). Correlation coefficients of Bravais-Pears®(*r*) were used to evaluate the effect size. To analyse differences in mean values of the three variables (CRF, SBP, DBP) according to schools and ethnic background, one-way ANOVAs were conducted for each variable independently. Differences within groups were evaluated with results from post-hoc tests. Variances are homogenous for $\dot{V}O_2$max and SBP (Levene-Test: $p > .05$) but not for DBP (Levene-Test: $p < .001$). Bonferroni post-hoc analysis was used for variables with homogeneous variances and for variables with no variance homogeneity Games-Howell post-hoc analysis was used. 95% CI were calculated.

6.8 Data Clearing

The total sample size counts 985 fourth- to sixth-grade children aged eight to 15 years. 17 children were excluded due to missing written consent, duplicate data entry or having left school while baseline testing phase. For the purpose of this paper, additional 98 subjects were excluded due to age restriction, missing information about date of birth, not having completed the clinical testing and/or the 20-m SRT. The excluding criteria are shown in the flow chart below (Figure 7).

To summarise, 870 children of which 49.1% (*n* = 427) were female and 50.9% (*n* = 443) were male, are included in the quantitative analysis of this study.

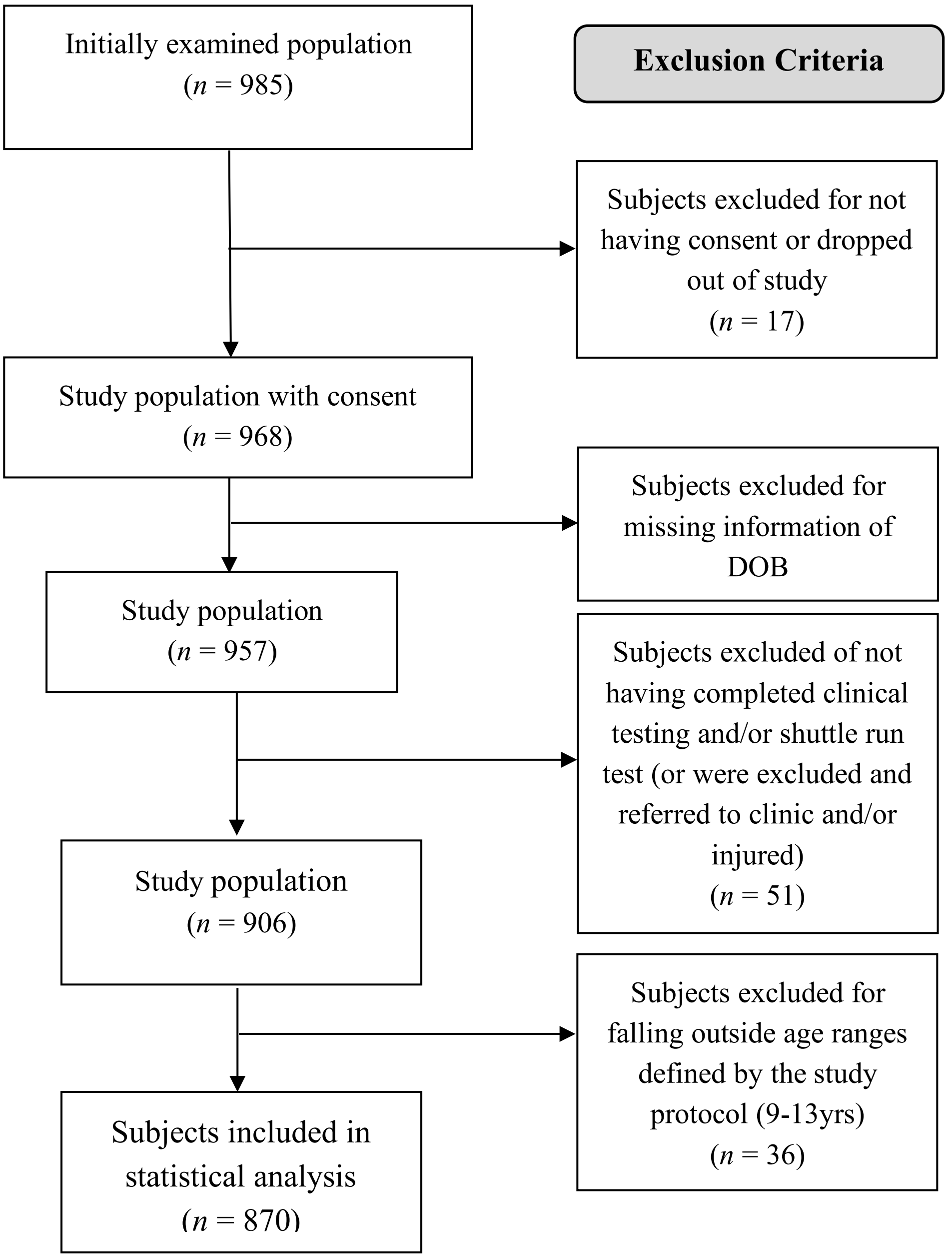


Figure 7: Process of data clearing (Flow Chart)

7 Results

The following chapter presents the results, which were obtained through the statistical analyses based on the selected study population.

7.1 Descriptive Statistics

Table 2 shows different characteristics of the study population (mean ± SD), whereas parameters are shown for girls, boys and the total population.

Table 2: Characteristics of the study population (mean ± SD)

	Girls (*n* = 427) M ± SD	**Boys (*n* = 443)** M ± SD	**Total (*n* = 870)** M ± SD
Age [years]	10.81 (.99)	11.07 (1.13)	10.9 (1)
$\dot{V}O_2max$ [mlO_2/min/kg]	41.58 (3.54)	44.38 (4.64)	43 (4.37)
Cumulative Laps 20-m SRT [number]	24 (12)	36 (18)	30 (16)
SBP [mmHg]	109.34 (13.93)	108.63 (13.02)	108.97 (13.47)
DBP [mmHg]	67.77 (10.95)	66.47 (10.87)	67.1 (10.92)
Height [cm]	140.63 (8.71)	139.52 (8.5)	140 (8.6)

Annotation: SRT = Shuttle Run Test; SBP = systolic blood pressure; DBP = diastolic blood pressure

Additional descriptive information about CRF, BP, associations of CRF and BP and demographic background is given in the following paragraphs.

7.1.1 Cardiorespiratory fitness

Cut-off values of CRF categories were defined as the follow:

Low CRF — Scores of children in the 1st quartile; 32.90 to 39.79 mlO_2/min/kg

Moderate CRF — Scores of children in the 2nd and 3th quartiles; 39.80 to 45.85 mlO_2/min/kg

High CRF — Scores of children in the 4th quartile; 45.86 to 58.15 mlO_2/min/kg

In Figure 8 and Figure 9, distributions of CRF levels in girls and boys are illustrated.

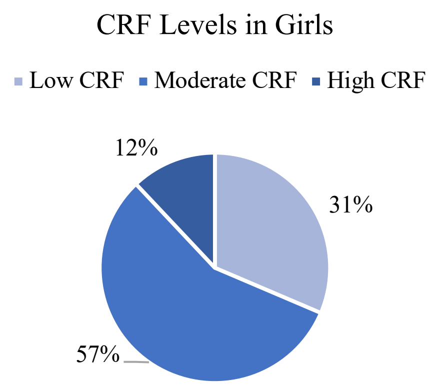


Figure 8: CRF levels in girls

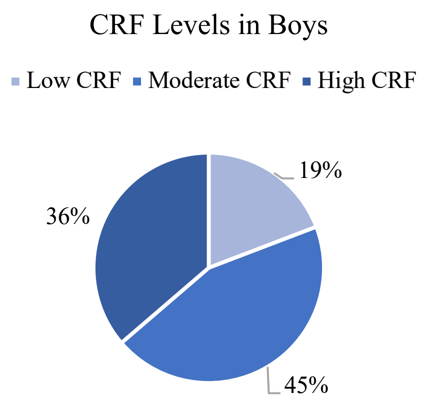


Figure 9: CRF levels in boys

Distribution of CRF levels across schools is visualised in Figure 10 below, which was created based on data from the table in Appendix 8.

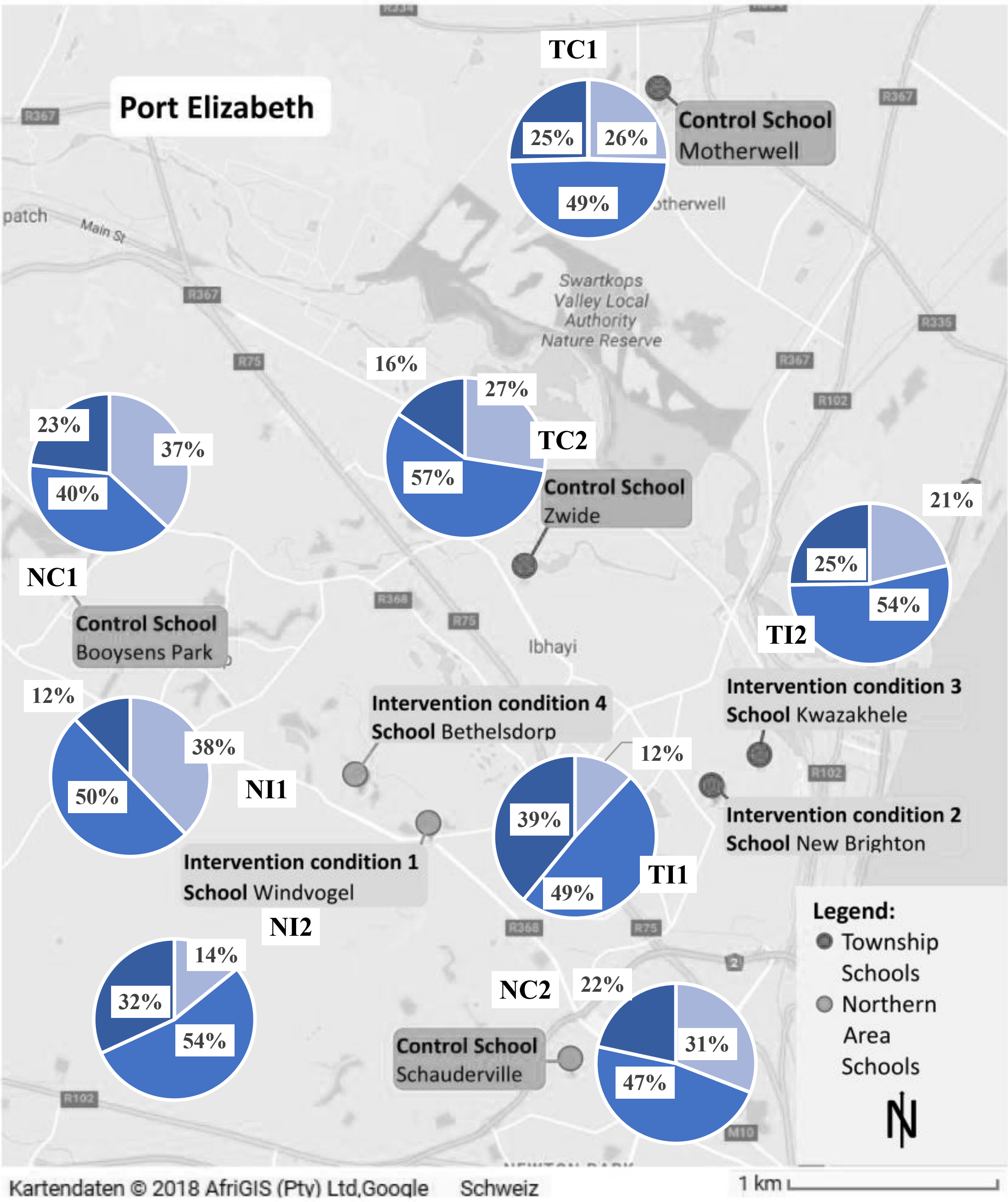


Figure 10: Cardiorespiratory fitness levels across schools

7.1.2 Blood pressure values

Mean BP values by gender are 109.3/67.8 mmHg (± 13.9/±10.9) measured in girls and 109/66 mmHg (±13.0/±10.8) measured in boys. Extreme high values for DBP, for girls (max = 138.5 mmHg) and boys (max = 124 mmHg), were measured, indicating pathology (Lurbe et al., 2016). Median values differed from mean values and median values were measured lower than mean values. Table 3 shows descriptive statistics for SBP and DBP. Tables illustrating BP values adjusted for age and gender groups are added in Appendix 2.

Table 3: Descriptive Statistics for SBP and DBP

	n	M	Median	SD	Min	Max.	Percentiles	
							90	95
SBP	870	108.98	107.5	13.46	67.50	163.50	125.95	132.50
DBP	870	67.10	65.50	10.92	45.00	138.50	79.00	85.23

Annotation: SBP = systolic blood pressure; DBP = diastolic blood pressure

Blood pressure data distribution showed large scattering with many outliers, according to the box plots in Figure 11. Furthermore, the standard deviation (SD) was very high (SBP = 13.46; DBP = 10.92). Extreme values for systolic BP were measured at =< 73 mmHg (2 cases) and >=144 mmHg (17 cases), whereas for diastolic BP values above >= 89 mmHg count as extreme values (34 cases). These values are still integrated in the analysis to not distort results.

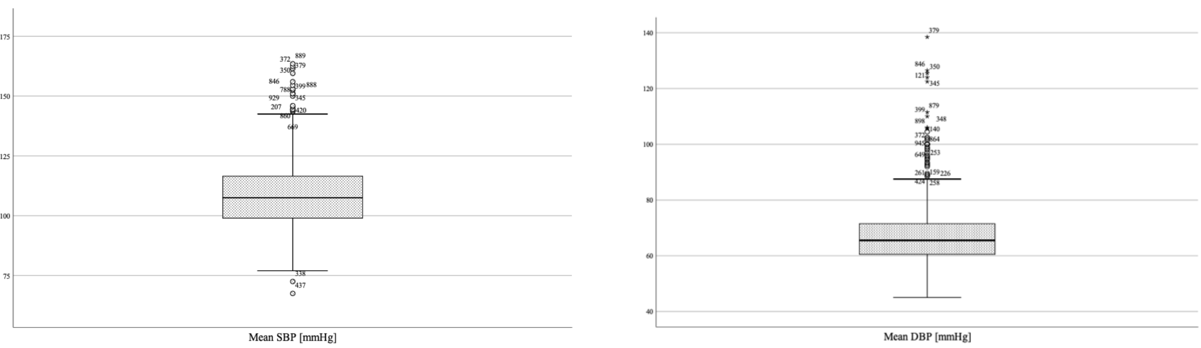


Figure 11: Scattering of blood pressure data (SBP and DBP)

BP values over age are relatively consistent in both gender, which is visible on Figure 12 below.

