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Hypertension among South African children in disadvantaged areas and associations with physical activity, fitness, and cardiovascular risk markers: A cross-sectional study

Nandi Joubert [a,b,c], Cheryl Walter [d], Rosa du Randt [d], Ann Aerts [e], Larissa Adams [d], Jan Degen [c], Stefanie Gall [c], Ivan Müller [c], Madeleine Nienaber [d], Siphesihle Nqweniso [d], Sarah des Rosiers [e], Harald Seelig [c], Danielle Smith [d], Peter Steinmann [a,b], Nicole Probst-Hensch [a,b], Jürg Utzinger [a,b], Uwe Pühse [c] and Markus Gerber [c]

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ABSTRACT

Childhood hypertension drives hypertension in later life; hence, assessing blood pressure in children is an important measure to determine current and future cardiovascular health. There is, however, a paucity of childhood blood pressure data, particularly for sub-Saharan Africa. This study explores blood pressure and associations with age, sex, socioeconomic status, physical activity, fitness, and cardiovascular risk markers. In the 'Disease, Activity and Schoolchildren's Health' (DASH) study, a cross-sectional analysis was conducted in disadvantaged neighbourhoods in the Eastern Cape province of South Africa. Assessments included blood pressure, accelerometer-measured physical activity, physical fitness, and cardiovascular risk markers. The study consisted of 785 children (383 boys, 402 girls, $M = 12.4 \pm 0.9$ years). Overall, 18% of the children were classified as hypertensive, while 20% were either overweight/obese, and almost four out of ten children did not meet global daily physical activity recommendations. Hypertensive children were more likely to be overweight/obese, χ^2 (2,785) = 14.42, $p < 0.01$, but only if they did not meet physical activity recommendations, χ^2 (2,295) = 11.93, $p < 0.01$. Considering the moderating effect which sufficient activity has on the relationship between hypertension and body weight, more emphasis should be placed on early primary health intervention and education strategies.

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KEYWORDS
Cardiovascular risk markers; hypertension; physical activity; physical fitness; schoolchildren; South Africa

1. Introduction

Hypertension is responsible for an estimated 7.5 million deaths globally, corresponding to 12.8% of total annual mortality, and causes a global burden of 57 million disability-adjusted life years (DALYs) (World Health Organization, 2015). During the past four decades, the highest prevalence of hypertension has shifted from high-income countries to low- and middle-income countries (LMICs), especially sub-Saharan Africa (Zhou et al., 2017). This is, for example, seen in South Africa, where, according to the World Health Organization (WHO) strategic advisory group of experts, nearly half of the adult population lives with hypertension, compared to higher-income countries, where the prevalence is lower, at around 35% (Ware et al., 2017).

Evidence suggests that a shift towards high blood pressure or hypertension during childhood is a driver of hypertension in later life, emphasising the importance of early high blood pressure detection, prevention and intervention (Chen & Wang, 2008). However, childhood hypertension is often underdiagnosed, either unassessed or incorrectly measured (Murigo-Shumba et al., 2019). This holds for LMICs, where even less is known about childhood hypertension, especially within the African context. This is apparent since only a single review is available, reporting on a total of 54,196 children concerning the prevalence of elevated blood pressure in African youth (Noubiap et al., 2017). Based on this meta-analysis, the prevalence of child and adolescent prehypertension (defined as systolic or diastolic blood pressure ≥90th percentile) and hypertension (defined as systolic or diastolic blood pressure ≥95th percentile) in Africa are estimated to be 12.7% (95% CI: 2.1, 30.4) and 5.5% (95% CI: 4.2, 6.9), respectively. In studies with South African children (Awotidebe et al., 2016; Monyeki et al., 2008; Motswagole et al., 2011), the mean prevalence was found to be slightly increased compared to the overall African population at 8.1% (95% CI: 4.3, 13.1).

Associations between hypertension and factors such as population growth and ageing, urbanisation, and socioeconomic conditions are well established globally (Zhou et al., 2017). The aetiology of childhood hypertension is, however, complex, and links between blood pressure and sociodemographic factors are

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List of abbreviations*ANCOVA*: Analyses of Covariance; *ANOVA*: Analyses of Variance; BMI: Body Mass Index; DALYs: Disability-Adjusted Life Years; DASH: Disease, Activity and Schoolchildren's Health; EKNZ: Ethics Committees of Northwest and Central Switzerland; HbA1c: Glycosylated Haemoglobin; HBSC: Health-Behaviour in School Aged Children; HDL: High Density Lipoprotein; ISRCTN: International Standard Registered Clinical/Social Study Number; LDL: Low Density Lipoprotein; LMICs: Low- and Middle-Income Countries; LPA: Light intensity Physical Activity; *M*: Mean; *Md*: Median; METs: Metabolic Equivalence; MPA: Moderate intensity Physical Activity; MVPA: Moderate-to-Vigorous intensity Physical Activity; NRF: National Research Foundation of South Africa; *SD*: Standard Deviation; SES: Socioeconomic Status; SNSF: Swiss National Science Foundation; SSAJRP: Swiss-South African Joint Research Programme; VO_2max: Maximal oxygen uptake in ml per kg body weight per minute; VPA: Vigorous intensity Physical Activity; WHO: World Health Organization; zBMI: BMI-for-age z-scores; χ^2: Chi-squared Test not consistently investigated in children and adolescents. Strong relationships have, however, been established between hypertension and lifestyle factors, such as dietary habits and physical activity (Popkin, 2006). Physical activity, for example, has been identified as a key modality in the prevention and treatment of high blood pressure in children (Zhou et al., 2017). The assessment and interpretation of the physical activity behaviour of children and adolescents is among the most challenging tasks in epidemiology (Mountjoy et al., 2011). Currently, lifestyle behaviours such as physical activity are often assessed through self-report measures (Guthold et al., 2019), providing conservative estimates at best (Ding et al., 2016). Self-reported questionnaires have been criticised because of their limited reliability, accuracy, and criterion validity, and because they tend to overestimate physical activity behaviour among children and adolescents (Adamo et al., 2009; Corder et al., 2008; Nigg et al., 2020). Therefore, more device-based childhood activity data are required to deepen the understanding regarding the relationship between activity and hypertension, particularly in LMICs. From a public health and epidemiological point of view, such insights would be important to determine whether different measures of physical activity are similarly associated with elevated blood pressure in African youth.

Additionally, although cardiovascular disease normally presents during adulthood, risk factors for these diseases can already be present in children (Xi et al., 2017). This has been confirmed in a large study where cardiometabolic risk factors (including hyperglycaemia, dyslipidaemia, and unfavourable body composition) have been found to track from childhood into adulthood, from ages as young as five years (Koskinen et al., 2017). These cardiometabolic risk factors usually co-occur and share determinants with elevated blood pressure, and hence, provide a rationale for the simultaneous assessment.

Against this background, the purpose of the present paper was five-fold. First, to estimate the prevalence of hypertension in South African children attending primary schools in selected disadvantaged communities in a typical South African urban area. Second, to examine whether hypertension is associated with children's age, sex, and socioeconomic status (SES). Third, to determine whether children classified as hypertensive differ from their prehypertensive and non-hypertensive peers regarding physical activity patterns (including self-reported and device-based measures), physical fitness (including cardiorespiratory fitness and grip strength), and cardiovascular risk markers (including body composition, blood lipids, and blood glucose levels). Fourth, to investigate whether children classified as hypertensive are more likely to be classified as overweight/obese, and to fall below recommended levels of physical activity, compared to their non-hypertensive peers. Finally, to explore whether the relationship between hypertension and body weight status is moderated by children's physical activity levels.

2. Materials and methods

2.1. Study set-up

The findings presented in this article stem from a cluster-randomised controlled trial, conducted within the frame of the 'Disease, Activity and Schoolchildren's Health' (DASH) study (Yap et al., 2015). The main purpose of the DASH study was to examine the effects of a school-based health promotion programme, targeting children's physical health, cognition, and psychosocial wellbeing. The health promotion intervention programme was conducted over a 10-week period, implemented twice, and focused on increasing physical activity, health and hygiene education, deworming, and nutritional supplementation. There were four data assessments: (i) at baseline before the intervention in February 2015; (ii) after the first 10-week intervention period in October 2015; (iii) after the second 10-week intervention period in May 2016; and (iv) in February 2018 for the final follow-up. For the present paper, only a cross-sectional analysis of the final follow-up data was carried out. This is due to financial limitations, only allowing accelerometer-based physical activity, average blood glucose and lipid data to be collected during the final follow-up data assessment phase.

Parents or guardians of children received detailed written and oral information about the aims of the study, the procedures applied, and potential risks and benefits. Parents/guardians were asked to provide written informed consent before the first data assessment took place. Additionally, children were informed and provided oral assent. Approval of the registered study protocol was obtained from the responsible ethical committees in South Africa and Switzerland. Additionally, the Eastern Cape Departments of Education and Health provided approval for the study. All procedures were in accordance with the ethical principles of the Declaration of Helsinki.

2.2. Participants

Participants were recruited from eight different quintile three primary schools located in Gqeberha in the Eastern Cape province of South Africa. Of note, in the South African school system, quintile one to three schools are schools that are considered as "disadvantaged", based on national poverty tables, income levels, dependency ratios, and literacy rates in the surrounding community. Quintile three is the lowest quintile found within the Gqeberha area. A detailed description of the school-selection procedures is available from the published study protocol (Yap et al., 2015). In brief, children were included in the study if they were willing to participate, had written informed consent from a parent/guardian, did not simultaneously participate in other clinical trials during the study period, and did not suffer from medical conditions that prevented participation in the study (as determined by a registered professional nurse).

All children (n = 1,009) were in grade four, aged 8–13 years at the baseline survey in February 2015. The wide age range can be explained by the fact that it is not unusual for children attending lower quintile ranking schools to fail a few grades, or the same grade more than once. From the baseline assessment, a total of 224 children were lost to follow-up, with 142 children leaving the school, and 82 children absent from school during the follow-up data assessment period in February 2018. The final study sample consisted of 785 grade seven children (383 boys, 402 girls, M = 12.4 ± 0.9 years) in February 2018.

Univariate analyses of variance (*ANOVAs*) showed that, compared to children included in the study, children lost to follow-up were significantly (p < 0.05) older at baseline

($M = 9.9 \pm 1.1$ years vs. $M = 9.4 \pm 0.9$ years), had lower SES ($M = 7.2 \pm 2.3$ vs. $M = 7.5 \pm 2.0$), had lower thickness of skinfold scores ($M = 19.5 \pm 8.5$ mm vs. $M = 21.4 \pm 10.8$ mm), performed better in the 20 m shuttle run test ($M = 39.4 \pm 17.4$ laps completed in the 20 m shuttle run test vs. $M = 35.2 \pm 17.0$ laps), and the handgrip strength test (absolute values: $M = 12.6 \pm 3.3$ kg vs. $M = 11.9 \pm 3.0$ kg; normalized values: $M = 39.8 \pm 8.7$ vs. $M = 41.9 \pm 37.8$). Chi-squared tests (χ^2) further showed that the dropout rate was significantly ($p < 0.05$) higher among boys (26%) compared to girls (18%). After controlling for age and sex, children who completed the study assessment, and those who did not, did not statistically differ in any of the study variables at baseline.

2.3. Assessment of blood pressure

To detect hypertension, blood pressure was assessed with a validated oscillometric digital blood pressure monitor (Omron® M6 AC; Hoofddorp, Netherlands). Before the measurement, children were asked to sit quietly for 5 min. With the left arm at heart level and the palm facing upward, the cuff was wrapped around the upper arm, in line with the brachial artery. The cuff-size (17–22 cm) was appropriate for children's arm circumference ranges. Three measurements (with an interval of 1 min between each measurement) were performed, and as indicators of systolic and diastolic blood pressure, the mean of the last two measurements was used. This is due to the first reading often overestimating both systolic and diastolic blood pressure. Normal and hypertensive blood pressure reference values exist for children living in Europe (Neuhauser et al., 2011) and the United States of America (Falkner & Daniels, 2004), whereas no values are currently available for children from sub-Saharan Africa (Agyemang et al., 2005). Accordingly, reference tables from a nationally representative sample of 12,199 non-overweight German children (aged 3–17 years) were used, because in this sample standardised blood pressure assessments were applied with a comparable automated oscillometric device (Neuhauser et al., 2011).

Based on percentiles, considering children's age, sex, and height, children were considered normotensive if they were below the 90th percentile, prehypertensive if they were between the 90th and 94th percentile, or hypertensive from the 95th percentile upwards. Classifications were done separately for systolic and diastolic blood pressure. Additionally, as in the case with adult hypertension classification, a combined classification system was created, where children were considered hypertensive if they were classified as being hypertensive either regarding systolic or diastolic blood pressure.

2.4. Assessment of physical activity

In the present study, self-reported and device-based measures of physical activity behaviour were determined. Self-reported physical activity was assessed through a single item from the Health-Behaviour in School-Aged Children (HBSC) study survey (Currie et al., 2010). The question read: "Over the past 7 days (1 week), on how many days were you physically active for a total of at least 60 minutes (1 hour) a day?". The answers ranged from zero to seven days. When more detailed activity questionnaires were compared to accelerometer measured physical activity, similar associations were found as with the single item used here (Scott et al., 2015). Moreover, similar items are used in epidemiological studies to estimate and monitor the global level of physical activity among children and adolescents (Guthold et al., 2019; Muthuri et al., 2014).

Device-based physical activity was measured with a light triaxial accelerometer (ActiGraph® wGT3X-BT; Pensacola, Florida, United States of America). These devices have been shown to accurately measure free-living physical activity in children (Hills et al., 2014). Children were asked to wear the device around the hip, for seven consecutive days (five weekdays and two weekend days), except during activities that involved water, such as bathing. A sample rate of 30 Hz was used, and data were stored in 10 sec epochs. ActiLife software (version 6.13.3) was used to analyse the raw data. Valid wear time was set at a minimum of eight hours per day (Aadland et al., 2017), whereas non-wear time was calculated with the Troiano algorithm (Troiano et al., 2008), using default settings. To be included in the final analyses, children had to have valid data for ≥4 weekdays and ≥1 weekend day (Clemente et al., 2016). Weekly physical activity scores were calculated as follows:

$$(sum\ of\ all\ valid\ days\ \div\ number\ of\ valid\ days)\ x\ 7$$

Cut-points, defined explicitly for children, were used to calculate an overall index for moderate-to-vigorous intensity physical activity (MVPA) (Evenson et al., 2008). This was done to establish whether children met the global minimum recommended amount of 60 min of MVPA daily (World Health Organization, 2010a).

2.5. Assessment of physical fitness

Children's cardiorespiratory fitness was assessed using the 20 m multistage shuttle run test, based on the standardised test protocol (Council of Europe Committee for the Development of Sport, 1993). The running speed, determined by a sound signal, started at 8 km/h and steadily increased by 0.5 km/h every minute. Children had to stop the test when they were not able to maintain the speed of the sound signal for two consecutive rounds. Based on the number of fully-completed 20 m laps, children's maximum oxygen uptake (VO_2max) was estimated, using a standard formula (Léger et al., 1988). The reliability and validity of the 20 m shuttle run test have been established in previous research (Liu et al., 1992; Mayorga-Vega et al., 2015). In the present paper, both the number of fully-completed laps ran and VO_2max (in ml/kg/min) are reported as outcomes of the 20 m shuttle run test.

To assess children's upper-body muscular strength, a handgrip strength test was performed (Council of Europe Committee for the Development of Sport, 1993), using a Saehan hydraulic handheld dynamometer (MSD Europe BVBA; Tisselt, Belgium). Each child was seated upright, with the elbow bent at a 90° angle, gripping the dynamometer, after it was adjusted to the individual hand size. A visual instruction was provided by a research assistant, and verbal instruction was given to grip the dynamometer as hard as possible. The dominant hand was noted before three attempts with each hand, with results recorded to the nearest 0.1 kg, were completed. A 30 sec rest period between trials with the same hand was provided. All trials were averaged to obtain the final grip strength score. Evidence for the reliability and validity of the grip strength test has been published (Ruiz et al., 2011; Wind et al., 2010). In the present study, both absolute and normalized *([grip strength, in kg / body mass, in kg] * 100)* scores are presented (Peterson et al., 2016).

2.6. Assessment of cardiovascular risk markers

To assess children's body composition, the body mass index (BMI) was calculated based on height and weight. Body weight was measured with an electronic platform scale (Micro T7E, Optima Electronics; George, South Africa), to the nearest 0.1 kg. Body height was measured with a Seca Stadiometer (Surgical SA; Johannesburg, South Africa), to the nearest 0.1 cm. The BMI was defined as:

$$weight\ (in\ kg) \div height^2 (in\ m)$$

Additionally, BMI-for-age z-scores (zBMI), stratified by sex, were calculated using the growth reference of WHO (2007). Children were considered overweight if they had a zBMI >+1 standard deviation (*SD*) above the WHO growth reference median. If their zBMI was >+2 *SD* above the WHO growth reference, they were classified as obese.

Thickness of skinfolds was assessed three times each at the triceps and the subscapular position with a Harpenden skinfold calliper (Baty International; West Sussex, United Kingdom), to the nearest 0.1 mm. To obtain an overall index, the mean of all six measurements was calculated (Slaughter et al., 1988).

Fasting capillary blood sampling was used to measure blood markers of cardiovascular risk, with the point-of-care Alere Afinion AS100 analyser (Abbott Technologies; Abbott Park; Illinois, United States of America). Children needed to fast overnight, not eating or drinking (except water) after dinner, until they competed blood sampling the next morning. Drops of blood were taken via finger prick to measure total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, and average blood glucose (HbA1c). Capillary blood sampling was used, since WHO considers this technology minimally invasive and painful, quicker, less distressing than venepuncture, and hence, it is well suited for paediatric research (World Health Organization, 2010b). Evidence of the clinical utility and accuracy of this method has been published previously (Parikh et al., 2009).

2.7. Assessment of socioeconomic status

SES was measured through a questionnaire assessing household-level living standards, including housing characteristics (i.e. house type, number of bedrooms, water, electricity, etc.) and durable assets (i.e. refrigerator, washing machine, television, etc.). An overall index was built with all binary outcomes (0 = poor quality/unavailable; 1 = high quality/available), where lower scores reflected lower SES. Similar measures have been validated in previous research (Filmer & Pritchett, 2001).

2.8. Statistical analysis

Means (*M*) and *SD* are reported for continuous variables without serious violation of normality. According to West et al. (1995) this is the case if skewness is <2 and kurtosis <7. In case of serious violation of non-normality, medians (*Md*) and interquartile ranges are reported. Prevalence rates are reported as frequencies (*n*), percentages (%) and 95% confidence interval (95% CI). To assess whether hypertension is associated with children's age, sex, or SES, we performed four separate χ^2 tests, comparing younger (10–12 years) and older children (13–16 years), boys and girls, and children with lower (0–7) and higher (8–9) SES scores.