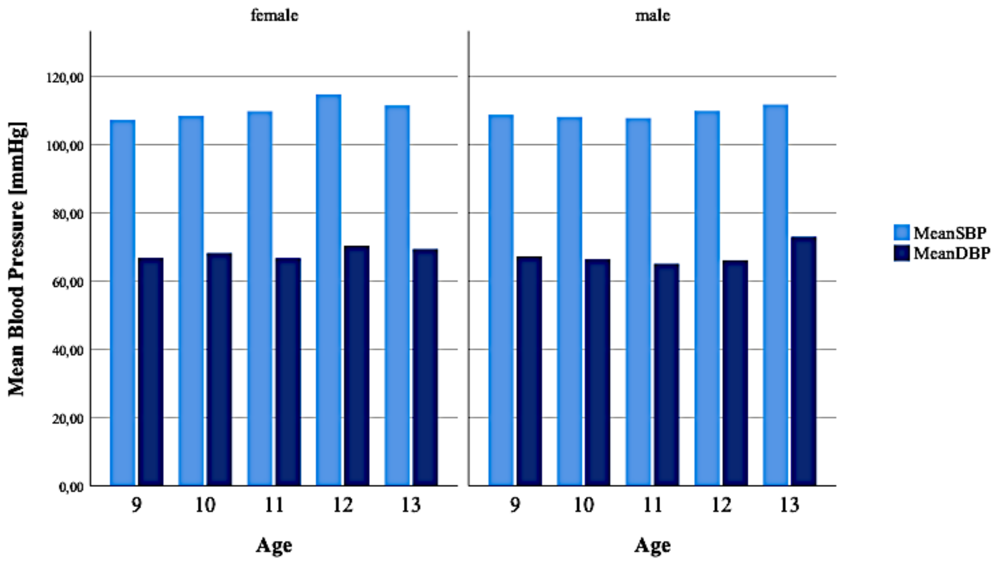


Figure 12: Mean systolic and diastolic blood pressure [mmHg] according to age and gender

According to the guidelines of ESH, BP values were categorized relative to the study population, whereas the 90th and 95th percentile count as cut-off points (see Table 4). In the case of data for this study, following values were defined (values of both sexes are included, age and height are not considered):

- 90th percentile 126/79 mmHg
- 95th percentile 132/85 mmHg

Children count as

- Normotensive when values are >126/79 mmHg (<90th percentile)
- Pre-hypertensive are those children with values ≥ 126/79 < 132/85 mmHg (≥90th to <95th percentile)
- Hypertensive are children with BP values ≥ 132/85 mmHg (hypertensive: ≥95th percentile)

The majority of the study population (84.7%) has normal BP values (>126/79 mmHg). 16.4% of girls and 13.9% of boys are equal or above 126/79 mmHg and count as pre-hypertensive or hypertensive. Distribution of BP categories among the study population is shown in Table 4.

Table 4: Blood Pressure Categories

	Girls (n = 427)		Boys (n = 443)		Total	
Blood Pressure Categories	**N**	**%**	**N**	**%**	**N**	**%**
Normotensive >126/79 mmHg	356	83.4	381	86.0	737	84.7
Pre-hypertensive ≥ 126/79 < 132/85 mmHg	29	6.8	29	6.5	58	6.7
Hypertensive ≥ 132/85 mmHg	42	9.8	33	7.4	75	8.6

Distribution of BP categories across schools is pictured in Figure 13, which was created based on data from the table in Appendix 8.

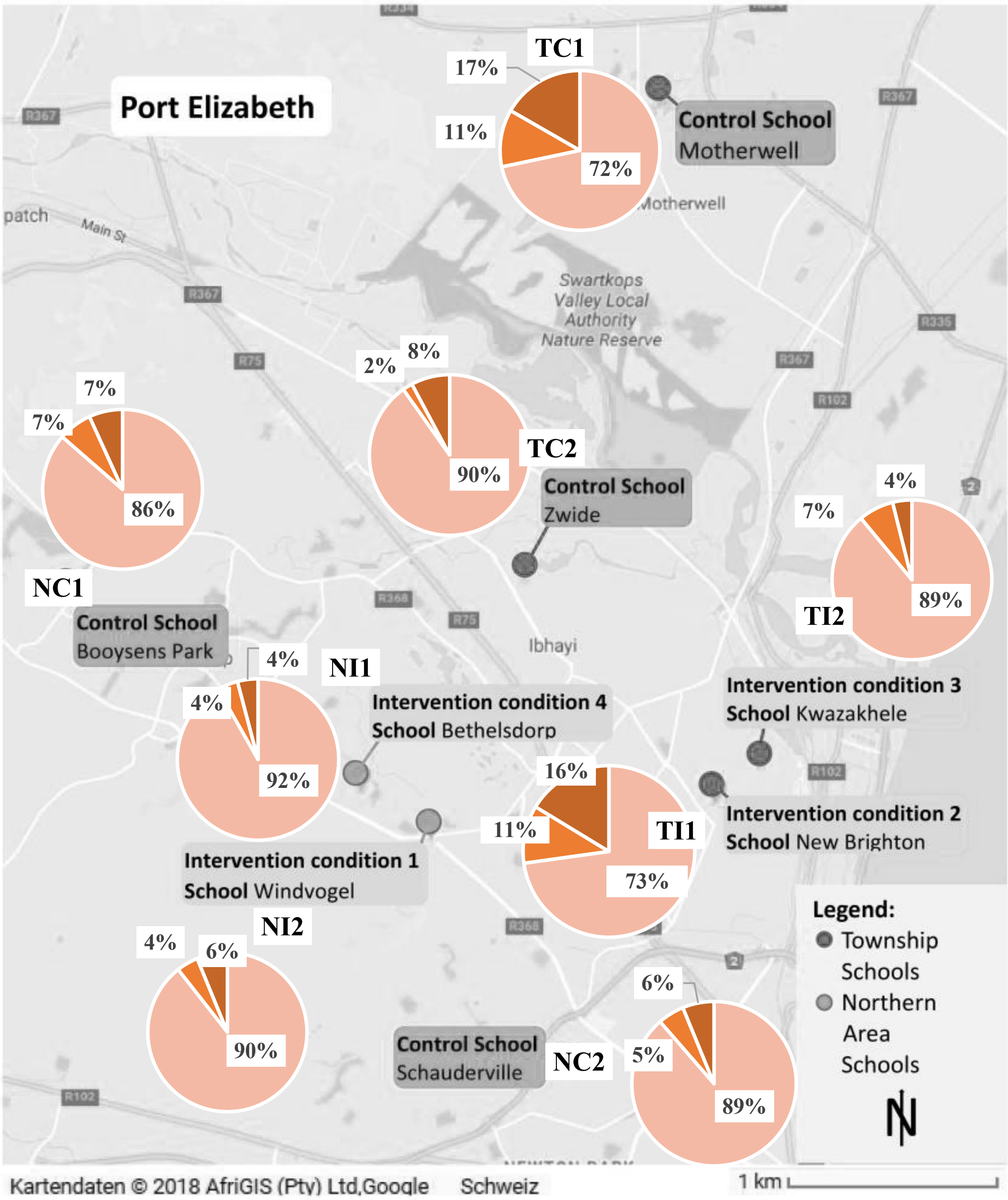


Figure 13: Blood pressure categories across to schools

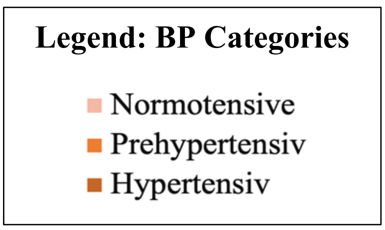


Table 5 below shows relations of parameter, influencing BP values. Pearson correlation coefficient were calculated to examine these relations in accordance with all possible inter-correlations.

Table 5: Inter-correlation matrix BP

		SBP	DBP	Gender	Height	Age
SBP	Pearson Correlation	1	,634**	-,026	,182**	,087*
	N	870	870	870	834	870
DBP	Pearson Correlation	,634**	1	-,060	,085*	,033
	N	870	870	870	834	870
Gender	Pearson Correlation	-,026	-,060	1	-,064	,139**
	N	870	870	870	834	870
Height	Pearson Correlation	,182**	,085*	-,064	1	,576**
	N	834	834	834	834	834
Age	Pearson Correlation	,087*	,033	,139**	,576**	1
	N	870	870	870	834	870

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Annotation: SBP = systolic blood pressure; DBP = diastolic blood pressure

7.1.3 Associations between CRF and BP

Table 6 and Table 7 on the following page show *M* and *SD* values of CRF ($\dot{V}O_2max$) within different BP categories and *M* and *SD* of BP values within CRF levels (*low CRF, moderate CRF, high CRF*). Groups were defined by cut-off values determined through inter subject reference values within this study population (see Chapter 6.6.1 and 6.6.2).

In girls, low CRF levels were associated with highest BP *M* values, whereas girls with high CRF showed lowest BP *M* values, and girls with moderate CRF levels showed medium BP *M* values. In boys, highest BP *M* values were also associated with low CRF levels, but in comparison to girls, boys with moderate CRF showed lowest BP *M* values, and boys with high CRF showed medium BP *M* values. Detailed values of mean BP values according to CRF levels are shown in Table 6.

Table 6: Cardiorespiratory fitness levels and related blood pressure values

CRF Levels	BP Values	Girls		Boys	
		M	*SD*	*M*	*SD*
low CRF	SBP	113	14.14	111	12.42
	DBP	69	12.14	69	10.09
moderate CRF	SBP	108	13.51	107	13.67
	DBP	67	9.58	66	11.27
high CRF	SBP	106	13.85	109	12.35
	DBP	66	13.1	66	10.71

Annotation: CRF = Cardiorespiratory Fitness; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure

CRF values differ between BP status, whereas CRF values decrease in girls and boys being categorized as normotensive to hypertensive. Detailed values of mean CRF values according to BP categories are shown in Table 7.

Table 7: BP Categories and related CRF values ($\dot{V}O_2max$)

	BP Status	CRF	Girls		Boys	
			M	*SD*	*M*	*SD*
SBP Category	normotensive	$\dot{V}O_2max$	41.71	3.58	44.43	4.53
	pre-hypertensive	$\dot{V}O_2max$	41.18	3.16	44.04	6.03
	hypertensive	$\dot{V}O_2max$	40.17	2.96	43.77	5.34
DBP Category	normotensive	$\dot{V}O_2max$	41.71	3.54	44.46	4.62
	pre-hypertensive	$\dot{V}O_2max$	40.4	2.94	43.92	5.16
	hypertensive	$\dot{V}O_2max$	40.5	3.87	43.45	4.62

Annotation: SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure

7.1.4 Demographic background information

Participation rates were 64.6% children of black African ethnicity (*n* = 543), 24.3% coloured children (*n* = 204) and 11.2% other (*n* = 94; mixed, white, Indian, other). Ethnicity is not homogenous in the NA, whereas black African children were predominantly found in TA schools.

All eight schools count between 92 and 138 learners, (TI1 = 92, TI2 = 127, TC1 = 138, TC2 = 102, NI1 = 98, NI2 = 113, NC1 = 103, NC2 = 97), gender was equally distributed in all eight schools, with slightly higher proportions for boys (overall 49.1% girls, 50.9% boys).

7.2 Hypotheses results

In the following section, results will be presented regards the hypotheses and assumptions will be tested on the data from the study population.

7.2.1 Hypothesis 1: Characteristics of CRF

H1a: CRF ($\dot{V}O_2max$) differs between gender (male/female) and age

CRF ($\dot{V}O_2max$) differed significantly between genders ($p < .01$; $F(1, 860) = 61.9$; $\eta^2 = .067$), ages ($p < .01$; $F(4, 860) = 13.3$; $\eta^2 = .058$) and the interaction between gender and age (*gender x age*) ($p = .028$; $F(4, 860) = 2.74$; $\eta^2 = .013$). Furthermore, all presented with weak effects sizes ($\eta^2 = .067$, $\eta^2 = .058$, $\eta^2 = .013$) (Cohen, 1992). By investigating group statistics, boys shown significantly higher mean values for relative $\dot{V}O_2max$ ($mlO_2/min/kg$) than girls (boys: M = 44.38, SD = 4.6 n = 443; girls: M = 41.58, SD = 3.5, n = 427). Significant higher mean values for boys are consistent over all age categories ($t(868) = -9.995$, $p < .01$). Lines of CRF over age groups are shown in Figure 14.

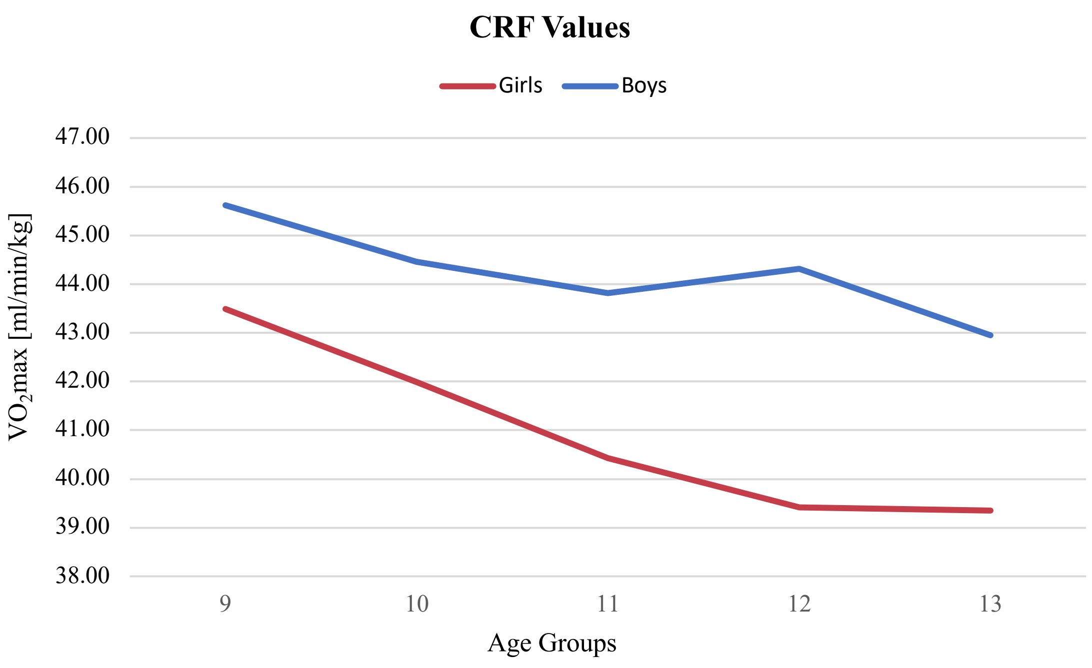


Figure 14: Mean Values of cardiorespiratory fitness within age groups and gender

Boys and girls at the age of nine had significantly higher $\dot{V}O_2max$ values than their older counterparts. Games-Howell post-hoc analysis showed significant differences for $\dot{V}O_2max$ levels in girls between nine and ten year old (1.5, 95%-CI[0.39, 2.6), between nine and 11 year old (3.1, 95%-CI[1.9, 4.2], between nine and 12 year old (4.1, 95%-CI[2.3, 5.8]), between 10 and 11 year old (1.5, 95%-CI[0.5, 2.6) and between ten and 12 year old (2.6, 95%-CI[0.8, 4.2]). In boys, only differences of $\dot{V}O_2$max values between nine and 11 year old are statistically significant (1.8, 95%-CI[0.2, 3.4]) (see Appendix 10.1 for detailed information of CRF among gender and age groups).