To examine whether children classified as hypertensive differ from their prehypertensive and normotensive peers regarding physical activity behaviour, physical fitness, and cardiovascular risk markers, we performed a series of univariate *ANOVAs* (in case of variables which seriously violated non-normality, log-transformations were performed before carrying out further inferential statistics). Separate classification systems were applied, based on children's systolic and diastolic blood pressure, and a combination of both. Moreover, three different models were considered to compare groups. Model 1 was based on uncontrolled *Welch* tests, as the number of normotensive children was higher than their prehypertensive and hypertensive peers. Model 2 was based on analyses of covariance (*ANCOVAs*), to control for children's age, sex, and SES. In Model 3, we added zBMI to account for the fact that in children, a close link may exist between hypertension and body composition. Furthermore, we performed two separate χ^2 tests to examine whether children classified as hypertensive were more likely to be classified as overweight/obese and/or to fall below physical activity recommendations (represented by children who met the 60 min of MVPA daily vs. those who did not). Additionally, to establish whether the association between children's hypertension and body weight status was moderated by their physical activity levels, another χ^2 test was performed, stratified by physical activity level (above vs. below the recommendation). All statistical analyses were carried out with SPSS version 25 for Mac (IBM; Armonk, New York, United States of America). The level of statistical significance was set at $p < 0.05$ for all analyses.

3. Results

3.1. Descriptive statistics

Descriptive statistics are presented in Table 1. Regarding systolic blood pressure, 646 (82%, 95% CI: 79.3, 84.8) of the children were classified as normotensive, 46 (6%, 95% CI: 4.5, 7.9) as prehypertensive, and 93 (12%, 95% CI: 9.6, 14.2) as hypertensive. Regarding diastolic blood pressure, 666 children (85%, 95% CI: 82.3, 87.4) were classified as normotensive, 41 (5%, 95% CI: 3.7, 6.9) as prehypertensive, and 78 (10%, 95% CI: 7.9, 12.2) as hypertensive. In total, 142 children (18%, 95% CI: 15.5, 20.9) were classified as hypertensive, either with regard to systolic or diastolic blood pressure. Furthermore, 104 (13%, 95% CI: 10.7, 15.5) of the children were classified as overweight, while 47 (6%, 95% CI: 6.8, 10.9) were obese. Regarding children's

Table 1. Descriptive statistics of all study variables, for the total sample, in February and March 2018.

Continuous variables	*n*[a]	*M*[j]	*SD*[j]
Age (years)	785	12.4	0.9
Socioeconomic status (0–9)	754	7.5	2.0
Systolic blood pressure (mm Hg)	785	109.8	11.3
Diastolic blood pressure (mm Hg)	785	66.6	8.1
Weight (kg)	785	43.6	11.9
Height (cm)	785	149.6	8.1
BMI (kg/m^2)	785	19.3	4.2
zBMI[b]	785	0.0	1.4
Skinfolds (mm)[c]	784	11.0	6.3
Total cholesterol (mmol/L)	685	3.5	0.7
HDL cholesterol (mmol/L)[d]	685	1.4	0.3
LDL cholesterol (mmol/L)[e]	685	1.8	0.6
HbA1c (%)[f]	735	5.5	0.2
20 m shuttle run performance (laps)	753	37.3	20.8
Cardiorespiratory fitness (VO_2max [ml/kg/min])	753	44.5	5.6
Grip strength (kg)	783	19.4	5.0
Normalized grip strength (kg/weight [kg]*100)	783	45.7	10.0
Number of physically active days [g]	785	4.0	2.2
Total METs[h]	751	1.7	0.2
Sedentary activity (min/day)	751	659.4	86.8
Light physical activity (min/day)	751	261.7	50.7
Moderate physical activity (min/day)	751	51.0	19.3
Vigorous physical activity (min/day)	751	22.2	15.8
MVPA (min/day)[i]	751	73.1	32.8
	n[a]	*Md*[j]	Interquartile range (25th-75th percentile)[j]
Triglycerides (mmol/L)	685	0.7	0.5–0.9
Categorical variables	*n*	%	
Sex			
Girls	402	51.2	
Boys	383	48.8	

[a]Number of learners varies due to different numbers of missing values in specific outcome variables.
[b]BMI-for-age z-scores.
[c]Mean of all six measurements.
[d]High-density lipoprotein cholesterol.
[e]Low-density lipoprotein cholesterol.
[f]Glycosylated haemoglobin.
[g]Number of days with ≥ 60 min MVPA per day.
[h]Metabolic equivalent.
[i]Moderate-to-vigorous physical activity.
[j]Results for continuous variables without serious violation of normality are presented with means (*M*) and standard deviations (*SD*), whereas variables with severe violation of normal distribution are presented with medians (*Md*) and inter-quartile ranges (25th – 75th percentile).

device-based physical activity levels, 295 children (39%, 95% CI:_35.6, 42.6) did not meet physical activity recommendations, whereas 456 children (61%, 95% CI: 57.4, 64.4) were in line with the current recommendation.

3.2. Hypertension and sociodemographic background

Girls and boys were similarly represented in the group classified as normotensive, prehypertensive, and hypertensive, independently of whether systolic (χ^2 [2,785] = 1.26 *p* = 0.533), diastolic blood pressure (χ^2 [2,785] = 2.87, *p* = 0.238), or the combined classification (χ^2 [1,785] = 0.96, *p* = 0.327) was used. Similarly, no significant associations were observed regarding children's age (younger vs. older; systolic: χ^2 [2,785] = 0.16, *p* = 0.925; diastolic: χ^2 [2,785] = 1.35, *p* = 0.509; combined: χ^2 [1,785] = 1.76, *p* = 0.184), or SES (lower vs. higher; systolic: χ^2 [2,754] = 3.02, *p* = 0.221; diastolic: χ^2 [2,754] = 3.13, *p* = 0.216; combined: χ^2 [1,754] = 1.33, *p* = 0.249).

3.3. Differences between normotensive, prehypertensive, and hypertensive children

3.3.1. Categorisation based on systolic blood pressure

If systolic blood pressure was used to classify children as normotensive, prehypertensive, or hypertensive, normotensive children had significantly lower values for systolic and diastolic blood pressure than prehypertensive and hypertensive peers (Table 2, Model 1). They also had lower body weight and height, lower BMI, lower zBMI, lower skinfold thickness, lower LDL cholesterol levels, and lower grip strength than hypertensive peers. By contrast, normotensive children performed better in the 20 m shuttle run test, and spent more time in vigorous-intensity physical activity (VPA) and MVPA, whereas hypertensive children engaged in more sedentary activities. No significant differences were found for the other cholesterol markers, HbA1c, or self-reported physical activity.

After controlling for age, sex, and SES (Table 2, Model 2), most group differences persisted (except for LDL cholesterol). Nevertheless, most of these differences seem to be attributable

Table 2. Differences between children classified as normotensive, prehypertensive, and hypertensive (based on systolic blood pressure), after controlling for age, sex, socioeconomic status, and zBMI scores.

		Normotensive		Pre-hypertensive		Hypertensive		Model 1: Uncontrolled, based on *Welch* test		Model 2: Controlled for age, sex, and SES		Model 3: Controlled for age, sex, SES, and zBMI	
	n[a]	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	η^2	*F*	η^2	*F*	η^2
Systolic blood pressure (mm Hg)	785 (646/46/93)	106.2	8.5	120.8	2.4	129.8	5.2	407.1***[k]	0.510	395.5***	0.514	360.7***	0.493
Diastolic blood pressure (mm Hg)	785 (646/46/93)	65.4	7.5	69.7	7.7	73.5	8.8	49.9***	0.113	47.1***	0.112	42.0***	0.101
Weight (kg)	785 (646/46/93)	32.6	10.8	44.5	12.2	50.1	16.0	16.8***[k]	0.041	19.7***	0.050	–	–
Height (cm)	785 (646/46/93)	149.2	8.1	149.5	7.1	152.3	8.2	6.1**	0.015	7.6**	0.020	–	–
BMI (kg/m^2)	785 (646/46/93)	19.0	3.8	19.7	4.1	21.5	5.8	14.7***[k]	0.036	17.0***	0.044	–	–
zBMI[b]	785 (646/46/93)	−0.1	1.3	0.1	1.3	0.7	1.4	13.4***	0.033	15.7***	0.040	–	–
Skinfolds (mm)[c]	784 (645/46/93)	10.6	5.8	12.1	7.2	13.5	8.0	9.7***[k]	0.024	12.1***	0.031	0.6	0.002
Total cholesterol (mmol/L)	685 (569/40/76)	3.5	0.7	3.6	0.6	3.7	0.7	3.0	0.009	2.6	0.008	2.7	0.008
HDL cholesterol (mmol/L)[d]	685 (569/40/76)	1.4	0.3	1.4	0.4	1.4	0.4	0.2	0.001	0.3	0.001	0.4	0.001
LDL cholesterol (mmol/L)[e]	685 (569/40/76)	1.8	0.5	1.9	0.6	1.9	0.6	3.3*	0.010	2.9	0.009	2.0	0.007
Triglycerides (mmol/L)[f]	685 (569/40/76)	0.8	0.3	0.8	0.3	0.8	0.4	0.7	0.002	0.3	0.001	0.2	0.000
HbA1c (%)[g]	735 (606/43/86)	5.5	2.4	5.5	2.4	5.5	2.5	0.0	0.000	0.2	0.000	0.1	0.000
20 m shuttle run performance (laps)	753 (621/44/88)	38.2	20.8	24.3	21.0	32.7	19.3	3.2*	0.009	3.7*	0.010	0.5	0.001
Cardiorespiratory fitness (VO_2max [ml/kg/min])	753 (621/44/88)	44.8	5.6	43.7	5.6	43.3	5.4	3.0*	0.008	3.3*	0.009	0.3	0.001
Grip strength (kg)	783 (644/46/93)	19.2	4.8	19.3	4.5	21.0	5.9	5.6**	0.014	7.5**	0.020	1.3	0.004
Normalized grip strength (kg/weight [kg]*100)	783 (644/46/93)	46.0	9.8	45.3	11.6	43.3	9.8	3.1*	0.008	4.0*	0.010	–	–
Number of physically active days[h]	785 (646/46/93)	4.0	2.2	4.2	2.0	3.7	2.0	1.2	0.003	1.3	0.004	1.4	0.004
Sedentary activity (min/day)[i]	751 (619/43/89)	655.6	87.1	654.5	89.1	688.5	78.7	5.8**	0.015	4.4*	0.012	4.3*	0.012
Light physical activity (min/day)[i]	751 (619/43/89)	261.9	52.3	266.9	48.5	257.2	38.5	0.6[k]	0.002	2.2	0.006	0.8	0.002
Moderate physical activity (min/day)[i]	751 (619/43/89)	51.7	19.6	49.8	16.4	46.5	17.6	2.9	0.008	2.2	0.006	0.6	0.002
Vigorous physical activity (min/day)[i]	751 (619/43/89)	22.8	16.0	21.3	15.9	18.0	13.9	3.8*	0.010	3.4*	0.010	1.5	0.004
MVPA (min/day)[i,j]	751 (619/43/89)	74.5	33.3	71.1	29.3	64.5	29.4	3.7*	0.010	5.2**	0.014	1.1	0.003

[a]Number of learners varies due to different numbers of missing values in specific outcome variables and reflects *n* before controlling for covariates. Numbers in brackets correspond to learners classified as normotensive, prehypertensive, and hypertensive (based on systolic blood pressure).
[b]BMI-for-age z-scores.
[c]Mean of all six measurements.
[d]High-density lipoprotein cholesterol.
[e]Low-density lipoprotein cholesterol.
[f]Variable was log-transformed before carrying out analyses.
[g]Glycosylated haemoglobin.
[h]Number of days with ≥ 60 min MVPA per day.
[i]Controlled for daily accelerometer wear time; across all models.
[j]Moderate-to-vigorous physical activity.
[k]Levene test is statistically significant ($p < 0.05$), indicating that variances differ between groups.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

to differences in body composition between normotensive, prehypertensive, and hypertensive children. Thus, after adding zBMI as an additional covariate (Table 2, Model 3), only three significant differences remained, indicating that hypertensive children have higher systolic and diastolic blood pressure, and engage in more sedentary activities than normotensive and prehypertensive peers.

3.3.2. Categorisation based on diastolic blood pressure

A similar pattern of results was found if diastolic blood pressure was used to classify children as normotensive, prehypertensive, or hypertensive. As shown in Table 3 (Model 1), significant group differences were found with regard to systolic and diastolic blood pressure, body weight, BMI, zBMI, skinfold thickness, total cholesterol, LDL cholesterol, triglycerides, HbA1c, normalized grip strength, as well as device-based light-intensity physical activity (LPA), moderate-intensity physical activity (MPA), VPA, and MVPA.

After controlling for age, sex, and SES (Table 3, Model 2), most of the differences persisted, indicating that independent from social and demographic background, normotensive children had lower body weight, lower BMI and zBMI, lower skinfold thickness, lower triglyceride levels, higher normalized grip strength, and less sedentary activity than hypertensive peers. By contrast, normotensive peers reported more time spent in LPA. After adding zBMI as an additional covariate (Table 3, Model 3), total cholesterol, LDL cholesterol, triglyceride, HbA1c, and LPA differences persisted.

3.3.3. Categorisation based on combined classification

When the distinction between normotensive and hypertensive participants was made both on children's systolic and diastolic blood pressure, hypertensive children had higher body weight and height, higher BMI and zBMI, higher thickness of skinfolds, higher total cholesterol and triglyceride levels, higher grip strength, and higher device-based sedentary activity (Table 4, Model 1). By contrast, normotensive children had higher cardiorespiratory fitness and engaged in more device-based LPA, MPA, VPA, and MVPA. Most of these differences persisted after controlling for the social and demographic background (Table 4, Model 2).

After adding zBMI as an additional covariate (Table 4, Model 3), differences in skinfold thickness, triglyceride levels, and physical fitness (both grip strength and cardiorespiratory fitness) disappeared, whereas the differences in (device-based) physical activity behaviour remained significant. No significant differences were found with regard to self-reported physical activity.

3.4. Hypertension, body composition, and device-based physical activity

Figure 1 highlights that a significant relationship exists between children's hypertension status and their body composition, χ^2 (2,785) = 14.42, $p < 0.01$. Thus, hypertensive children are statistically overrepresented in the group of overweight/obese children. Whereas 19.2% were classified as overweight/obese among normotensive children, in hypertensive children, 31.9% fell into this category.

Moreover, as depicted in Figure 2, based on accelerometer data, children classified as hypertensive were less likely to meet recommended levels of MVPA than normotensive peers, χ^2 (1,751) = 7.39, $p < 0.01$. Whereas 63.0% achieved recommended MVPA standards among normotensive children, this percentage was markedly lower in their hypertensive peers at 50.4%. Furthermore, the prevalence of overweight/obese children was 13.6% among children above physical activity recommendations (8.8% overweight, 4.8% obese), whereas this percentage was 34.2% (18.6% overweight, 15.6% obese) among children below physical activity recommendations, χ^2 (2,751) = 46.48, $p < 0.001$.

The relationship between hypertension and body weight status was moderated by children's device-based MVPA levels. As illustrated in Figure 3, if children did not meet recommended levels of physical activity, the percentage of children who were classified as overweight/obese was significantly higher among hypertensive children (50.8%) than among normotensive peers (29.4%), χ^2 (2,295) = 11.93, $p < 0.01$. By contrast, no significant difference was found between hypertensive (16.2% overweight/obese) and normotensive children (13.2% overweight/obese) among children who were above current physical activity recommendations, χ^2 (2,456) = 1.12, $p = 0.571$.

4. Discussion

The principal findings of this paper involve the interplay between blood pressure, body composition, and physical activity, within a sample of children attending primary schools located in disadvantaged communities in South Africa. A significant relationship between hypertension and body composition was found, with hypertensive and overweight/obese children being less likely to meet the global daily MVPA recommendation. Most of the differences measured between normotensive, prehypertensive, and hypertensive children were found to be due to body composition, independent of sociodemographic factors. The relationship between hypertension and body mass was further found to be moderated by the achievement of recommended MVPA levels. In other words, being sufficiently physically active seems to protect hypertensive children from being overweight/obese.

The present paper pursued five aims, and each of these will now be further elaborated upon. First, we aimed at gaining a deeper understanding of the prevalence of hypertension in South African children attending primary schools in disadvantaged communities. Reported childhood hypertension prevalence varies greatly within the African population, ranging from 0.2–24.8%, in a recent review and meta-analysis (Noubiap et al., 2017). Within our sample, a prevalence of 18% hypertension was observed, using both systolic and diastolic blood pressure measurements. Previous comparable studies measured lower hypertension prevalence within South African children, at between 4.3% and 13% for the same age ranges and within similar geographic and community settings (Awotidebe et al., 2016; Monyeki et al., 2008; Motswagole et al., 2011). As these studies were conducted between 4 and 12 years ago, the global trend of increasing childhood hypertension, reported on in

Table 3. Differences between children classified as normotensive, prehypertensive, and hypertensive (based on diastolic blood pressure), after controlling for age, sex, socioeconomic status, and zBMI scores.

		Normotensive		Pre-hypertensive		Hypertensive		Model 1: Uncontrolled, based on *Welch* test		Model 2: Controlled for age, sex, and SES		Model 3: Controlled for age, sex, SES, and zBMI	
	n[a]	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	η^2	*F*	η^2	*F*	η^2
Systolic blood pressure (mm Hg)	785 (646/46/93)	108.2	10.8	115.0	9.3	120.8	9.9	54.6***	0.123	49.5***	0.117	45.7***	0.109
Diastolic blood pressure (mm Hg)	785 (646/46/93)	64.3	6.0	75.5	1.4	81.7	6.2	354.3***[k]	0.475	336.2***	0.473	327.2***	0.468
Weight (kg)	785 (646/46/93)	43.0	11.1	44.4	12.7	48.8	16.1	8.7***[k]	0.022	7.2**	0.019	–	–
Height (cm)	785 (646/46/93)	149.3	8.0	149.1	9.0	151.6	8.3	2.8	0.007	2.4	0.006	–	–
BMI (kg/m^2)	785 (646/46/93)	19.1	3.9	19.8	4.8	21.0	5.7	7.5***[k]	0.019	6.1**	0.016	–	–
zBMI[b]	785 (646/46/93)	–0.1	1.3	0.2	1.4	0.4	1.5	4.7**	0.012	4.1*	0.011	–	–
Skinfolds (mm)[c]	784 (645/46/93)	10.7	5.8	11.7	8.1	13.3	8.1	6.0**[k]	0.015	4.8**	0.013	0.9	0.002
Total cholesterol (mmol/L)	685 (569/40/76)	3.5	0.7	3.4	0.7	3.7	0.7	4.3**	0.012	3.9*	0.012	3.8*	0.012
HDL cholesterol (mmol/L)[d]	685 (569/40/76)	1.4	0.3	1.4	0.4	1.4	0.4	0.2	0.001	0.3	0.001	0.5	0.001
LDL cholesterol (mmol/L)[e]	685 (569/40/76)	1.8	0.5	1.6	0.6	1.9	0.6	4.5**	0.014	4.4*	0.014	4.0*	0.013
Triglycerides (mmol/L)[f]	685 (569/40/76)	0.8	0.3	0.8	0.4	0.9	0.6	4.6**[k]	0.013	4.5*	0.014	3.8*	0.012
HbA1c (%)[g]	735 (606/43/86)	5.5	0.2	5.6	0.3	5.5	0.2	8.1***[k]	0.022	6.9**	0.019	7.2**	0.020
20 m shuttle run performance (laps)	753 (621/44/88)	37.9	21.1	35.6	17.0	33.4	19.2	1.7	0.004	0.9	0.003	0.2	0.001
Cardiorespiratory fitness (VO_2max [ml/kg/min])	753 (621/44/88)	44.7	5.6	44.3	4.4	43.1	5.6	2.7	0.007	1.5	0.004	0.4	0.001
Grip strength (kg)	783 (644/46/93)	19.4	4.8	19.4	5.9	19.7	5.6	0.1	0.000	0.2	0.001	0.2	0.001
Normalized grip strength (kg/weight [kg]*100)	783 (644/46/93)	46.2	9.8	44.8	10.8	41.9	10.1	6.6**	0.017	5.3**	0.014	–	–
Number of physically active days[h]	785 (646/46/93)	4.0	2.1	4.0	2.2	4.0	2.3	0.0	0.000	0.1	0.000	0.1	0.000
Sedentary activity (min/day)[i]	751 (619/43/89)	660.4	84.1	634.2	104.2	664.8	97.8	1.9	0.005	4.9**	0.013	1.6	0.005
Light physical activity (min/day)[i]	751 (619/43/89)	263.4	50.7	274.8	39.1	239.8	51.0	8.9***	0.023	5.0**	0.014	6.6**	0.018
Moderate physical activity (min/day)[i]	751 (619/43/89)	51.5	19.5	52.7	18.4	45.4	17.4	3.5*	0.009	1.0	0.003	1.1	0.003
Vigorous physical activity (min/day)[i]	751 (619/43/89)	22.6	16.2	23.7	12.4	17.6	12.7	3.7*	0.010	1.3	0.004	0.8	0.002
MVPA (min/day)[i,j]	751 (619/43/89)	74.1	33.4	76.4	29.0	63.0	27.9	4.1*	0.011	1.4	0.004	1.1	0.003