15.7% (adjusted $R^2 = .157$) of the dispersion of $\dot{V}O_2$max among the total mean value can be explained through age, gender and the interaction between age and gender (age x gender). $\dot{V}O_2$max levels of girls follow the linear relation of decreasing $\dot{V}O_2$max, as age increases, but $\dot{V}O_2$max levels of boys did not show this relationship. The group of 12-year old boys constitute an exception. Mean $\dot{V}O_2$max values of 12-year old boys are higher than values of the 11 and 13 years old but still lower than their nine and ten-year old counterparts. However, these differences were not statistically significant ($p = .788$).

H1b: Weather conditions' influence on performance of the 20-m SRT

Results of the univariate model for CRF by gender and age doesn't change meaningfully by including weather condition as a covariate ($F(10, 859) = 18.5$; $p < .001$; $\eta^2 = 0.177$, $n = 870$). Partial eta-squared of the corrected model was only slightly adapted (from .165 to .177) what count as strong effect (Cohen, 1988). The interaction of gender and age has slightly lowered (from $\eta^2 = .013$ to $\eta^2 = .012$) with present weak effects (Cohen, 1988). Weather had a significant influence on $\dot{V}O_2$max ($F(1, 859) = 12.4$; $p < .001$; $\eta^2 = .014$).

Multiple comparison between $\dot{V}O_2$max and weather condition showed significant differences between mean values in "hot" and "extremely windy" conditions ($p < .05$ 1.99, 95%-CI[0.4, 3.6]). Children had higher CRF in "hot" conditions (43.4 ml/min/kg) than in "extremely windy" conditions (41.5 ml/min/kg). Results of the univariate analysis of covariate (ANCOVA) are shown in Appendix 10.2.

7.2.2 Hypothesis 2: Associations of CRF and BP

H2a: SBP and DBP correlate negatively with CRF ($\dot{V}O_2$max)

The bivariate correlation of the study data shows that CRF ($\dot{V}O_2$max) is significantly negative correlated ($p = .005$) with BP; both SBP ($r = -.095$; $p = .005$; $n = 870$) and DBP ($r = -0,094$; $p = .005$; $n = 870$) with present weak negative effects (Cohen, 1992). These trends are visible on Figure 15.

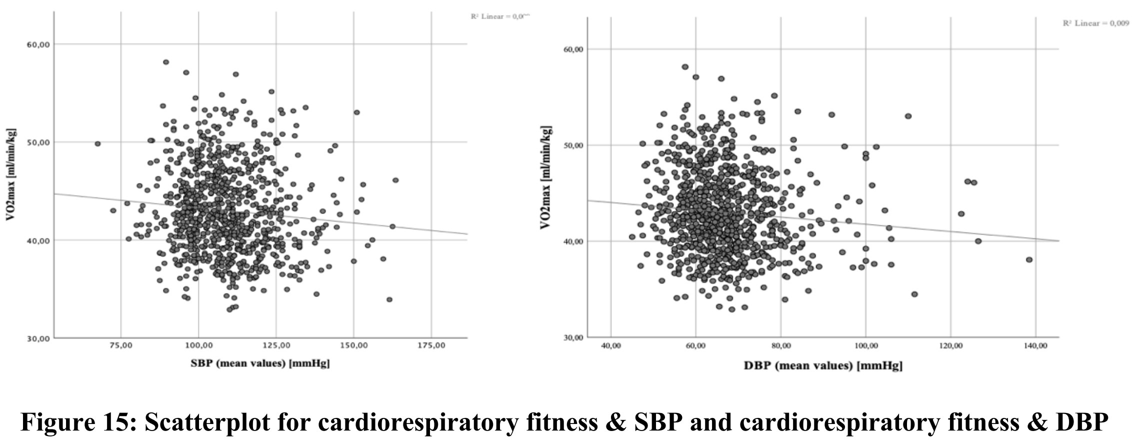


Figure 15: Scatterplot for cardiorespiratory fitness & SBP and cardiorespiratory fitness & DBP

The correlation coefficients of Bravais-Pearson within the variables are highly significant (indicated with **) at the significant level of .01 (2-tailed), which is shown in the table below (Table 8).

Table 8: Correlations within the main variables (CRF, SBP, DBP)

		CRF	SBP	DSB
CRF	Pearson Correlation	1	-,095**	-,094**
	Sig. (2-tailed)		,005	,005
	n	870	870	870
SBP	Pearson Correlation	-,095**	1	,634**
	Sig. (2-tailed)	,005		,000
	n	870	870	870
DBP	Pearson Correlation	-,094**	,634**	1
	Sig. (2-tailed)	,005	,000	
	n	870	870	870

** Correlation is significant at the .01 level (2-tailed).

Annotation. SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure

H2b: CRF has a direct influence on SBP and DBP

Results from the regression analysis, with $\dot{V}O_2max$ as predictor, show significant results for both dependent variables (p_{SBP}, p_{DPB} = .05), with present weak effects (R^2 = .009) (Cohen, 1988). 0.9% of the variance of SBP and DBP can be explained through the predictor ($\dot{V}O_2max$). Unstandardized coefficient B for SBP is -.293 (standard error: .104), for DBP unstandardized coefficient B is -.236 (standard error: .085). Detailed results of the regression analysis for CRF in dependency of SBP and DBP are shown in Appendix 10.3.

H2c: Height has an influence on SBP and DBP

Height of the children (for both gender) correlates positively with BP values. Therefor the effect is highly significant (at the .01 level) among SBP values (r = .182; p < .001; n = 834) and significant (at the .05 level) among DBP values (r = .085; p = .014; n = 834). Both effects are weak in size (Cohen, 1992).

Regression analysis for SBP and DBP with height as predictor is significant with present weak effects (R^2 for SBP = .033; R^2 for DBP = .007) (Cohen, 1988). Unstandardized coefficient B for SBP is .286 (standard error = .053), for DBP unstandardized coefficient B is .109 (standard error = .044). Detailed esults of the regression analysis for SBP in dependency of height are shown in Appendix 10.4.

7.2.3 Hypothesis 3: Spatial and ethnical differences of CRF and BP

H3a: SBP, DBP and CRF differ between children from the NA and TA

Variant homogeneity is only assumed for CRF (Levene's test: $F(1, 868)$ = .067, p = .796), hence for SBP and DBP results from t-test with Welch's correction are analysed. Differences of mean values between NA and TA are significant for CRF (t = 2.825, p = .005; M_{NA} = 42.57 vs, M_{TA}

= 43.4) and DBP ($t = 4.56$, $p < .001$;. $M_{NA} = 65.34$ mmHg, $M_{TA} = 68.69$ mmHg). SBP mean-values don't differ significantly between NA and TA ($p > .05$; $M_{NA} = 108.74$ mmHg, $M_{TA} = 109.19$ mmHg). Correlation coefficients of Bravais-Pearson were all weak effects (CRF: $r = .095$; SBP: $r = .017$; DBP: $r = .16$) (Cohen, 1992). Descriptive statistics of CRF, SBP, DBP for NA and TA are shown in Appendix 10.5.

H3b: SBP, DBP and CRF differ between the schools within areas

Further investigation with regards to the differences of mean values of each school, showed statistically significant differences between schools within the areas. Analyses for all one-way ANOVAs are statistically significant ($p < .05$) and therefor differences of mean values in CRF, SBP and DBP do exist within the schools, independent from areas.

Differences of CRF within the schools

CRF differ significantly between schools ($F(7, 862) = 4.4$; $p < .01$; $\eta^2 = .034$); $R^2 = .034$. Effect size is $f = .19$, a weak effect (Cohen, 1988). Post-hoc test with Bonferroni correction show significant differences ($p < .05$) within several schools. Especially the school TI1 with significant differences in mean CRF in comparison to other schools in the NAS but also within the TSS. Children from TI1 have highest mean value of CRF ($M = 44.57$, $SD = 3.87$) whereas children from NI1 have the lowest CRF ($M = 41.79$, $SD = 4.3$), indicating a significant difference (2.78; 95%-CI[-4.7, -0.8]). Other significant differences can be found between TI1 and NC2 (2.26; 95%-CI[-4.2, -0.29]), between TI1 and NC1 (2.16; 95%-CI[-4.09, -0.22]) and between TI1 and TC2 (2.16; 95%-CI[-4.1, -0.2]). Whereas differences do practically not exist between TI2, NI1, NI2, NC1, NC2, TC1 or TC2 ($p > .05$).

Differences of SBP within the schools

SBP mean values differ significantly between schools ($F(7, 862) = 6.99$; $p < .01$; $\eta^2 = .054$); $R^2 = .054$, with a weak effect size $f = .24$ (Cohen, 1988). Post-hoc test with Bonferroni correction show significant differences ($p < .05$) within several schools from TSS and NAS. Mean values from TI1 and TI2 are highlighted with significant differences in mean SBP values in comparison to the other schools. Investigating the group statistics highest mean values for TI1 ($M = 114.5$, $SD = 15.5$) and lowest mean values for TI2 (M = 103.4, SD = 12.2) were shown (11.18; 95%-CI[5.5, 16.8]). Other significant differences were found between TI1 and NI1 (7.04; 95%-CI[1.06, 13.02]), TI1 and NI2 (6.02; 95%-CI[0.23, 11.8]), TI1 and NC2 (6.3; 95%-CI[0.32, 12,3]), TI1 and TC2 (6.28; 95%-CI[0.36, 12.2]), TC1 and TI2 (8.3; 95%-CI[3.22, 13.35]), NC1 and TI2 (7.27; 95%-CI[1.8, 12.7]).

Differences of DBP within the schools

DBP mean values differ significantly between schools ($F(7, 862) = 8.37$; $p < .01$; $\eta^2 = .064$); $R^2 = .064$, with a medium effect size $f = .26$ (Cohen, 1988). Post-hoc test with Bonferroni correction show significant differences ($p < .05$) within several schools from TSS and NAS. TI1 differ significantly from all NAS but also from TI2 as a TSS. TC1 has significantly higher mean values compared to all the NAS and TI2. Highest mean values were observed in TI1 ($M = 71.7$, *SD* = 14.33), second highest in TC1 (*M* = 71.3, *SD* = 12.4) and lowest in NI1 (*M* = 64.26, *SD* = 8). Significant differences on DBP mean values at the .05 level were found between TI1 and TI2 (6.9; 95%-CI[1.7, 12.1]), TI1 and NI1 (7.46; 95%-CI[2.22, 12.69]), TI1 and NI2 (5.8; 95%-CI[0.5, 11.1]), TI1 and NC2 (5.7, 95%-CI[0.44, 10.9]), TI1 and NC1 (6.6, 95%-CI[1.2, 12]), TC1 and TI2 (6.55, 95%-CI[2.5, 10.6]), TC1 and NI1 (7.1; 95%-CI[3, 11]), TC1 and NI2 (5.4; 95%-CI[1.3, 9.6]), TC1 and NC2 (5.3; 95%-CI[1.22, 9.4]), and TC1 and NC1 (6.2; 95%-CI[1.9, 10.5]).

H3c: SBP, DBP and CRF differ between ethnicities (black African and coloured)

Differences in mean values were statistically significant for DBP (p = .02), but not for CRF and SBP (p > .05). Detailed tables of the analyses are found in Appendix 10.6.

DBP mean values differ significantly between ethnicities ($F(2, 838) = 3.9$; $p = .02$; $\eta^2 = .009$); $R^2 = .009$, with a weak effect size $f = 0.095$ (Cohen, 1988). Post-hoc test with Bonferroni correction showed significant mean value differences ($p < .05$) within black African (*M* = 67.94; *SD* = 12.1) and coloured (*M* = 65.43; *SD* = 8.65) ethnicities, with $p = .05$ (2.5; 95%-CI[0.63, 4.4]).

8 Discussion

The following sections discuss the findings of this study in relation to the hypotheses and on the basis of the literature. Associations between CRF and BP were tried to be explained and several assumptions were made. The discussion provides an approach to understand current situation of CRF and BP among the examined study population.

Key Findings

The key findings of this study are that CRF correlates significantly and negatively with BP values. CRF differs significantly between gender and age, whereas boys in average have higher mean values of CRF than girls, and older children have lower CRF than their younger counterparts. A third of all the girls are classified in the low CRF level, with the majority of children assessed showing moderate CRF levels. Blood pressure values are relatively constant over gender, whereas age only influences systolic blood pressure. A high proportion of 8.6% of the total study population also shown blood pressure values in the pre-hypertensive stage (≥ 132/85 mmHg).

8.1 Hypothesis 1: Characteristics of CRF

H1a: CRF ($\dot{V}O_2$max) differs between gender (male/female) and age

Results from the ANOVA showed significant higher values of CRF for boys, compared girls over all age categories. This outcome corresponds to general literature about trends observed in CRF during the growing processes and among gender (Shvartz & Reibold, 1990; Rowland, 2005). Due to maturing processes during growth, boys have naturally more favourable conditions for higher CRF than girls (Rowland, 2005). Findings of CRF patterns in the study sample over age groups show declining values of relative $\dot{V}O_2$max in both genders, while Rowland (2005, p. 109) described declining rates over years of growth only among girls while values in boys were raising. Due to the fact that this study only included baseline data from a cross-sectional survey, individual changes over maturing processes could not have been analysed and only assumptions about general trends within this study sample could have been formulated. Considering the fact that relative $\dot{V}O_2$max values are closely related to lean body mass (Rowland, 2005; Rowland, 2007) it can be assumed that boys of the study sample in comparison to international subjects, show a relative higher increase in body fat, in terms of BMI, or the contrast, showing a lower increase in skeletal muscle mass in relation to growth. Both of these factors presumed, would lead to declining relative CRF level. All assumptions made above should be proved in further research of analysis by applying a statistical analysis adjusted for body mass and / or body composition within gender- and age groups.

Values of calculated CRF from the study sample were set in international relation to evaluate the current situation of CRF levels within a greater setting. Due to no existing reference values of CRF in the SSA setting, mean values of Shvartz and Reibold (1990) were considered to set findings in an international perspective. International reference values about CRF levels among girls correspond approximately with relative cut-off values defined within this study (1^{st}, 2^{nd} & 3^{th}, 4^{th} quartile; for *low, moderate and high CRF*). For boys, relative cut-off values defined within this study are lower than international comparison (*Moderate CRF* of –9.80 - 45.85 ml/min/kg vs. *Average Fitness* of 46 ml/min/kg). Boys in all age groups would be classified in the *poor fitness* levels according to reference values of Shvartz and Reibold (1990), whereas according to our reference values, boys in all age groups fall within the *moderate CRF* level. Nine to 11-year old girls were on *average* rated in the *moderate CRF* category and girls 12 and 13-year old in the *low CRF* level. Reference values of CRF based on international data are available in Appendix 6, based on data of the authorship Shvartz and Reibold (1990).

Our data of CRF can be set in context of health, by considering health-related cut-off values defined by Ruiz *et al.* (2016). It was found, that about 1.6% of girls (≤ 35 ml/min/kg) and 30.7% of boys (≤ 42 ml/kg/min) in our study population are at risk for developing CVD in later life. For girls, children at the age of 12 and 13 years, are affected, and of boys between the age groups of nine to 13 years) represented higher risk for CVD (see detailed table of health-related CRF values, differentiated by gender and age-groups from the *KaziBantu* study population T1 in Appendix 7). These children in particular would benefit the most from activity intervention programs (seen as primary prevention) by addressing cardiovascular health though increased activity levels, improved aerobic fitness and management of healthy body weight (Ruiz et al., 2016).

H1b: Weather conditions' influence on performance of the 20-m SRT

The 20-m SRT count as highly valid instrument to evaluate CRF in children and internationally recognized (Castro-Piñero et al., 2009; Mayorga-Vega, Aguilar-Soto, & Viciana, 2015; Tomkinson et al., 2019). Nevertheless, methodological variability can occur due to different environmental conditions and therefor testing reliability can be limited (Tomkinson et al., 2019). Due to the fact that the sample size in this study was very large (n = 870), it was not possible to test all the children during one single day or at one specific location. Environmental conditions, such as weather and ground condition, were slightly different for each cluster. According to Tomkinson *et al.* (2019) it is recommended to exactly protocol these conditions to minimize methodological variability and achieve valid results. After integrating weather condition (hot, extremely windy, overcast, drizzling, cold) as a covariate in the linear regression model (ANCOVA), results with the ANOVA were compared. Adjustment for weather as a confounder (covariate) did not change these results significantly and partial eta-squared of the corrected model was only slightly adapted (from 0.165 to 0.177). This underlines the statement of having met testing reliability.

Having a closer look at the within-subject differences, significant differences of mean CRF could have been found between hot and extremely windy conditions ($p < 0.05$ 1.99, 95%-CI[0.4, 3.6]). Detailed information about the weather conditions each testing day show bias within the assessment of the weather conditions. At several testing days (see detailed weather condition in Appendix 4), more than one weather condition was ticked and therefor test supervisors were not united in their subjective assessment of weather conditions. These findings highlight the fact, that firstly, application of the testing protocol must be consistent among test supervisors to guarantee objectivity and therefore testing reliability. In the case of this study, weather condition can't be taken as consistent confounder and therefore should not distort interpretation of CRF levels.

8.2 Hypothesis 2: Associations of CRF and BP

H2a: SBP and DBP correlate negatively with CRF ($\dot{V}O_2max$)

Findings of the correlation analysis showed significant inverse associations between general CRF and SBP as well as general CRF and DBP. Additional descriptive information about *M* of SBP and DBP within each CRF level group was consulted to describe differences numerically (see Table 6 and Table 7, p. 38). Girls show clear rising SBP and DBP values from low to high CRF (from 113/69 mmHg in low CRF to 106/66 in high CRF). These tendencies are not observed among boys, whereas BP values among boys in moderate CRF are lower than among boys in high CRF (low CRF: 111.22/68.49mmHg; moderate CRF 107/66 mmHg; high CRF 109/66 mmHg). Tendencies in CRF ($\dot{V}O_2max$) can be identified by comparing mean values. Among both gender, children categorised as normotensive (SBP and DBP) had higher mean values of CRF than their counterparts in pre-hypertensive and hypertensive status (both SBP and DBP). Taking into account the literature about health-related cardiovascular biomarker, assumptions about general health condition of the children can be made: Lower BP values and higher CRF are strongly associated with health benefits (Musa & Williams, 2012; Agostinis-

Sobrinho et al., 2018; Lang et al., 2019), whereas higher CRF contribute to better BP profile (Musa & Williams, 2012). Therefor children in moderate and high CRF levels, simultaneously with BP values in normotensive state, have a better cardiovascular health and therefor might be at lower risk for further CVD or cardiovascular events such as strokes.

Even though results from the correlation analysis were significant, present effect sizes were weak (SBP: $r = -.095$; DBP: $r = -.094$) (Cohen, 1992), hence practical relevance is not guaranteed. This might be caused by the fact that neither height nor body weight was included in the correlation analysis, and CRF and BP were thus not adjusted for these parameters. Distinction within gender and age groups were not made, which could also influence results. Having a look at the effect sizes of the conducted analyses (ANCOVA) to estimate tendencies within groups (CRF levels vs. BP categories), a strong effect ($\eta^2 = .10$) was found among DBP in CRF levels. Effect sizes for SBP in CRF levels and CRF in BP categories were both weak ($\eta^2 = .018$; $\eta^2 = .007$). Interpretation of eta-squared must be treated cautious due to the fact that partial eta-squared are easily biases and therefor often exaggerates effect size (Okada, 2013).

While significant correlations between CRF and BP were found with simultaneously small effect sizes, extreme scattering of BP values might have been of consequence and can cause bias. SBP values range from a minimum of 68 mmHg to a maximum of 164 mmHg. DBP values ranged from a minimum of 45 mmHg to a maximum of 139 mmHg. The upper values in both SBP and DBP counted as extremely and hazardously high. Conditional through the cut-off values, defined by the 90th and the 95th percentile of the data pool within the subjects, 6.8% of girls and 6.5% of boys were classified as pre-hypertensive, whereas 9.8% of girls and 7.4% of boys were classified as hypertensive. According to the ESH guidelines values above 160-179/100-109 mmHg (for youth 16 years of age and older) can be classified as stage 2 HTN. Children with detected HTN stage 2 should immediately be clinically clarified and further anamnesis must take place. A 24-hours BP monitoring is recommended to finally confirm diagnosis (Licht & Büscher, 2018). Treatments with antihypertensive medication and clarifications about comorbidities (such as metabolic syndrome, diabetes mellitus or chronic kidney disease) must be undertaken if diagnosis has been verified. By diagnosing primary HTN, antihypertensive therapy should first target the risk factors of elevated BP such as overweight, increased salt intake and physical inactivity (Lurbe et al., 2016). In the cases of children showing extreme BP values during office measurements in the frame of the field-testing, non of these children were stating or exhibiting any symptoms according to HTN while being medically examined by a registered nurse, nor having stated to take medication related to BP control. This might underline the fact that HTN in children often stays asymptomatic and therefor no symptoms or complaints were mentioned. Other assumption of not properly performed BP examination or inaccurate transfer of BP values throughout the examination phase or during data entry can be formulated. Information about physical and medical information was protocolled during the clinical examination by nurses and health professionals and was recorded on the individual sheet for monitoring (consider example of monitoring sheet in Appendix 3). Low quality of measurement accuracy or not precisely following of the protocol could have furthermore confounded BP values. Possible explanations by surmising adequate examination the white-coat effect could have occurred as a result of examination situation and hence children showed exaggerated BP values (Lurbe et al., 2016; Licht & Büscher, 2018).

Nevertheless, as in the literature widely discussed, BP should be regularly assessed to track BP patterns in children into adulthood to avoid undetected HTN and subsequent health hazards in childhood and adulthood (Chen & Wang, 2008; Flynn, 2019). Our findings might lead to the necessity to further track BP among this population to avoid manifested HTN and therefor prevent adult HTN causing CVDs. To achieve sustainable healthy learners with favourable health parameters, it is recommended to integrate aerobic MVPA in intervention programs to increase CRF levels and therefor achieve healthy BP profiles and to shift subjects to either moderate or high CRF with consequently normotensive BP values (Ortega et al., 2008).

H2b: CRF has a direct influence on SBP and DBP

The regression analysis with CRF as predictor, allowed assumptions about cause-effect relation of CRF and BP. Inverse association were underlined, and the association becomes numerically comprehensible. For each additional unit of CRF, systolic blood pressure declines 0.293 units, and diastolic blood pressure declines 0.236 units. Thus, giving extra assumption that increased CRF contributes to lower BP values and higher CRF are related to better health outcome, which may influence cardiovascular health later in life.

Considering the systematic review and meta-analysis from the authorship Noubiap *et al.* (2017) the prevalence of elevated BP was highly associated with BMI. This analysis might be more meaningful by having included other factors such as BMI. Pozuelo-Carrascosa *et al.* (2017) emphasised the importance of integrating BMI into analysis of BP to adjust results.

H2c: Height has an influence on SBP and DBP values

Height count as one of the most important factors which creates BP variability among children (Banker et al., 2016). As literature emphasised, height need to be taken into consideration when evaluating childhood BP values to achieve valid results (Licht & Büscher, 2018). That is why in a separate analysis height and its direct influence on BP values was evaluated. Height of both genders correlated significantly and positively, with present weak effects ($r < .03$). The regression analysis with height as predictor, allowed assumptions about cause-effect relation of BP and height. Positive linear association were underlined, and the association becomes numerically comprehensible. For each additional unit of height [cm], SBP increases .293 units, and DBP increases .236 units. Thus, giving extra assumption that with the process of growth during childhood, SBP and DBP increase slightly. Nevertheless, causal statements must be formulated cautiously, as BP is dependent on many other factors and the interaction of these variables is very complex (Ewald & Haldeman, 2016).

8.3 Hypothesis 3: Spatial and ethnical differences of CRF and BP

H3a: SBP, DBP and CRF differ between children from the NA and TA

By considering historical facts of the apartheid era, which is still evident today with ethnic spatial segregation and interrelated inequality of SES among ethnicities, it was initially assumed that within NA and TA differences may exist. NA and TA are faced with lower standards of infrastructure (Christopher, 1987) and low SES was associated with higher rates of general vulnerability towards low CRF levels and elevated CVD risk factors (Walter, 2014). Health standards are closely related to SES, whereas low SES have lower accessibility to health care services (Ataguba & McIntyre, 2009; Mayosi et al., 2009; Williams & Mohammed, 2009; Mayosi & Benatar, 2014). Combining these facts with the general poor state of safety in South Africa (EDA, 2019), children from NA and TA don't have the needed access to a suitable environment to play, move freely and participate in PA, especially out of school. Even Draper *et al.* (2018, p. 407) clearly concluded with regards to the 2018 HAKSA Report Card that South Africa "is making insufficient progress with regards to the promotion of PA opportunities that are safe and accessible for the greatest number of children and adolescents in SA." The given environmental setting of the TA and NA seems to not encourage pupils to engage in regular PA and thus, assumptions of differences in health and health related markers, such as BP and CRF, between children from NA and children from TA were a formulated. It was hypothesized that children in TA are at an even greater risk for danger while moving outdoors and are less likely to have sufficient CRF and therefor favourable BP profiles. In summary, it was assumed that children from the TA are even more exposed to risk factors than children from NA.

Results from the t-test showed significant differences for CRF and DBP between children from the two areas but both with weak effects. Reversely than above assumed, children from TA (black African children) had higher mean values of CRF (M_{TA} = 43.4) than children from NA (coloured children) (M_{NA} = 42.57). This evidence might be explained through the fact of elevated violent gang activitie rates, recorded predominantly in the NA (Mudzwiti, 2019, 14 June).

Mean values of DBP do favour in children from NA (M_{NA} = 65.34 mmHg) in comparison to DBP values of children from TA (M_{TA} = 68.69 mmHg). Differences in mean SBP were not significant (M_{NA} = 108.74 mmHg vs. M_{TA} = 109.19 mmHg). Findings of favoured DBP are not relied on favoured CRF levels in view of differences within the areas. These findings lead to the urge for further spatial analyses of the chosen geographical groups and their characteristics and therefor further differentiate within these areas (NA and TA). Areas seem not to be the suitable dimension to cluster learners. As an effect, H3b was formulated and mean values of CRF and BP were analysed based on the school settings.

H3b: SBP, DBP and CRF differ between the schools within areas

Results from the ANOVA were significant and thus differences between SBP, DBP and CRF do exist between the different schools, furthermore, differences were also measured between the different areas. This calls into question and raises doubts about clustering pupils in NA and TA. Where do the spatial differences come from? Are schools the right dimension to cluster learners? What derivations can be made by analysing differences in mean values among schools? Beside the findings of the differences between the areas, other factors might complement the explanations of spatial differences in CRF and BP among TA and NA. As shown in Chapter 6.4 schools are also influenced by low SES and NAS and TSS are characterized by low SES which is expressed in unfavourable schooling conditions such as big class sizes and lack of sufficient infrastructure and equipment. Sports facilities and access to sports infrastructure are weak among NAS and TSS and therefor PE is neglected (Müller et al., 2019). By detecting the school with the children with the best rates in CRF and most favourable BP values, it might become apparent which school within our study frame provides the most favourable condition for children having a satisfying cardiovascular health profile, or to detect schools which need to improve their learning and activity environments.

By ranking the schools by their *M* values for CRF, SBP, and DBP, no clear favoured school stands out and no clear trends are visible. Concluding that schools of the study sample can't be clustered simply within areas and stand-alone statements limited to areas must be interpreted carefully.