[a]Number of learners varies due to different numbers of missing values in specific outcome variables and reflects *n* before controlling for covariates. Numbers in brackets correspond to learners classified as normotensive, prehypertensive, and hypertensive (based on systolic blood pressure).
[b]BMI-for-age z-scores.
[c]Mean of all six measurements.
[d]High-density lipoprotein cholesterol.
[e]Low-density lipoprotein cholesterol.
[f]Variable was log-transformed before carrying out analyses.
[g]Glycosylated haemoglobin.
[h]Number of days with ≥ 60 min MVPA per day.
[i]Controlled for daily accelerometer wear time; across all models.
[j]Moderate-to-vigorous physical activity.
[k]Levene test is statistically significant ($p < 0.05$), indicating that variances differ between groups.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 4. Differences between children classified as normotensive, and hypertensive (based on combined systolic and diastolic blood pressure), after controlling for age, sex, socioeconomic status, and zBMI scores.

		Normotensive		Hypertensive		Model 1: Uncontrolled, based on *Welch* test		Model 2: Controlled for age, sex, and SES		Model 3: Controlled for age, sex, SES, and zBMI	
	n[a]	*M*	*SD*	*M*	*SD*	*F*	η^2	*F*	η^2	*F*	η^2
Systolic blood pressure (mm Hg)	785 (646/46/93)	106.6	8.9	124.5	9.0	467.3***	0.374	441.3***	0.371	391.3***	0.345
Diastolic blood pressure (mm Hg)	785 (646/46/93)	64.5	6.4	76.0	8.5	331.7***[k]	0.298	318.3***	0.298	302.0***	0.289
Weight (kg)	785 (646/46/93)	42.5	10.6	49.0	15.3	35.9***[k]	0.044	37.0***	0.047	–	–
Height (cm)	785 (646/46/93)	149.0	8.1	151.9	8.1	14.2***	0.018	14.0***	0.000	–	–
BMI (kg/m^2)	785 (646/46/93)	19.0	3.7	21.1	5.5	30.1***[k]	0.037	31.8***	0.041	–	–
zBMI[b]	785 (646/46/93)	−0.1	1.3	0.5	1.4	24.9***	0.031	28.6***	0.037	–	–
Skinfolds (mm)[c]	784 (645/46/93)	10.6	5.8	13.1	7.8	18.3***[k]	0.023	20.4***	0.027	0.1	0.000
Total cholesterol (mmol/L)	685 (569/40/76)	3.5	0.7	3.6	0.7	3.5*	0.005	3.7*	0.005	4.0*	0.006
HDL cholesterol (mmol/L)[d]	685 (569/40/76)	1.4	0.3	1.4	0.4	0.7	0.001	0.8	0.001	0.0	0.000
LDL cholesterol (mmol/L)[e]	685 (569/40/76)	1.8	0.5	1.9	0.6	3.5 [k]	0.005	3.9*	0.006	2.7	0.004
Triglycerides (mmol/L)[f]	685 (569/40/76)	0.8	0.3	0.9	.05	4.6*[k]	0.007	4.2*	0.006	2.6	0.004
HbA1c (%)[g]	735 (606/43/86)	5.5	0.2	5.5	0.2	0.7	0.001	0.5	0.001	1.0	0.001
20 m shuttle run performance (laps)	753 (621/44/88)	38.1	21.0	33.3	19.3	5.9*	0.008	6.4*	0.009	0.5	0.001
Cardiorespiratory fitness (VO_2max [ml/kg/min])	753 (621/44/88)	44.8	5.6	43.3	5.4	8.2**	0.011	7.2**	0.010	0.7	0.001
Grip strength (kg)	783 (644/46/93)	19.2	4.8	20.4	5.7	7.3**	0.009	9.6**	0.013	0.7	0.001
Normalized grip strength (kg/weight [kg]*100)	783 (644/46/93)	46.2	9.9	43.2	10.0	10.8**	0.014	11.7**	0.015	–	–
Number of physically active days[h]	785 (646/46/93)	4.0	2.2	3.9	2.2	0.6	0.001	1.0	0.001	0.8	0.001
Sedentary activity (min/day)[i]	751 (619/43/89)	655.4	86.3	677.6	86.8	7.3**	0.010	13.2***	0.018	4.3*	0.006
Light physical activity (min/day)[i]	751 (619/43/89)	264.2	51.1	250.1	46.9	8.7**	0.012	7.5**	0.010	6.2*	0.009
Moderate physical activity (min/day)[i]	751 (619/43/89)	52.0	19.4	46.1	17.8	10.5**	0.014	7.6**	0.010	3.7*	0.005
Vigorous physical activity (min/day)[i]	751 (619/43/89)	23.1	16.1	18.0	13.3	11.5**	0.015	10.8**	0.015	4.2*	0.006
MVPA (min/day)[i]	751 (619/43/89)	75.1	33.3	64.2	28.9	12.5***	0.016	10.9**	0.015	4.4*	0.006

[a]Number of learners varies due to different numbers of missing values in specific outcome variables and reflects *n* before controlling for covariates. Numbers in brackets correspond to learners classified as normotensive, prehypertensive and hypertensive (based on systolic blood pressure).
[b]BMI-for-age z-scores.
[c]Mean of all six measurements.
[d]High-density lipoprotein cholesterol.
[e]Low-density lipoprotein cholesterol.
[f]Variable was log-transformed before carrying out analyses.
[g]Glycosylated haemoglobin.
[h]Number of days with ≥ 60 min MVPA per day.
[i]Controlled for daily accelerometer wear time; across all models.
[j]Moderate-to-vigorous physical activity.
[k]Levene test is statistically significant ($p < 0.05$), indicating that variances differ between groups.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

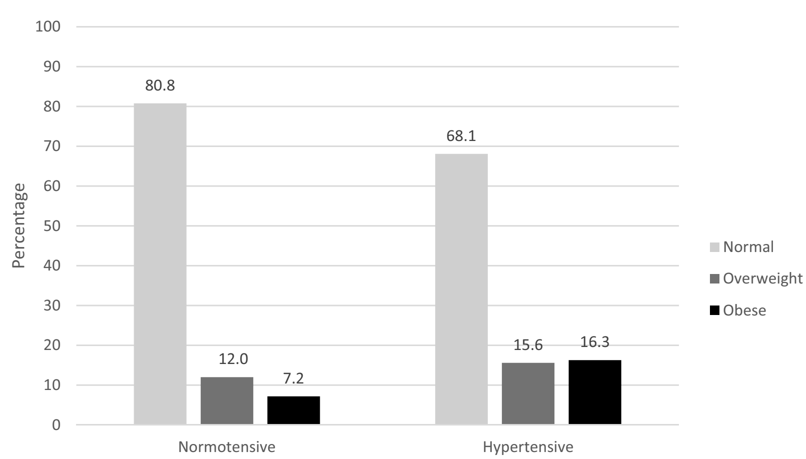

Figure 1. Percentage of children classified as normal, overweight, or obese, stratified by blood pressure status (normotensive vs hypertensive) (n = 785).

a global review and meta-analysis, appears to be supported in South Africa (Song et al., 2019).

The second purpose was to examine whether hypertension is associated with children's age, sex, and SES. Literature findings regarding youth hypertension and associations with sociodemographic factors are controversial. Although no associations were found within our sample, investigations into associations between health and sociodemographic factors are important in settings such as South Africa, as social inequalities frequently appear in the distribution of diseases. A possible influence on our findings might be the homogenously low SES of the entire study sample, typical within equal

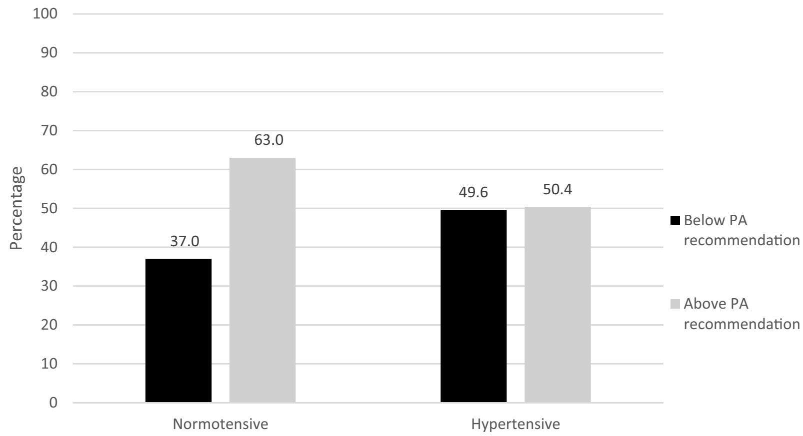

Figure 2. Percentage of children below or above physical activity recommendations (≥ 60 min MVPA per day), stratified by blood pressure status (normotensive vs hypertensive) ($n = 751$).