Children from TI1 are highly ranked in CRF, while BP values are close to the lowest ranking values. Another TSS such as TI2 measured in the upper ranks with regards to SBP and DBP but only ranked four with regard to CRF. NI1 closes at lowest ranking in CRF but children show favourable BP values.

Ranking of the schools with regards to CRF, SBP and DBP are shown in Table 9, Table 10 and Table 11. High ranking of CRF is associated with high mean values of $\dot{V}O_2max$ [ml/min/kg], high ranking of SBP and DBP are associated with low mean values of BP [mmHg].

Table 9: Ranking of CRF among schools

CRF			
Rank	**School**	***M***	***SD***
1st	TI1	44.58	3.87
2nd	NI2	43.59	4.11
3d	TC1	43.51	4.96
4th	TI2	43.22	4.57
5th	TC2	42.42	3.51
6th	NC1	42.41	4.44
7th	NC2	42.32	4.18
8th	NI1	41.79	4.32

Annotation. CRF = Cardiorespiratory Fitness

Table 10: Ranking of SBP among schools

SBP			
Rank	**School**	***M***	***SD***
1st	TI2	103.37	12.2
2nd	NI1	107.51	11.91
3d	NC2	108.23	11.61
4th	TC2	108.26	13.71
5th	NI2	108.53	13.29
6th	NC1	110.64	13.17
7th	TC1	111.66	13.55
8th	TI1	114.55	15.58

Annotation. SBP = Systolic Blood Pressure

Table 11: Ranking of DBP among schools

DBP			
Rank	**School**	***M***	***SD***
1st	NI1	64.26	8.05
2nd	TI2	64.8	9.14
3d	NC1	65.13	9.37
4th	NI2	65.88	9.12
5th	NC2	66.03	8.11
6th	TC2	67.19	12.58
7th	TC1	71.35	12.39
8th	TI1	71.72	14.34

Annotation. DBP = Diastolic Blood Pressure

By considering the fact that CRF is significantly associated with gender, differentiation must additionally be made. Ranking of CRF receives another dimension and differ between boys and girls. Name TC2 as an example, in general measured CRF close to rank five. Looking at gender differences, girls ranked close to the second position and boys close to the eight position (see Table 12).

Table 12: School ranking of CRF differentiated by gender

CRF							
Girls				**Boys**			
Rank	**School**	***M***	***SD***	**Rank**	**School**	***M***	***SD***
1st	TI1	42.85	3.77	1st	TC1	45.82	5.26
2nd	TC2	42.41	2.97	2nd	TI1	45.79	3.48
3d	NI2	42.08	3.52	3d	NI2	45.07	4.14
4th	TI2	41.90	3.77	4th	TI2	44.73	4.96
5th	TC1	41.14	3.25	5th	NC1	44.19	4.71
6th	NC2	40.96	3.84	6th	NC2	43.70	4.08
7th	NI1	40.94	3.52	7th	NI1	42.58	4.84
8th	NC1	40.60	3.32	8th	TC2	42.43	3.99

Annotation. CRF = Cardiorespiratory Fitness

No claim for the most favourable school can therefore be formulated, by ranking the schools either according to CRF, SBP or DBP. For greater understanding of how spatial differences influence CRF and therefor BP profiles, it would be interesting to detect other factors within the schools and school locations. Questions like “how does the out-of-school-setting looks like and how does it favour PA?”, “how safe are the school districts and to what extend do children move freely and spend time outdoors?”, “how is the local accessibility for children to facilities or guided opportunities for PA?”. These questions might bring further information of children’s differences in CRF and BP. Besides the spatial possibilities for participating and being encouraged to perform PA, it would further be interesting to analyse how teacher and family members influence learner’s attitudes to PA (teacher-learner-relationships, guardian/parent/sibling-child-relationship) and if there might be differences in teaching and educating philosophy between schools and areas.

There is another fact which need to be envisaged. Children from TSS are very homogeneous in ethnicity (93% black African children), whereas children at the NAS are ethnically very heterogenous (33.1% black African children, 50.4% coloured children, 16.6% other ethnicity). Analyses, which are made from clustering pupils within schools, must be interpreted with caution due to this fact. Children from TSS and children from NAS might attend similar teaching environment but it is assumed that children from different ethnicities and different locations have different family and cultural backgrounds and are therefore imprinted differently. This led to the interest of examining differences in CRF and BP among ethnicities and not just school clusters.

H3c: SBP, DBP and CRF differ between ethnicities (black African and coloured)

Considering the sad fact that during apartheid, black African people were even discriminated against in terms of rights and freedom, compared to other ethnic groups (Christopher, 1987; South African History Online, 2019). As a result, higher rates of low SES, poverty and poor access to health care are found among black African people, compared to others ethnical groups, including the coloured and mixed race ethnic groups (Statistics South Africa, 2017). According to literature, black African population often come off poorly with regards to cardiovascular risk factor and physical fitness, which was discussed in Chapter 3.3.1 and Chapter 3.7.3. Research on ethnical disparities showed very low access rates to PE (Armstrong et al., 2011), general lower physical activity levels (McVeigh et al., 2014) and lower rates of CRF (Armstrong et al., 2011) among black African children.

H3c was formulated to examine differences between the two main ethnic groups (black African and coloured) of our study population, based on literature background according to the evidence that black African in many settings and dimensions are underprivileged and discriminated (McVeigh et al., 2004 [lower PA levels, lower PE participation, low SES]; Armstrong et al., 2011 [lower CRF levels]; Bucher et al., 2013 [higher CVD risk]; Lackland, 2014 [higher BP values]; Fuller-Rowell et al., 2016 [higher BP values, higher CVD risk]; James, 2017 [discrimination according to health care services]; Statistics South Africa, 2017 [higher inequality and poverty rates]). Results of the analysis have shown, that only mean values of DBP differ significantly between the two main ethnical groups (black African and coloured), with present weak effect what can be interpreted as no meaningful relevance for practice. Differences in CRF and SBP are furthermore neglectable. For analysing differences within ethnicities, it might be reasonable to enlarge the study sample and include children from white ethnicity as well. Nevertheless, in all cases of statements out of comparing ethnicities, results must be analysed with caution and with regards to other factors such as SES and cultural backgrounds, which might be more informative to explain disparities within the setting of South Africa.

8.4 Additional findings

Cumulative Laps and $\dot{V}O_2max$

It was interesting to see that with increasing age, CRF measured in $\dot{V}O_2max$, was declining. It must be recalled, that $\dot{V}O_2max$ was estimated and calculated with the mathematical formula from Léger *et al.* (1988) and age was integrated in the values. By investigating the isolated 20-m SRT performance, trends are reverse: with increased age, cumulative laps were also increasing and age therefor had a significant positive effect on the number of laps ($F(1, 868) = 55.7$, $p < .001$; Adjusted $R^2 = .059$; 3.7 additional laps for each year of age). It can be assumed that through the mathematical calculation of $\dot{V}O_2max$, age was relatively higher weighted than other factors and therefor CRF was adjusted downwards. This underlines the need for accurate application of testing protocol and caution with formulating general statements out of test results. Even though at first sight, older children have more cumulative laps than younger, it can't be automatically assumed that CRF of older children is better than CRF of their younger counterparts. CRF is a complex construct, and growth factors besides must be taken into consideration.

The theory of running economy is another approach which might explain differences in CRF among younger and older pupils. Plowman and Smith (2014) have shown that running economy is not very pronounced in childhood and therefor children use too much of aerobic energy in a too early stage of performance and are not capable to really reach maximum power in the setting of a field test.

9 Study limitations and strengths

As great advantage of the study the large sample size ($n = 870$) can be mentioned, which provides a representative data pool. Distribution in gender is equal across the study population and all clusters are approximately even in sample size.

By interpreting the findings of this study and setting any results in a larger context, additional factors need to be envisaged and formulation of general statements must occur with caution. Even though the selection of the study sample in clusters (schools) were randomly assigned, geographical areas of interest were antecedently defined and were limited to the disadvantaged neighbourhoods of Port Elizabeth, in the Eastern Cape Province of South Africa. Making national assumptions are therefore not possible.

Results from this master thesis are furthermore only based on cross-sectional data and does not indicate causalities. Data has not been standardized and all outliers have been included in the analysis. Mean values have been taken as reference values for all parameters, whereas median values might have been more appropriate by comparing BP values, for example, due to large scattering of the data. Results might be confounded by not having integrated additional important factors such as body composition/body weight, height, dietary habits, family history, SES or pubertal status (which was not assessed). Moreover, CRF has not been adjusted for body weight, BP not for height, which can confound the statistical results. The clustering of CVD risk factors was detected as a stronger indicator for evaluating status of health in children (Castro-Piñero et al., 2017). This was not fulfilled in this study, and which doesn't allow for the formulation of statements about general health conditions of the children.

The assessment of BP was performed with the Omron M6® digital blood pressure monitor, which can be categorized as oscillometric equipment. Algorithms indirectly calculate BP values. Due to the fact that these devices are often designed for adult examination, it is recommended that auscultatory methods must be applied additionally to confirm HTN in children. Values obtained by oscillometric equipment are considerably higher than provided reference values, which are obtained through auscultatory method (Lurbe et al., 2009). To properly detect hypertension among children, further assessment is needed. Furthermore, hypertension can't be diagnosed in a single assessment, repeated detection on several days are needed for final diagnosis (Licht & Büscher, 2018). Therefore, the collected data cannot be taken alone to diagnose hypertension in the study sample.

Cut-off values for CRF levels and BP status in this study were calculated within all subjects and refer to the whole study sample. As literature recommends, CRF cut-off values should be differentiated between gender (Shvartz & Reibold, 1990), or even additionally within age ranges, pubertal status and body composition (Rowland, 2005). Gender adjusted cut-off values might serve for more accurate classification and comparison of boys and girls, especially within growth phases. Lastly, BP values in children should be adjusted for age, sex, height, SES, pubertal status and waist circumference or BMI (Agostinis-Sobrinho et al., 2018).

9.1 Quality criteria

Assessment methods (20-m SRT and BP) were all standardized and allowed a repeated conduct of data collection within the frame of the same study protocol. Therefor testing reliability is fulfilled. In terms of validity, the 20-m SRT is a widely recognised method to estimate CRF (Castro-Piñero et al., 2009; Mayorga-Vega et al., 2015; Tomkinson et al., 2019). Despite that fact that calculated $\dot{V}O_2max$ values are only estimated (construct validity). Factors such as motivation and volition, inappropriate ground conditions and/or sportswear, as well as weather conditions, can bring variability in test performance and maximum performance might not always be guaranteed.

The baseline assessment (T1) duration was long (from February to March 2019) which demanded long-term commitment of the test supervisors. By the end of the assessment period, differences in measurement accuracy and individual patience of the test supervisors were observed, which might have influenced test objectivity over time.

10 Conclusion and Outlook

The aim of this master thesis was to provide evidence from primary schoolchildren which was collected from a large sample in the TA and NA of Port Elizabeth, South Africa. Associations between cardiorespiratory fitness and blood pressure values as markers of cardiovascular health were analysed, and trends were identified. Key findings showed negative and significant associations between CRF and BP, both systolic and diastolic. Children with physical fitness classified as «good» shown lower blood pressure values than children classified as «low» fitness levels. Congruent to literature, boys had higher CRF than girls, whereas older children had higher CRF than their younger counterparts. According to subject-related cut-off values, the majority of the study population was classified in a moderate CRF level, but still a third of overall girls and almost a fourth of boys were classified in low CRF. BP values were relatively constant over gender, and age influenced only SBP significantly (r = .087). According to the ESH guidelines, BP cut-off values were determined and were calculated on the basis of the individual BP values throughout the study population. According to these cut-off values, stages of normotension, pre-hypertension and HTN were defined. A high proportion of 6.7% of all the boys and girls were classified as pre-hypertensive (≥ 126/79 < 132/85 mmHg) and 8.6% of all the boys and girls were classified as hypertensive (≥ 132/85 mmHg). These numbers can be seen as an alarming sign. Processes of clinically diagnosing hypertension are complex and therefor no final diagnosis can be made. Nevertheless, these findings lead to the fact, that regular tracking of BP values in children of this setting gains importance to prematurely detect children at risk for CVDs in later life. It can be concluded that, independent from ethnicity and geographical location, better CRF are associated with favoured BP profiles and children with better cardiovascular health markers are at lower risk for developing cardiovascular diseases in adulthood (Klasson-Heggebø et al., 2004; Lee et al., 2010; Castro-Piñero et al., 2017; Agostinis-Sobrinho et al., 2018; Lang et al., 2019). Children should be encouraged to improve their CRF to sustainably guarantee a satisfying cardiovascular health.

Provided data should be integrated into future longitudinal designs or retrospective cohort studies to identify cause-and-effect relationships and long-term trends. CRF data should be complemented with children's PA patterns, in- and out-of-school, to develop an overall picture of children's activity patterns related CRF. Information about leisure activities might bring light to PA patterns and sources of sedentary time can be identified. Furthermore, assessment of body compositions and dietary habits, as important indicators of health behaviour, should complement future analysis of cardiovascular health markers. This complementary information is needed to detect the most vulnerable subjects and develop the most suitable intervention programs. Cardiovascular health is complex and multidimensional and need to be assessed in a wide perspective to generate overall trends and outcomes of behavioural changes among children. Further research within the *KaziBantu* study should integrate clustered CVD markers to generate overall pictures of health status in paediatric population in Port Elizabeth, South Africa. Evidence based data offers the possibility to raise public attention and justify the need for further engagement in health-promoting policies and primary prevention programs among the most vulnerable groups within South Africa.