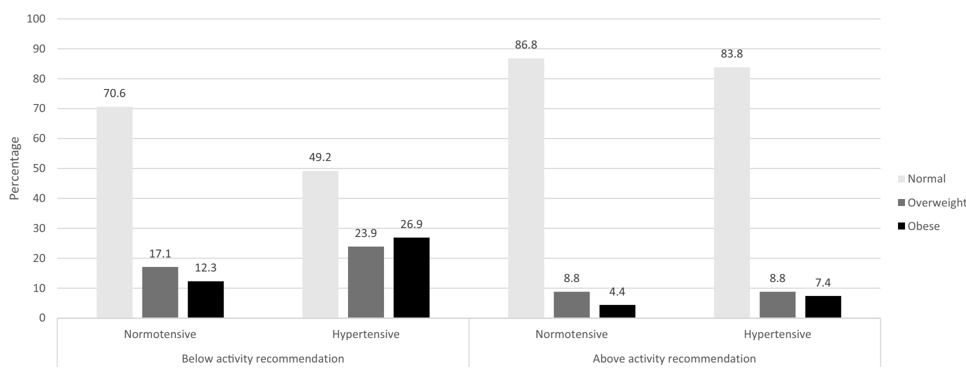

Figure 3. Association between normal, overweight, or obese and blood pressure status (normotensive vs hypertensive) among children classified below or above physical activity recommendation (≥ 60 min MVPA per day) ($n = 751$).

quintile ranked schools. In contrast, a study conducted in Brazil, a sociodemographically comparable country to South Africa, found significant associations between sex, age, and SES. Males, older children, and children attending state schools (as opposed to private schools), presented with higher blood pressure (Reuter et al., 2019).

The third aim was to determine whether children classified as hypertensive differed from their prehypertensive and non-hypertensive peers regarding physical activity, physical fitness, and cardiovascular risk markers. As expected, children classified as hypertensive were less likely to meet global activity recommendations, spent more time being sedentary, and presented with lower cardiorespiratory fitness, compared to their prehypertensive and non-hypertensive peers. Moreover, children classified as hypertensive showed less favourable body composition, as well as higher average glucose and cholesterol values. These findings are consistent with previous research highlighting associations of hypertension with physical activity, cardiorespiratory fitness, and metabolic profiles in children (Ekelund et al., 2007; Gopinath et al., 2011; Knowles et al., 2013). The prevalence of clustered cardiometabolic risk factors has been found in children as young as nine years (Bugge et al., 2013). Recent studies have demonstrated an increase in this clustered risk in children, which has further been associated with accelerated atherogenesis (Seo et al., 2018). Subclinical atherosclerosis therefore starts in childhood which can lead to morphological changes impacting vascular functioning, leading to artery related diseases and conditions in adulthood, as consistent tracking of these clustered risk factors have been found from childhood or adolescence into adulthood (Bugge et al., 2013; Gooty et al., 2018; Seo et al., 2018). Early cluster risk factor detection can therefore help prevent chronic disease later in life (Seo et al., 2018). Our findings suggest that elevated blood pressure is only linked to device-based physical activity, whereas no association was found between elevated blood pressure and self-reported physical activity. This is important to note because most previous studies in African countries have relied on self-reported physical activity data (Guthold et al., 2019; Muthuri et al., 2014). The fact that self-reported and device-based MVPA were only weakly correlated in the present study ($r = 0.19$, $p < 0.001$; data not shown) indicates that both measures may assess slightly different constructs.

Thus, while self-reported MVPA proved to be associated with health-related quality of life among South African children (Gall et al., 2020; Salvini et al., 2018), our findings suggest that from a hypertension prevention perspective, device-based MVPA assessments might provide more valuable information as they are more closely linked to elevated blood pressure.

Our fourth aim was to investigate whether children classified as hypertensive were more likely to be classified as overweight/obese and to fall below recommended levels of physical activity compared to normotensive peers. Regarding body composition, as with the present study, prior research conducted in South Africa with similarly aged children found significant correlations between blood pressure and body composition (measured through waist girth, skinfolds, and BMI) (Goon et al., 2013; Monyeki et al., 2008). Not only were children with less favourable body composition measures more likely to present with elevated blood pressure, but they were also more likely to present with clustered cardiometabolic risk factors. It is hypothesised that excess fat leads to elevated blood pressure through increased sympathetic activation, sodium reabsorption, and peripheral vascular resistance, both in children and adults (Noubiap et al., 2017). Regarding physical activity, previous research corroborates our findings that hypertensive children are less likely to meet the 60 min per day MVPA recommendation, with an inverse dose-response relationship between MVPA and systolic and diastolic blood pressure found (Mark & Janssen, 2008).

The fifth and final aim of this paper was to explore whether the relationship between hypertension and body weight status is moderated by children's physical activity levels. Overweight is a well-established risk factor for hypertension. Research, however, indicates a counteracting role of sufficient physical activity on the adverse effects that unfavourable body composition can have on health outcomes. Within our study, the relationship between hypertension and body weight status was moderated by children's MVPA levels. It is therefore concerning that children tend to become less active and more sedentary as they move from early to late childhood and then into adolescence (Basterfield et al., 2011). In Europe, this can be seen in that 25% of 11-year-olds meet the recommended physical activity level, compared to just 16% of 15-year-olds (World Health Organization, 2016). Similarly, a recent worldwide survey showed that in sub-Saharan Africa, 86.2% of 11- to 17-year-old adolescents do not engage in sufficient physical activity (Guthold et al., 2019). The same holds in South Africa, where it is estimated that one-third of children are physically inactive and that up to 80% do not accumulate the recommended physical activity per day (Uys et al., 2019). It is therefore suggested that physical inactivity and elevated blood pressure, as well as contributing factors such as overweight, should be addressed through primary prevention, namely by promoting a healthy, active lifestyle, especially from childhood into adolescence (Noubiap et al., 2017).

4.1. *Strengths and limitations of the study*

Strengths of the study include the relatively large sample size of primary schoolchildren, attending disadvantaged school settings within the poorest province of South Africa, contributing to alleviate the paucity of childhood health data within LMICs. Furthermore, comprehensive cardiovascular assessments were employed, including three blood pressure measurements, a full lipid panel and 2- to 3-month average blood glucose screening with a validated HbA1c test. Lastly, a device-based approach was used to assess children's physical activity, using accelerometer data, providing the most reliable and valid activity data in current research, especially in younger aged participants.

Despite these strengths, some limitations are important to consider when interpreting our findings. First, the cross-sectional design of the study prevents investigation of any temporal trend or inferring causality. Although DASH was initially designed as an intervention trial, due to limited (financial) resources, the assessment of accelerometer data and some of the cardiovascular risk markers (HbA1c, blood lipids) was not possible during the first three data assessments. These assessments became only possible due to additional funding acquired for the fourth and final follow-up data assessment. We also acknowledge that in the present article, an emphasis was placed on a categorization of variables, rather than using them as continuous variables. While we admit that such a categorization is associated with certain shortcomings (e.g. may reduce statistical power, if percentiles are used, cut-offs are population specific and place different populations at unequal position), such a procedure is relevant from a clinical perspective as it allows for the identification of children with elevated blood pressure and increased risk for future diseases. At the time of publication, no childhood reference values existed for sub-Saharan Africa. As a consequence, we referred to European blood pressure classifications because they were established with a similar automated oscillometric device as was used in the present study. However, this also means that prevalence rates with regard to prehypertension and hypertension reported in the present paper need to be interpreted with caution. The accelerometer data additionally only provides activity data on seven consecutive days. It is, therefore, conceivable that the activity within these seven days might not reflect routine activity patterns, due to the novelty of the device. It should also be noted that although accelerometers are considered more objective and valid than self-reported measures, several (arbitrary) decisions are also required by researchers (e.g. definition of acceptable wear time, choice of intensity thresholds). Accelerometers further have difficulties to accurately assess certain types of physical activities (e.g. cycling, weight-bearing activities or activities performed in water) (Reilly et al., 2008). Finally, the indirect assessment of body composition, although widely used and accepted, could have resulted in a more considerable error margin, when compared to direct assessment methods.

5. Conclusion

This study contributes to the growing body of knowledge highlighting the importance of physical activity, by emphasising the moderating role that MVPA may have on the relationship between hypertension and body weight, as seen in primary schoolchildren in disadvantaged settings in South Africa. High hypertension prevalence, overweight, and insufficient daily MVPA are of concern in this setting. The importance of early hypertension detection and primary health intervention strategies, focusing on increasing physical activity and improving body composition, should be emphasized in LMICs, especially in disadvantaged communities. The accurate and reliable detection of the prevalence of childhood hypertension serves as the basis of adequate intervention strategies, and therefore more high-quality epidemiological investigations on childhood hypertension, specifically in sub-Saharan Africa, are needed (Song et al., 2019). Accompanying research should focus on investigating hypertension, overweight, and physical activity in a longitudinal manner, with additional confounders such as dietary patterns, environmental factors, and genetic contributions, to allow for a broader understanding on the topic and improved prevention and treatment strategies. Establishing reference tables for elevated blood pressure for (South) African children based on nationally representative samples should be seen as a further priority.