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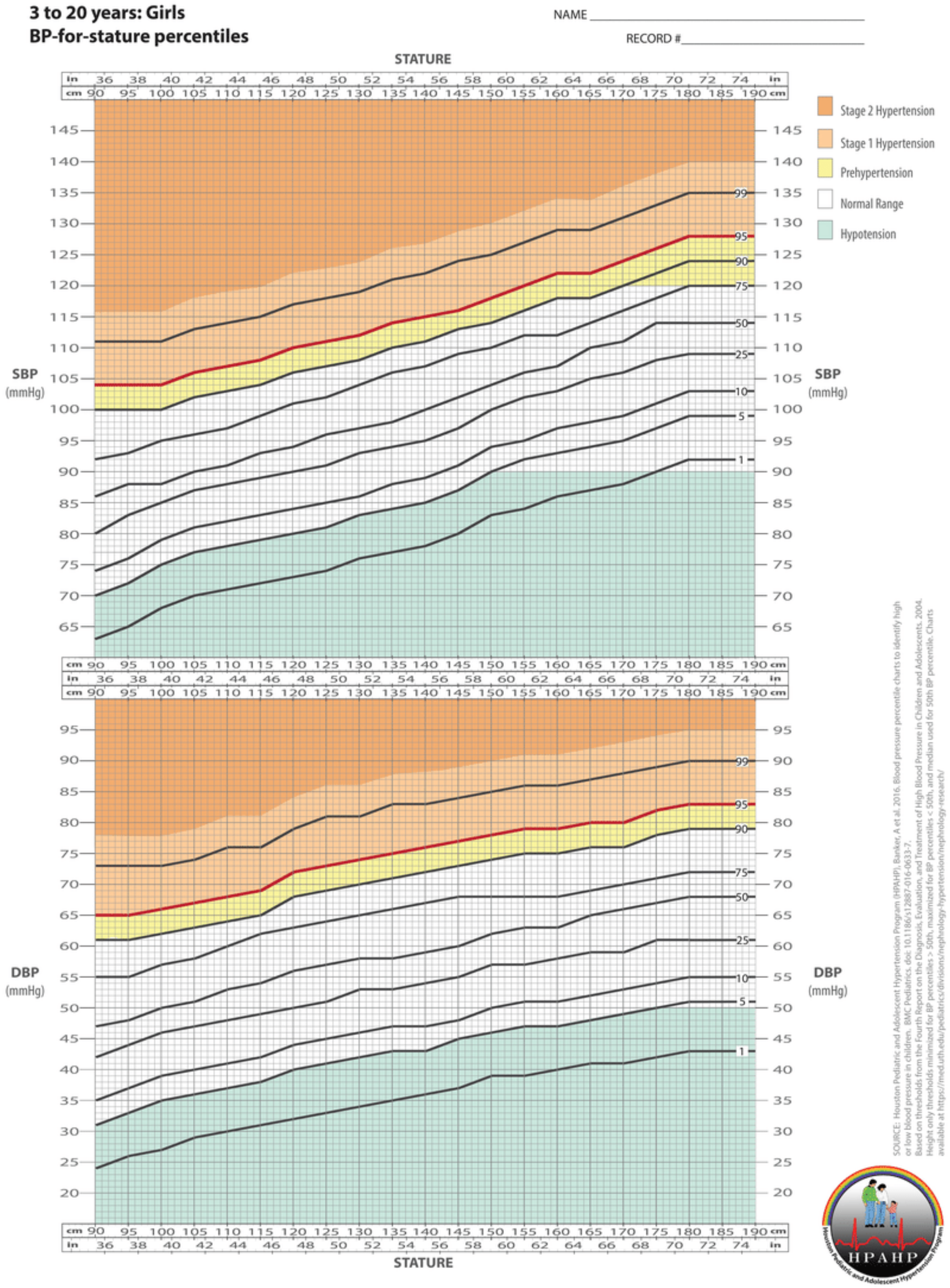
Appendix

Appendix 1: Height-sensitive BP charts for children aged 3 to 20 years

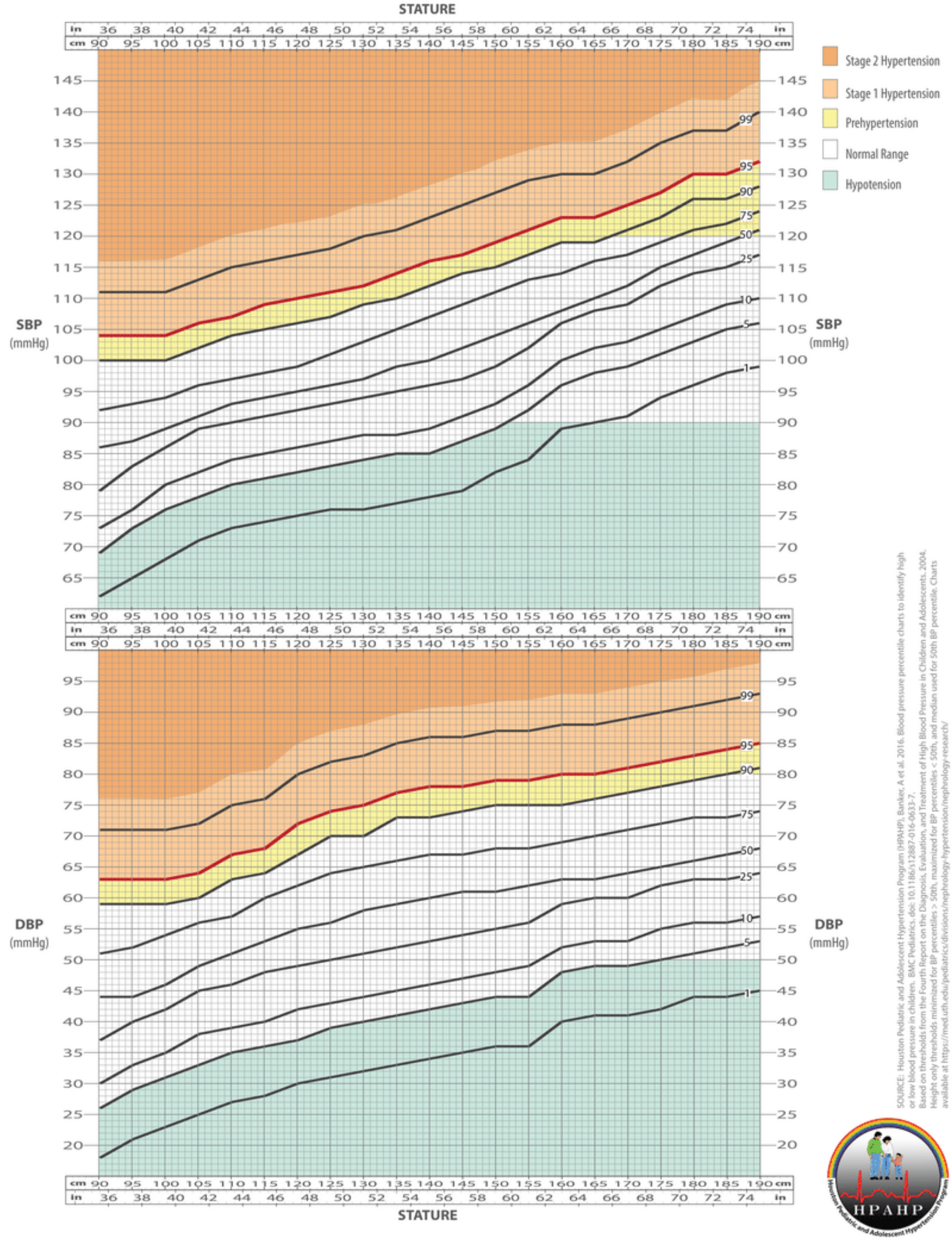
Source: Banker, A., Bell, C., Gupta-Malhotra, M., & Samuels, J. (2016). Blood pressure percentile charts to identify high or low blood pressure in children. *BMC Pediatrics, 16*(1): 98.



3 to 20 years: Boys
BP-for-stature percentiles

NAME ________________________

RECORD # ________________________

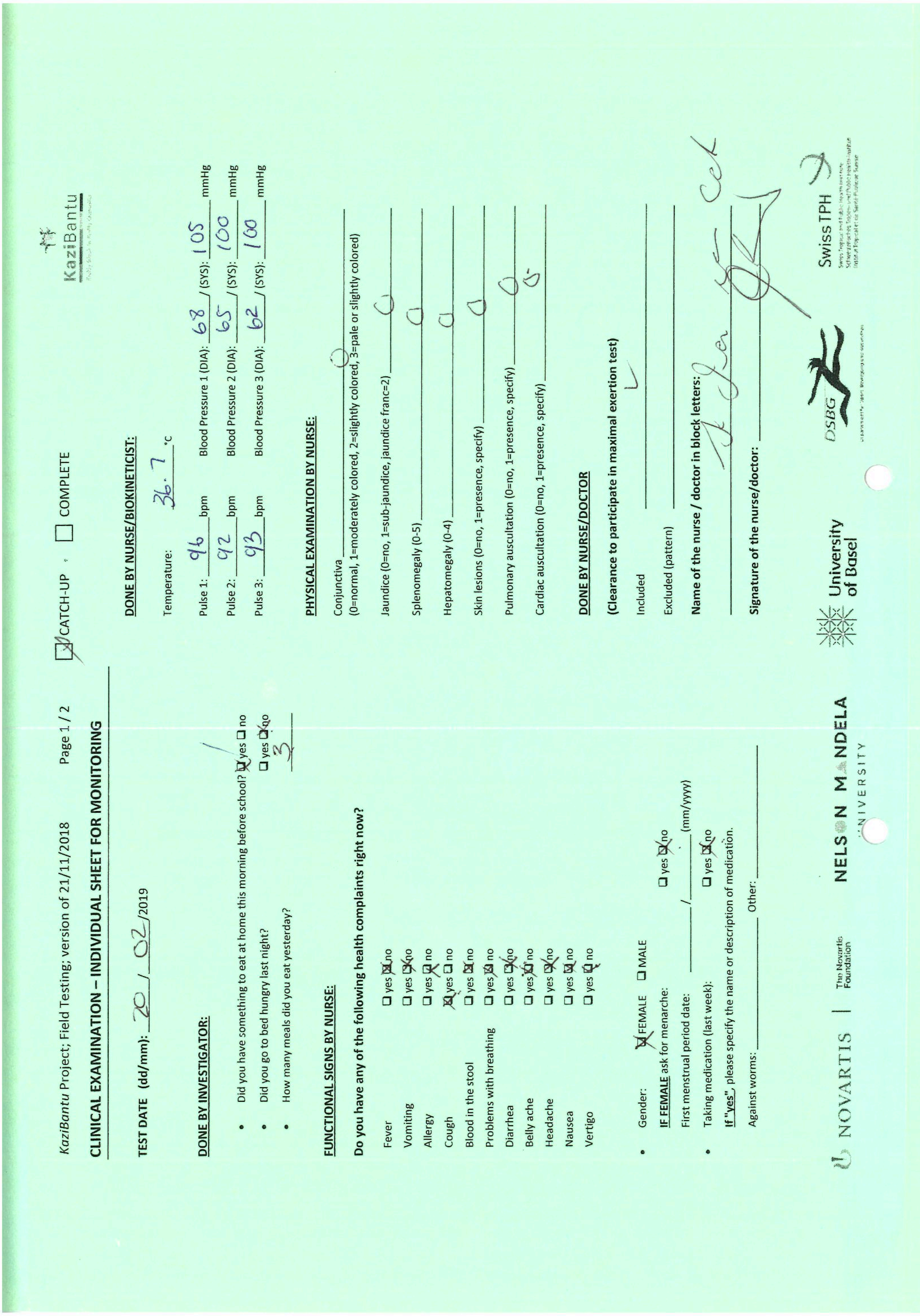


SOURCE: Houston Pediatric and Adolescent Hypertension Program (HPAHP), Banker, A et al. 2016. Blood pressure percentile charts to identify high or low blood pressure in children. BMC Pediatrics. doi: 10.1186/s12887-016-0633-7.
Based on thresholds from the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. 2004.
Height only thresholds minimized for BP percentiles > 50th, maximized for BP percentiles < 50th, and median used for 50th BP percentile. Charts available at https://med.uth.edu/pediatrics/divisions/nephrology-hypertension/nephrology-research/

Appendix 2: Blood pressure values of the *KaziBantu* T1 study population by age groups and gender

		Girls						Boys						Total					
	Age	N	M	Med	SD	Max	Min	N	M	Median	SD	Max	Min	N	M	Median	SD	Max	Min
SBP	9	103	107.29	106,00	13,47	145,50	81,50	78	108,75	106,75	11,96	151,00	85,00	181	107,92	106,50	12,83	151,00	81,50
	10	150	108.46	107,00	14,33	163,50	67,50	137	108,13	105,00	14,16	162,50	72,50	287	108,30	106,00	14,23	163,50	67,50
	11	117	109.82	108,50	12,54	150,00	81,50	127	107,77	107,00	13,64	152,50	80,00	244	108,75	108,00	13,14	152,50	80,00
	12	50	114.75	113,25	16,38	161,50	77,50	79	109,91	109,00	10,61	144,50	89,00	129	111,78	110,00	13,30	161,50	77,50
	13	7	111.50	111,50	2,86	117,00	107,50	22	111,77	110,75	13,65	136,00	87,50	29	111,71	111,00	11,90	136,00	87,50
DBP	9	103	66,80	64,50	10,17	100,00	48,00	78	67,25	66,00	11,52	122,50	50,50	181	66,99	65,00	10,74	122,50	48,00
	10	150	68,25	66,25	12,29	138,50	48,00	137	66,43	64,00	11,93	124,00	45,00	287	67,39	65,50	12,13	138,50	45,00
	11	117	66,78	66,50	8,18	95,50	49,50	127	65,09	63,50	9,56	100,00	47,00	244	65,90	65,00	8,95	100,00	47,00
	12	50	70,41	68,00	13,99	126,50	47,00	79	66,15	65,00	8,71	106,00	51,50	129	67,80	66,50	11,21	126,50	47,00
	13	7	69,43	68,50	3,45	76,00	65,50	22	73,00	67,75	13,86	102,00	56,50	29	72,14	68,50	12,21	102,00	56,50

Appendix 3: Clinical examination sheet & fitness score sheet *KaziBantu* T1



KaziBantu Project; Field Testing; version of 21/11/2018 Page 1 / 2 ☒ CATCH-UP ☐ COMPLETE

CLINICAL EXAMINATION – INDIVIDUAL SHEET FOR MONITORING

TEST DATE (dd/mm): 20 / 02 /2019

DONE BY INVESTIGATOR:

- Did you have something to eat at home this morning before school? ☒ yes ☐ no
- Did you go to bed hungry last night? ☐ yes ☒ no
- How many meals did you eat yesterday? 3

FUNCTIONAL SIGNS BY NURSE:

Do you have any of the following health complaints right now?

Fever	☐ yes ☒ no
Vomiting	☐ yes ☒ no
Allergy	☐ yes ☒ no
Cough	☒ yes ☐ no
Blood in the stool	☐ yes ☒ no
Problems with breathing	☐ yes ☒ no
Diarrhea	☐ yes ☒ no
Belly ache	☐ yes ☒ no
Headache	☐ yes ☒ no
Nausea	☐ yes ☒ no
Vertigo	☐ yes ☒ no

- Gender: ☒ FEMALE ☐ MALE

IF FEMALE ask for menarche: ☐ yes ☒ no

First menstrual period date: ______ / ______ (mm/yyyy)

- Taking medication (last week): ☐ yes ☒ no

If "yes" please specify the name or description of medication.