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Disclosure of interest

Ann Aerts and Sarah des Rosiers are employees of the Novartis Foundation. All other authors declare no competing or conflict of interests. The funders played no role in the study design, data collection, analysis or interpretation, or decision to publish.

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Ethical approval

The following ethics committees reviewed and approved the study. The ethics committees of Northwest and Central Switzerland (EKNZ) (reference no.: 2014-179, approved on 17 June 2014), the Nelson Mandela University research ethics committee (human) (study no.: H14-HEA-HMS-002, approved on 4 July 2014), the Eastern Cape Department of Education (approved on 3 August 2014), and the Eastern Cape Department of Health (approved on 7 November 2014). The study is further registered at the International Standard Radomized Controlled Trial Number registry (ISRCTN) under controlled-trials.com (identifier: ISRCTN68411960, registered on 1 October 2014).

Authors' contributions

Study design: CW, RdR, IM, HS, PS, NP-H, JU, UP, and MG

Funding acquisition: CW, RdR, IM, HS, PS, NP-H, JU, UP and MG

Project administration: CW, RdR, IM, UP, and MG

Fieldwork: NJ, CW, RdR, LA, JD, SG, IM, MN, SN, DS, UP, and MG

Data entry, cleaning, and preparation of the database: NJ, LA, JD, SG, IM, MN, SN, and DS

Statistical analysis: MG

Original draft: NJ and MG

Reviewing and editing: NJ, CW, RdR, AA, LA, JD, SG, IM, SN, SdR, DS, HS, PS, NP-H, JU, UW, and MG

All authors have read and approved the final version of the paper before submission.

References

Aadland, E., Andersen, L. B., Skrede, T., Ekelund, U., Anderssen, S. A., & Resaland, G. K. (2017). Reproducibility of objectively measured physical activity and sedentary time over two seasons in children; comparing a day-by-day and a week-by-week approach. *PLoS One*, *12*(12), e0189304. https://doi.org/10.1371/journal.pone.0189304

Adamo, K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S., & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: A systematic review. *International Journal of Pediatric Obesity*, *4*(1), 2–27. https://doi.org/10.1080/17477160802315010

Agyemang, C., Redekop, W. K., Owusu-Dabo, E., & Bruijnzeels, M. A. (2005). Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. *BMC Public Health*, 5, 114. https://doi.org/10.1186/1471-2458-5- 114

Awotidebe, A., Monyeki, M. A., Moss, S. J., Strydom, G. L., Amstrong, M., & Kemper, H. C. G. (2016). Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of South African adolescents: The PAHL study. *Journal of Human Hypertension*, *30*(4), 245–251. https://doi.org/10.1038/jhh.2015.81

Basterfield, L., Adamson, A. J., Frary, J. K., Parkinson, K. N., Pearce, M. S., & Reilly, J. J. (2011). Longitudinal study of physical activity and sedentary behavior in children. *Pediatrics*, *127*(1), 24–30. https://doi.org/10.1542/peds.2010-1935

Bugge, A., El-Naaman, B., Mcmurray, R. G., Froberg, K., & Andersen, L. B. (2013). Tracking of clustered cardiovascular disease risk factors from childhood to adolescence. *Pediatric Research*, *73*(2), 245–249. https://doi.org/10.1038/pr.2012.158

Chen, X., & Wang, Y. (2008). Tracking of blood pressure from childhood to adulthood: A systematic review and meta-regression analysis. *Circulation*, *117*(25), 3171–3180. https://doi.org/10.1161/CIRCULATIONAHA.107.730366

Clemente, F. M., Nikolaidis, P. T., Martins, F. M. L., & Mendes, R. S. (2016). Physical activity patterns in university students: Do they follow the public health guidelines? *PLoS One*, *11*(3), e0152516. https://doi.org/10.1371/journal.pone.0152516

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physical activity in youth. *Journal of Applied Physiology*, *105*(3), 977–987. https://doi.org/10.1152/japplphysiol.00094.2008

Council of Europe Committee for the Development of Sport. (1993). *EUROFIT: European tests of physical fitness* (2nd ed.). Council of Europe.

Currie, C., Griebler, R., Inchley, J., Theunissen, A., Molcho, M., Samdal, O., Dür, W. (2010). *Health Behaviour in School-Aged Children (HBSC) study protocol: background, methodology and mandatory items for the 2009/10 survey*. Retrieved January 7, 2020, from http://www.hbsc.org/methods/. Edinburgh: CAHRU & Vienna: LBIHPR.

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., & Pratt, M. (2016). The economic burden of physical inactivity: A global analysis of major non-communicable diseases. *The Lancet*, *388*(10051), 1311–1324. https://doi.org/10.1016/S0140-6736 (16)30383-X

Ekelund, U., Anderssen, S. A., Froberg, K., Sardinha, L. B., Andersen, L. B., & Brage, S. (2007). Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: The European youth heart study. *Diabetologia*, *50*(9), 1832–1840. https://doi.org/10.1007/s00125-007-0762-5

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences*, *26*(14), 1557–1565. https://doi.org/10.1080/02640410802334196

Falkner, B., & Daniels, S. R. (2004). Summary of the fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Hypertension*, *44*(4), 387–388. https://doi.org/10.1161/01.HYP.0000143545.54637.af

Filmer, D., & Pritchett, L. (2001). Estimating wealth effects without expenditure data - or tears: An application to educational enrollments in states of India. *Demography*, *38*(1), 115–132. https://doi.org/10.2307/3088292

Gall, S., Walter, C., du Randt, R., Adams, L., Joubert, N., Müller, I., Nqweniso, S., Pühse, U., Seelig, H., Smith, D., Steinmann, P., Utzinger, J., & Gerber, M. (2020). Changes in self-reported physical activity predict health-related quality of life among South African schoolchildren: Findings from the DASH intervention trial. *Frontiers in Public Health*, *8, 492618*, 1-11. https://doi.org/10.3389/fpubh.2020.492618 .

Goon, D., Amusa, L., Mhlongo, D., Khoza, L., & Any-Anwu, F. (2013). Elevated blood pressure among rural South African children in Thohoyandou, South Africa. *Iran Journal of Public Health*, *42*(5), 489–496. Retrieved January 20, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3684457/ pdf/ijph-42-489.pdf

Gooty, V. D., Sinaiko, A. R., Ryder, J. R., Dengel, D. R., Jacobs, D. R., & Steinberger, J. (2018). Association between carotid intima media thickness, age, and cardiovascular risk factors in children and adolescents. *Metabolic Syndrome and Related Disorders*, *16*(3), 122–126. https://doi.org/10.1089/met.2017.0149

Gopinath, B., Hardy, L. L., Teber, E., & Mitchell, P. (2011). Association between physical activity and blood pressure in prepubertal children. *Hypertension Research*, *34*(7), 851–855. https://doi.org/10.1038/hr.2011.46

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2019). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *Lancet Child & Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Hills, A. P., Mokhtar, N., & Byrne, N. M. (2014). Assessment of physical activity and energy expenditure: An overview of objective measures. *Frontiers in Nutrition*, *1*(5), 1–16. https://doi.org/10.3389/fnut.2014.00005

Knowles, G., Pallan, M., Thomas, N. G., Ekelund, U., Cheng, K. K., Barrett, T., & Adab, P. (2013). Physical activity and blood pressure in primary school children: A longitudinal study. *Hypertension*, *61*(1), 70–75. https://doi.org/10.1161/HYPERTENSIONAHA.112.201277

Koskinen, J., Magnussen, C. G., Sinaiko, A., Woo, J., Urbina, E., Jacobs, D. R., Steinberger, J., Prineas, R., Sabin, M. A., Burns, T., Berenson, G., Bazzano, L., Venn, A., Viikari, J. S. A., Hutri-Kähönen, N., Raitakari, O., Dwyer, T., & Juonala, M. (2017). Childhood age and associations between childhood metabolic syndrome and adult risk for metabolic syndrome, type 2 diabetes mellitus and carotid intima media thickness: The International Childhood Cardiovascular Cohort Consortium. *Journal of the American Heart Association*, *6*(8), 1–16. https://doi.org/10.1161/JAHA.117.005632

Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6*(2), 93–101. https://doi.org/10.1080/02640418808729800

Liu, N. Y. S., Plowman, S. A., & Looney, M. A.(1992). The reliability and validity of the 20-meter shuttle test in American students 12 to 15 years old. *Research Quarterly for Exercise and Sport*, *63*(4), 360–365. https://doi.org/10.1080/02701367.1992.10608757

Mark, A. E., & Janssen, I. (2008). Dose-response relation between physical activity and blood pressure in youth. *Medicine & Science in Sports & Exercise*, *40*(6), 1007–1012. https://doi.org/10.1249/MSS.0b013e318169032d

Mayorga-Vega, D., Aguilar-Soto, P., & Viciana, J. (2015). Criterion-related validity of the 20-m shuttle run test for estimating cardiorespiratory fitness: A meta-analysis. *Journal of Sport Science and Medicine*, *14*(3), 536–547. Accessed January 7, 2020. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4541117/ pdf/jssm-14-536.pdf

Monyeki, K. D., Kemper, H. C. G., & Makgae, P. J. (2008). Relationship between fat patterns, physical fitness and blood pressure of rural South African children: Ellisras longitudinal growth and health study. *Journal of Human Hypertension*, *22*(5), 311–319. https://doi.org/10.1038/jhh.2008.3

Motswagole, B. S., Kruger, H. S., Faber, M., van Rooyen, J. M., & de Ridder, J. H. (2011). The sensitivity of waist-to-height ratio in identifying children with high blood pressure. *Cardiovascular Journal of Africa*, *22*(4), 4. https://doi.org/10.5830/CVJA-2010-062