Against worms: ______ Other: ______

DONE BY NURSE/BIOKINETICIST:

Temperature: 36.7 °C

Pulse 1: 96 bpm Blood Pressure 1 (DIA): 68 / (SYS): 105 mmHg

Pulse 2: 92 bpm Blood Pressure 2 (DIA): 65 / (SYS): 100 mmHg

Pulse 3: 93 bpm Blood Pressure 3 (DIA): 62 / (SYS): 100 mmHg

PHYSICAL EXAMINATION BY NURSE:

Conjunctiva (0=normal, 1=moderately colored, 2=slightly colored, 3=pale or slightly colored) 0

Jaundice (0=no, 1=sub-jaundice, jaundice franc=2) 0

Splenomegaly (0-5) 0

Hepatomegaly (0-4) 0

Skin lesions (0=no, 1=presence, specify) 0

Pulmonary auscultation (0=no, 1=presence, specify) 0

Cardiac auscultation (0=no, 1=presence, specify) 0

DONE BY NURSE/DOCTOR

(Clearance to participate in maximal exertion test)

Included ✓

Excluded (pattern) ______

Name of the nurse / doctor in block letters: [illegible]

Signature of the nurse/doctor: [illegible]

NOVARTIS | The Novartis Foundation NELSON MANDELA UNIVERSITY University of Basel DSBG Swiss TPH KaziBantu

KaziBantu Project; Field Testing; version of 21/11/2018 Page 2 / 2 ☒ CATCH-UP ☐ COMPLETE

PARTICIPANT EVALUATION – FITNESS SCORE SHEET

BIOGRAPHICAL INFORMATION

ID STICKER		TEST DATE	(dd / mm): 20 / 02 / 2019
WEATHER CONDITIONS	☐ Hot ☐ Overcast ☐ Drizzling ☒ Extremely Windy ☐ Cold		

PHYSICAL FITNESS TESTS

			Tick Dominant Hand	TRIAL 1	TRIAL 2	TRIAL 3
Station 1	Muscular Strength	Grip Strength (kg)	☒ Right	22	18	17
			☐ Left	20	18	20

Station 2	Cardiorespiratory Fitness	Shuttle Run (completed laps)	Bib Number	6
			Cumulative Laps	17

Special Notes:

KaziBantu NOVARTIS The Novartis Foundation NELSON MANDELA UNIVERSITY University of Basel DSBG Swiss TPH

Appendix 4: Weather condition each fitness testing day (20-m SRT) *KaziBantu* T1

Weather Condition	Frequency according to test participants	%
Hot	488	56.1
Overcast	229	26.3
Drizzling	94	10.8
Extremely windy	59	6.8

Testing Date	Hot	Overcast	Drizzling	Extremely windy	Retrospective Temperature in °C (accuweather.com)
22. Jan 19	x	x			27°C
24. Jan 19	x				24°C
25. Jan 19		x	x		20°C
28. Jan 19	x			x	25°C
30. Jan 19			x		28°C
31. Jan 19		x	x	x	23°C
01. Feb 19		x		x	24°C
05. Feb 19	x				26°C
15. Feb 19	x			x	29°C
21. Feb 19		x			26°C
27. Feb 19	x	x		x	23°C
28. Feb 19	x	x			25°C

Appendix 5: 20-m shuttle run test protocol

20-meter shuttle run

Purpose

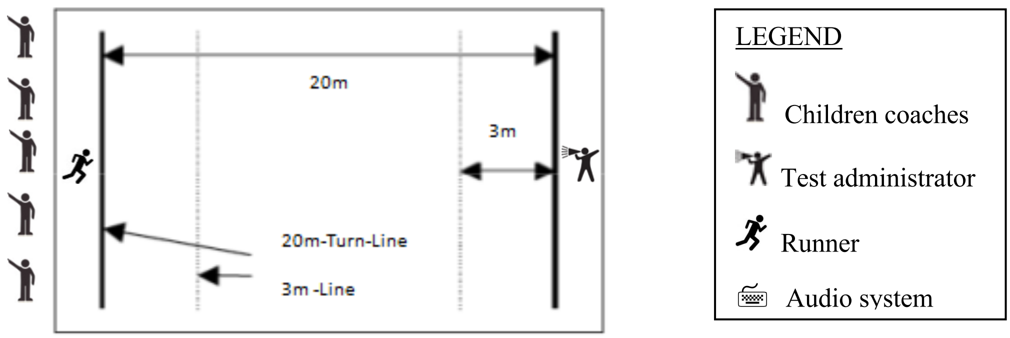
Measurement of cardiovascular endurance

Equipment

- Numbered sports bibs (1 – 50)
- Portable audio system
- USB stick with audio
- Scoreboard (numbered 1-100)
- 50 colour co-ordinated beacons
- 80m rope
- Four tent pegs
- Minimum number of people required to run test: 8
  - 1 runner
  - 1 manager of audio system and scoreboard
  - 1 test administrator ensuring children fulfil test requirements
  - 5 children coaches (4 children per coach, maximum of 20 children per shuttle run)

Site construction

An 80m rope is used to mark the 20m x 20m demarcated area. The 80m rope is premeasured at each 20m point which allows the researcher to mark the area using the four tent pegs. One beacon is placed 3m from each corner of the turn-line which is used as a control measure (Adaptation from original test description which states 2m). Forty coloured cones are placed along each 20m turn-line (20 cones per line which must be colour coordinated). Each child is assigned to a coloured cone to ensure the children run in a straight line. Before the test starts children should know the colour of their cone that they were assigned to.



Procedure

The shuttle run test is administered between two lines 20m apart, the child runs between the two lines in time to the recorded audio signals. The running speed is controlled by intervals of recorded sound signals, also known as “beeps”. The test starts with the child standing behind one of the turn-lines facing the direction of the other turn-line and should begin running when instructed by the audio. At the beginning of the test, the running speed is 8.5 km/h. The child will run continuously between the two turn-lines and turn only when they reach the 20m turning line. The child must touch the line with their foot and turn as quickly as possible. Every minute, the audio will signal an increase in speed by 0.5 km/h in which the beep signals will be closer together. The children run at a uniform pace, this means that they do not run faster or slower than the speed specified by the sound signals.

Instruction to participant

The test administrator explains the procedure in the children’s home language afterwards the runner will demonstrate the test prior to the test being conducted.

“The test starts slowly and gets faster and faster. At each ‘beep’ you have to touch the marked line (which represents the 20m mark) with your foot. You must reach the turn-line on time and you must wait until the signal is heard, only then are you allowed to run. If you are not at the turning line on time, you have to catch up, by running faster to reach the turn-line in time. A ‘runner’ will run with you, please do not overtake him. Stop only when you are tired or if the test administrator says that the test is completed."

Data collection and error sources

- A volunteer will keep record of the number of the completed lengths with a scoreboard which is displayed during the test.
- Scoring: Record the last completed lap (and not necessarily the lap stopped at)
- The test result is the number of full laps completed.
- If a child has not reached the 20m turning line, they need to catch up and run faster to touch the line with their foot before they can continue.
- If the child runs before the time, the test administrator must ask the child to return to the line.
- If the children stop running, they should leave the field as quickly as possible without disturbing the other children.
- Termination of test:
  - If children stop by themselves due to exhaustion.
  - If children do not reach the 3m-line twice in a row after a warning.
  - The test administrator determines whether the child has reached the 3m- line or not.

KaziBantu Standardization

- The test administrator must ensure that the testing environment has limited noise and distraction. Volunteers will be placed on each side of the 20m line to inform the children to run to their designated cone/ not to run to fast or not to run not to run ahead of the runner.
- Giving instructions before the test is advisable (tying shoelaces, run in a straight line, run faster or slower, wait at the line etc.)
- Encouraging the children is allowed!

Source

- Test-protocol from Léger *et al*. 1984

Table 1: Test Protocol Summery

Lev-els	Shut-tles	Cumulative Shuttles	Speed (km/h)	Shuttle Time (s)	Total level time (s)	Distance (m)	Cumulative Distance (m)	Cumulative Time (mm:ss)
1	7	7	8.5	9.00	63.00	140	140	01:03
2	8	15	9.0	8.00	64.00	160	300	02:07
3	8	23	9.5	7.58	60.63	160	460	03:08
4	9	32	10.0	7.20	64.80	180	640	04:12
5	9	41	10.5	6.86	61.71	180	820	05:14
6	10	51	11.0	6.55	65.50	200	1020	06:20
7	10	61	11.5	6.26	62.61	200	1220	07:22
8	11	72	12.0	6.00	66.00	220	1440	08:28
9	11	83	12.5	5.76	63.36	220	1660	09:31
10	11	94	13.0	5.54	60.92	220	1880	10:32
11	12	106	13.5	5.33	64.00	240	2120	11:36
12	12	118	14.0	5.14	61.71	240	2360	12:38
13	13	131	14.5	4.97	64.55	260	2620	13:43
14	13	144	15.0	4.80	62.40	260	2880	14:45
15	13	157	15.5	4.65	60.39	260	3140	15:46

The 20 m shuttle run test: Prediction of $\dot{V}O_2max$ according to speed and age

The age of the participating child and the speed at which the child stopped running will be converted into the maximum volume of oxygen that can be utilized within 1 min during exhaustive exercise (VO_2 max). The equation below will be used to calculate the VO2 max value, the equation is as follows:

$$Y = 31.025 + 3.238 * X - 3.248 * A + 0.1536 * A * X$$

Y = $\dot{V}O_2max$ Value

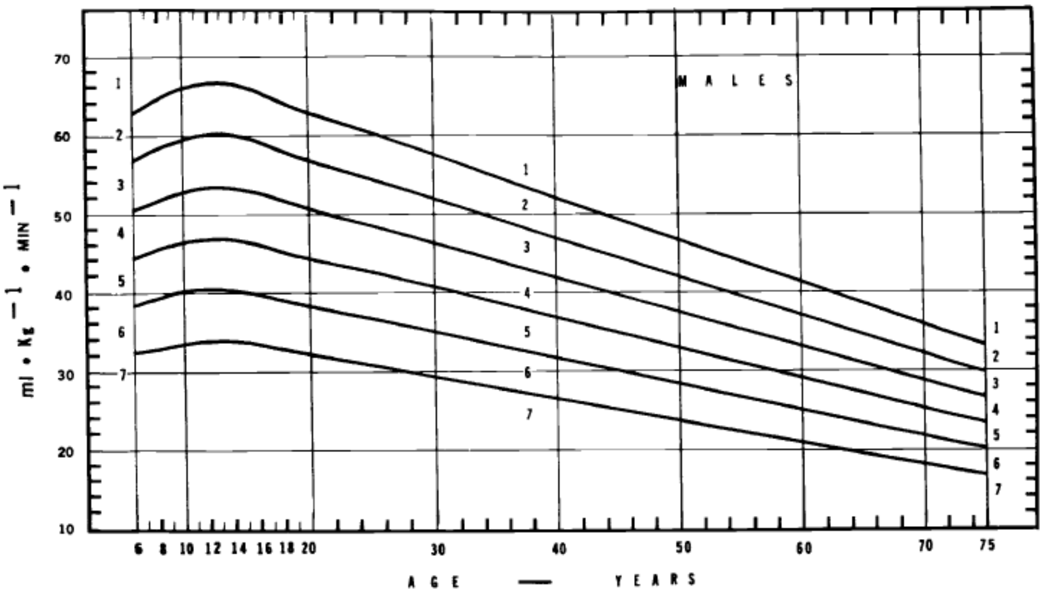
X = reached speed (km/h)

A = rounded lower age

Appendix 6: Reference values of CRF according to Shvartz and Reibold (1990)

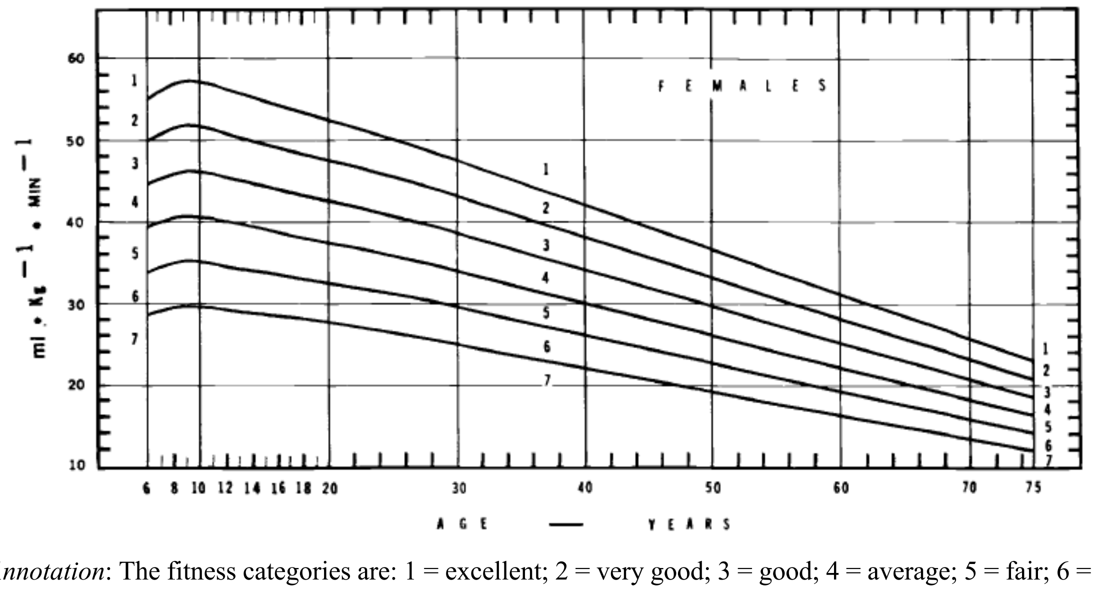
Source: Shvartz, E. & Reibold, R. C. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: A review. *Aviat Space Environ Med, 61*(1), 3-11.

Boys 9-13 yrs	Poor Fitness	33 ml/min/kg
	Average Fitness	46 ml/min/kg
	Good Fitness	53 ml/min/kg
	Very good to excellent Fitness	60-66 ml/min/kg



Annotation: The fitness categories are: 1 = excellent; 2 = very good; 3 = good; 4 = average; 5 = fair; 6 = poor; 7 = very poor.

Girls 9-13 yrs	Poor Fitness	30 ml/min/kg
	Average Fitness	40 ml/min/kg
	Good Fitness	46 ml/min/kg
	Very good to excellent Fitness	50-58 ml/min/kg



Annotation: The fitness categories are: 1 = excellent; 2 = very good; 3 = good; 4 = average; 5 = fair; 6 = poor; 7 = very poor.

Cut-off values according to the *KaziBantu* T1 study population: **Girls and Boys 9-13 yrs**

Low CRF	32.90 - 39.79 ml/min/kg
Moderate CRF	39.80 - 45.85 ml/min/kg
High CRF	45.86 - 58.15 ml/min/kg

Appendix 7: Health-related cut-off values of CRF according to Ruiz *et al.* (2016)

Health-related cut-off CRF for girls (study population *KaziBantu* T1**)**			
	Age	**n**	**%**
≤ 35 ml/min/kg *Poor cardiovascular health*	12	4	0.94
	13	3	0.70
Total		7	1.64
> 35 ml/min/kg *Good cardiovascular health*	9	103	24.12
	10	150	35.13
	11	117	27.40
	12	46	10.77
	13	4	0.94
Total		420	98.36
Total		***427***	***100.00***

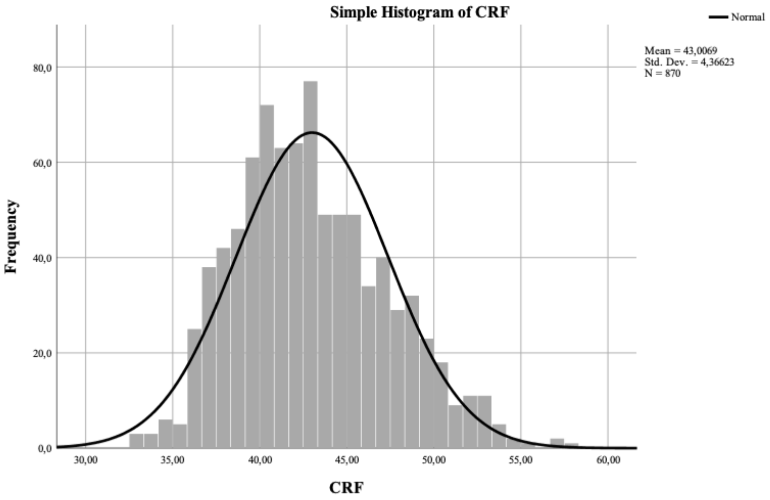
Health-related cut-off CRF for boys (study population *KaziBantu* T1**)**			
	Age	**n**	**%**
≤ 42 ml/kg/min *Poor cardiovascular health*	9	9	2.03
	10	40	9.03
	11	52	11.74
	12	25	5.64
	13	10	2.26
Total		136	30.70
> 42 ml/kg/min *Good cardiovascular health*	9	69	15.58
	10	97	21.90
	11	75	16.93
	12	54	12.19
	13	12	2.71
Total		307	69.30
Total		***443***	***100***

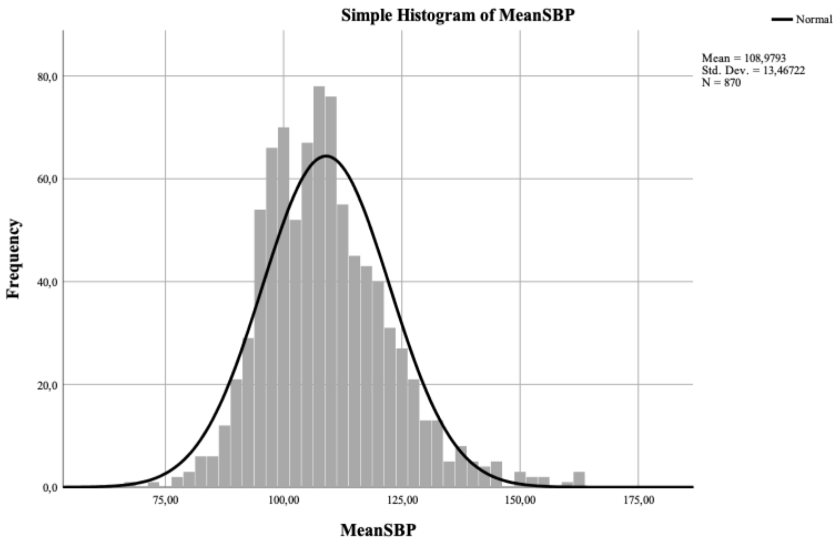
Appendix 8: Detailed tables for BP categories an CRF levels of the *KaziBantu* T1 study population across schools

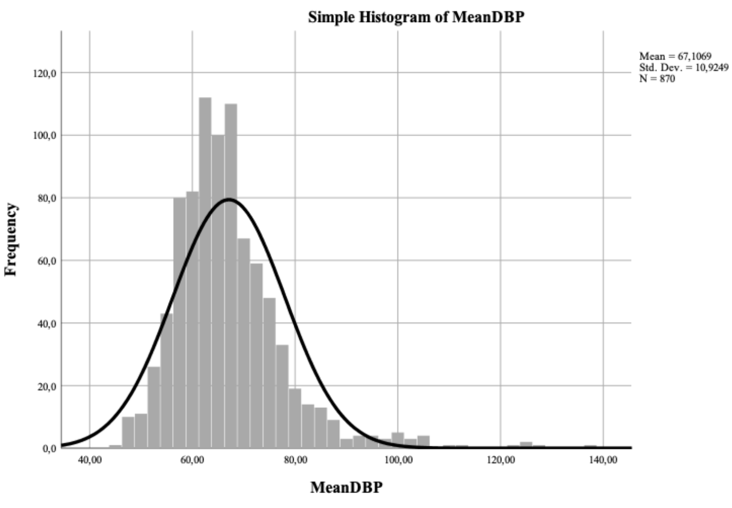
BP Categories	normotensive			pre-hypertensive			hypertensive		
	Count	Column N %	Row N %	Count	Column N %	Row N %	Count	Column N %	Row N %
TI2	113	15,3%	89,0%	9	15,5%	7,1%	5	6,7%	3,9%
NI1	90	12,2%	91,8%	4	6,9%	4,1%	4	5,3%	4,1%
NI2	101	13,7%	89,4%	5	8,6%	4,4%	7	9,3%	6,2%
NC2	86	11,7%	88,7%	5	8,6%	5,2%	6	8,0%	6,2%
NC1	89	12,1%	86,4%	7	12,1%	6,8%	7	9,3%	6,8%
TC2	92	12,5%	90,2%	2	3,4%	2,0%	8	10,7%	7,8%
TI1	67	9,1%	72,8%	10	17,2%	10,9%	15	20,0%	16,3%
TC1	99	13,4%	71,7%	16	27,6%	11,6%	23	30,7%	16,7%
Total	737	100,0%	84,7%	58	100,0%	6,7%	75	100,0%	8,6%

CRF Levels	low CRF			moderate CRF			high CRF		
	Count	Column N %	Row N %	Count	Column N %	Row N %	Count	Column N %	Row N %
TI2	27	12,2%	21,3%	68	15,6%	53,5%	32	15,1%	25,2%
NI1	37	16,7%	37,8%	49	11,2%	50,0%	12	5,7%	12,2%
NI2	16	7,2%	14,2%	61	14,0%	54,0%	36	17,0%	31,9%
NC2	30	13,5%	30,9%	46	10,6%	47,4%	21	9,9%	21,6%
NC1	38	17,1%	36,9%	41	9,4%	39,8%	24	11,3%	23,3%
TC2	28	12,6%	27,5%	58	13,3%	56,9%	16	7,5%	15,7%
TI1	11	5,0%	12,0%	45	10,3%	48,9%	36	17,0%	39,1%
TC1	35	15,8%	25,4%	68	15,6%	49,3%	35	16,5%	25,4%
Total	222	100,0%	25,5%	436	100,0%	50,1%	212	100,0%	24,4%

Appendix 9: Histograms for CRF, SBP, DBP data







Appendix 10: Detailed tables with results of the statistical analysis (Source: SPSS)

Appendix 10.1 Hypothesis 1a *CRF ($\dot{V}O_2$max) differs between gender (male/female) and age*

		CRF [mlO_2/min/kg]	
		Girls (*n* = 427)	**Boys (*n* = 443)**
9 year old	M (±SD)	43.49 (3.2) *moderate*	45.62 (3.3) *moderate*
10 year old	*M* (±*SD*)	41.99 (3) *moderate*	44.46 (4.5) *moderate*
11 year old	*M* (±*SD*)	40.43 (3) *moderate*	43.82 (4.9) *moderate*
12 year old	*M* (±*SD*)	39.41 (3.9) *low*	44.32 (5.2) *moderate*
13 year old	*M* (±*SD*)	39.35 (6.5) *low*	42.95 (4.9) *moderate*
Total	*M* (±*SD*)	41.58 (3.5) *moderate*	44.38 (4.6) *moderate*

Appendix 10.2 Hypothesis 1b: *Weather conditions' influence on performance of the 20-m SRT*

Results of the univariate analysis of covariate (ANCOVA)

Tests of Between-Subjects Effects CRF, Gender, Age, Gender*Age, Weather (Covariate)

Dependent Variable: CRF

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2937,557a	10	293,756	18,515	,000	,177
Intercept	285983,440	1	285983,440	18024,737	,000	,955
Weather	196,792	1	196,792	12,403	,000	,014
Gender	1009,750	1	1009,750	63,642	,000	,069
Age	825,727	4	206,432	13,011	,000	,057
Gender*Age	170,293	4	42,573	2,683	,030	,012
Error	13629,035	859	15,866			
Total	1625715,208	870				
Corrected Total	16566,592	869				

a R Squared = ,177 (Adjusted R Squared = ,168)

Weather Condition used as the covariate in ANCOVA to adjust for weather condition

Descriptive Statistics of CRF in different Weather Conditions

	n	M	SD	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Hot	488	43,3391	4,25224	,19249	42,9609	43,7173	32,90	58,15
Overcast	229	42,8759	4,71237	,31140	42,2623	43,4895	33,13	57,08
Drizzling	94	42,6413	4,41614	,45549	41,7368	43,5458	36,06	53,34
Extremely windy	59	41,3502	3,35231	,43643	40,4766	42,2238	34,22	50,83
Total	870	43,0069	4,36623	,14803	42,7164	43,2975	32,90	58,15

Appendix 10.3 Hypothesis 2b: *CRF has a direct influence on SBP and DBP*
Results of the regression analysis for CRF in dependency of SBP

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,095a	,009	,008	13,41402

a Predictors: (Constant), CRF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1422,768	1	1422,768	7,907	,005b
	Residual	156184,360	868	179,936		
	Total	157607,128	869			

a Dependent Variable: Mean SBP
b Predictors: (Constant), CRF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	121,583	4,505		26,988	,000
	CRF	-,293	,104	-,095	-2,812	,005

a Dependent Variable: Mean SBP

Results of the regression analysis for CRF in dependency of DBP

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,094a	,009	,008	10,88238

a Predictors: (Constant), CRF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	924,209	1	924,209	7,804	,005b
	Residual	102793,849	868	118,426		
	Total	103718,059	869			

a Dependent Variable: Mean DBP
b Predictors: (Constant), CRF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	77,265	3,655		21,140	,000
	CRF	-,236	,085	-,094	-2,794	,005

a Dependent Variable: Mean DBP

Appendix 10.4 Hypothesis 2c: *Height has an influence on SBP and DBP values*

Results of the regression analysis for SBP in dependency of height

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,182a	,033	,032	13,28710

a Predictors: (Constant), height

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5053,881	1	5053,881	28,626	,000b
	Residual	146887,082	832	176,547		
	Total	151940,963	833			

a Dependent Variable: Mean SBP
b Predictors: (Constant), height

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	68,891	7,500		9,185	,000
	q014_height	,286	,053	,182	5,350	,000

a Dependent Variable: MeanSBP

Results of the regression analysis for DBP in dependency of height

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,085a	,007	,006	10,93951

a Predictors: (Constant), height

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	730,280	1	730,280	6,102	,014b
	Residual	99567,751	832	119,673		
	Total	100298,031	833			

a Dependent Variable: Mean DBP

b Predictors: (Constant), height

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	51,899	6,175		8,404	,000
	q014_height	,109	,044	,085	2,470	,014

a Dependent Variable: MeanDBP

Appendix 10.5 Hypothesis 3a: *SBP, DBP and CRF differ between children from the NA and TA*

Descriptive statistics of CRF, SBP, DBP in NA and TA

		Location	
		NA (*n* = 411)	**TA (*n* = 459)**
CRF	*M* (±*SD*)	42.57 (4.3)	43.40 (4.39)
SBP	*M* (±*SD*)	108.74 (12.56)	109.19 (14.24)
DBP	*M* (±*SD*)	65.34 (8.7)	68.69 (12.38)

Annotation: SBP = Systolic Blood Pressure [mmHg]; DBP = Diastolic Blood Pressure [mmHg]

Appendix 10.6 Hypothesis 3c: *SBP, DBP and CRF differ between ethnicities*

Differences of CRF within the ethnicities

ANOVA

CRF

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1,993	2	,996	,052	,949
Within Groups	16102,518	838	19,215		
Total	16104,511	840			

Differences of SBP within the ethnicities

ANOVA

Mean SBP

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	277,443	2	138,721	,750	,473
Within Groups	154951,276	838	184,906		
Total	155228,718	840			

Differences of DBP within the ethnicities

Tests of Between-Subjects Effects

Dependent Variable: DBP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	952,751a	2	476,376	3,941	,020	,009
Intercept	2304800,615	1	2304800,615	19069,297	,000	,958
Ethnicity	952,751	2	476,376	3,941	,020	,009
Error	101284,433	838	120,864			
Total	3900367,750	841				
Corrected Total	102237,184	840				

a R Squared = ,009 (Adjusted R Squared = ,007)

Multiple Comparisons *(Games-Howell, Dependent Variable: DBP)*

(I) Ethnicity	(J) Ethnicity	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
black	coloured	2,5097*	,79763	,005	,6348	4,3846
	other	1,1592	1,02066	,494	-1,2546	3,5730
coloured	black	-2,5097*	,79763	,005	-4,3846	-,6348
	other	-1,3505	1,06710	,416	-3,8720	1,1709
other	black	-1,1592	1,02066	,494	-3,5730	1,2546
	coloured	1,3505	1,06710	,416	-1,1709	3,8720

Based on observed means.

The error term is Mean Square(Error) = 120,864.

* The mean difference is significant at the ,05 level.

Declaration of authenticity

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