Mountjoy, M., Andersen, L. B., Armstrong, N., Biddle, S., Boreham, C., Bedenbeck, H. P. B., Ekelund, U., Engebretsen, L., Hardman, K., Hills, A., Kahlmeier, S., Kriemler, S., Lambert, E., Ljungqvist, A., Matsudo, V., McKay, H., Micheli, L., Pate, R., Riddoch, C., Schamasch, P., & van Mechelen, W. (2011). International Olympic Committee consensus statement on the health and fitness of young people through physical activity and sport. *British Journal of Sports Medicine*, *45*(11), 839–848. https://doi.org/10.1136/bjsports-2011-090228

Murigo-Shumba, D., Bhimma, R., & Naicker, E. (2019). Severe hypertension in children at a central referral hospital in KwaZulu-Natal province, South Africa. *South African Journal of Child Health*, *13*(1), 44–48. https://doi.org/10.7196/SAJCH.2019.v13i1.1564

Muthuri, S. K. S., Wachira, L. J. M., Leblanc, A. G., Francis, C., Sampson, M., Onywera, V., & Tremblay, M. (2014). Temporal trends and correlates of physical activity, sedentary behaviour, and physical fitness among school-aged children in sub-Saharan Africa: A systematic review. *International Journal of Environmental Research and Public Health*, *11*(3), 3327–3359. https://doi.org/10.3390/ijerph110303327

Neuhauser, H. K., Thamm, M., Ellert, U., Hense, H. W., & Schaffrath Rosario, A. (2011). Blood pressure percentiles by age and height from nonoverweight children and adolescents in Germany. *Pediatrics*, *127*(4), 4. https://doi.org/10.1542/peds.2010-1290

Nigg, C. R., Fuchs, R., Gerber, M. (2020). Assessing physical activity through questionnaires – A consensus of best practices and future directions. *Psychology of Sport and Exercise*, 50, 101715, https://doi.org/10.1016/j.psychsport.2020.101715

Noubiap, J. J., Essouma, M., Bigna, J. J., Jingi, A. M., Aminde, L. N., & Nansseu, J. R. M. (2017). Prevalence of elevated blood pressure in children and adolescents in Africa: A systematic review and meta-analysis. *Lancet Public Health*, *2*(8), 375–386. https://doi.org/10.1016/S2468-2667(17)30123-8

Parikh, P., Mochari, H., & Mosca, L. (2009). Measurement issues: Clinical utility of a fingerstick technology to identify individuals with abnormal blood lipids and high-sensitivity C-reactive protein levels. *American Journal of Health Promotion*, *23*(4), 279–282. https://doi.org/10.4278/ajhp.071221140

Peterson, M. D., Zhang, P., Saltarelli, W. A., Visich, P. S., & Gordon, P. M. (2016). Low muscle strength thresholds for the detection of cardiometabolic risk in adolescents. *American Journal of Preventive Medicine*, *50*(5), 593–599. https://doi.org/10.1016/j.amepre.2015.09.019

Popkin, B. M. (2006). Global nutrition dynamics: The world is shifting rapidly toward a diet linked with noncommunicable diseases. *American Journal of Clinical Nutrition*, *84*(2), 289–298. https://doi.org/10.1093/ajcn/84.2.289

Reilly, J. J., Penpraze, V., Hislop, J., Davies, G., Grant, S., & Paton, J. Y. (2008). Objective measurement of physical activity and sedentary behaviour: Review with new data. *Archives of Disease in Childhood*, *93*(7), 614–619. https://doi.org/10.1136/adc.2007.133272

Reuter, C. P., Rodrigues, S. T., Barbian, C. D., Silveira, J. F. D. C., Schneiders, L. D. B., Soares, S. S., Burgos, L. T., & Burgos, M. S. (2019). High blood pressure in schoolchildren: Associated sociodemographic and biochemical factors. *Revista Portuguesa de Cardiologia*, *38*(3), 195–201. https://doi.org/10.1016/j.repce.2018.06.009

Ruiz, J. R., Castro-Piñero, J., España-Romero, V., Artero, E. G., Ortega, F. B., Cuenca, M. M., Jimenez-Pavon, D., Chillon, P., Girela-Rejon, M. J., Mora, J., Gutierrez, A., Suni, J., Sjostrom, M., & Castillo, M. J. (2011). Field-based fitness assessment in young people: The ALPHA health-related fitness test battery for children and adolescents. *British Journal of Sports Medicine*, *45*(6), 518–524. https://doi.org/10.1136/bjsm.2010.075341

Salvini, M., Gall, S., Müller, I., Walter, C., du Randt, R., Steinmann, P., Utzinger, J., Pühse, U., & Gerber, M. (2018). Physical activity and health-related quality of life among schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa. *Quality of Life Research*, *27*(1), 205–216. https://doi.org/10.1007/s11136-017-1707-1

Scott, J. J., Morgan, P. J., Plotnikoff, R. C., & Lubans, D. R. (2015). Reliability and validity of a single-item physical activity measure for adolescents. *Journal of Paediatrics and Child Health*, *51*(8), 787–793. https://doi.org/10.1111/jpc.12836

Seo, Y. G., Choi, M. K., Kang, J. H., Lee, H.J., Jang, H. B., Park, S. I., Ju, Y. S., & Park, K. H. (2018). Cardiovascular disease risk factor clustering in children and adolescents: A prospective cohort study. *Archives of Disease in Childhood*, *103*(10), 968–973. https://doi.org/10.1136/archdischild-2017-313226

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van Loan, M. D., & Bemben, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology*, *60* (5), 709–723. PMID: 3224965. https://www.jstor.org/stable/41464064?seq=1

Song, P., Zhang, Y., Yu, J., Zha, M., Zhu, Y., Rahimi, K., & Rudan, I. (2019). Global prevalence of hypertension in children: A systematic review and meta-analysis. *JAMA Pediatrics*, *173*(12), 1154–1163. https://doi.org/10.1001/jamapediatrics.2019.3310

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & Mcdowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise*, *40*(1), 181–188. https://doi.org/10.1249/mss.0b013e31815a51b3

Uys, M., Bassett, S. H., Draper, C. E., Kruger, H. S., Micklesfield, L. K., Monyeki, A., Lambert, E. V., & HAKSA Science Advisory Group. (2019). Results from the healthy active kids South Africa 2018 report card. *South African Journal of Child Health*, *13*(3), 130–136. https://doi.org/10.7196/SAJCH.2019.v13.i3.1640

Ware, L. J. J., Charlton, K., Schutte, A. E. E., Cockeran, M., Naidoo, N., & Kowal, P. (2017). Associations between dietary salt, potassium and blood pressure in South African adults: WHO SAGE Wave 2 Salt and Tobacco. *Nutrition, Metabolism and Cardiovascular Diseases*, *27*(9), 784–791. https://doi.org/10.1016/j.numecd.2017.06.017

West, S. G., Finch, J. F., & Curran, P. J. (1995). Structural equation models with non-normal variables: Problems and remedies. In R.H. Hoyle (Ed.) *Structural equation modeling: Concepts, issues, and applications* (pp. 56–75). Sage Publications, Inc.

Wind, A. E., Takken, T., Helders, P. J. M., & Engelbert, R. H. H. (2010). Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *European Journal of Pediatrics*, *169*(3), 281–287. https://doi.org/10.1007/s00431-009-1010-4

World Health Organization. (2016). *Health behaviour in school-aged children study: Physical activity in adolescents key facts and figures*. Retrieved January 9, 2020, from http://www.euro.who.int/__data/assets/pdf_file/0018/303480/HBSC-No.7_factsheet_Physical.pdf?ua=1

World Health Organization. (2010a). *Global recommendations on physical activity for health*. Retrieved January 3, 2020, from https://www.who.int/publications/i/item/9789241599979 .

World Health Organization. (2010b). *WHO guidelines on drawing blood: Best practices in phlebotomy*. Retrieved January 7, 2020, from https://www.euro.who.int/__data/assets/pdf_file/0005/268790/WHO-guidelines-on-drawing-blood-best-practices-in-phlebotomy-Eng.pdf?ua=1

World Health Organization. (2015). *Raised blood pressure: Situation and trends*. Retrieved January 3, 2020, from https://www.who.int/gho/ncd/risk_factors/blood_pressure_prevalence_text/en/

World Health Organization. (2007). *Growth reference data for 5-19 years*. Retrieved January 17, 2020, from https://www.who.int/tools/growth-reference-data-for-5to19-years

Xi, B., Zhang, T., Li, S., Harville, E., Bazzano, L., He, J., & Chen, W. (2017). Can pediatric hypertension criteria be simplified?: A prediction analysis of subclinical cardiovascular outcomes from the Bogalusa heart study. *Hypertension*, *69*(4), 691–696. https://doi.org/10.1161/HYPERTENSIONAHA.116.08782

Yap, P., Müller, I., Walter, C., Seelig, H., Gerber, M., Steinmann, P., Damons, B. P., Smith, D., Gall, S., Bänninger, D., Hager, T., Htun, N. S. N., Steenkamp, L., Gresse, A., Probst-Hensch, N., Utzinger, J., Du Randt, R., & Pühse, U. (2015). Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: A study protocol Health behaviour, health promotion and society. *BMC Public Health*, *15*, 1285. https://doi.org/10.1186/s12889-015-2636-y

Zhou, B., Bentham, J., Di Cesare, M. (2017). Worldwide trends in blood pressure from 1975 to 2015: A pooled analysis of 1479 population-based measurement studies with 19.1 million participants. *Lancet*, *389*(10064), 37–55. https://doi.org/10.1016/S0140-6736 (16)31919-5