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ORIGINAL ARTICLE

Prevalence of elevated blood pressure and association with overweight in children of a rapidly developing country

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We assessed the prevalence of elevated blood pressure (BP) and the association with excess body weight among a large sample of children in the Seychelles, a middle-income rapidly developing country in the African region. Weight, height and BP were measured in all children of four school grades in the Seychelles (Indian Ocean). Excess weight categories ('overweight' and 'obesity') were defined according to the criteria of the International Obesity Task Force. Two BP readings were obtained on one occasion. 'Elevated BP' was defined based on US reference tables. Data were available in 15 612 (86%) of 18 119 eligible children aged 5–16 years in 2002–2004. In all, 13.0% of Boys and 18.8% of girls were overweight or obese. The prevalence of elevated BP was 9.1% in boys and 10.1% in girls. Both systolic and diastolic BP were strongly associated with body mass index (BMI) in boys and in girls. In children with 'normal weight', 'overweight (and not obesity)' and 'obesity', respectively, proportions with elevated BP were 7.5, 16.9 and 25.2% in boys, and 7.5, 16.1 and 33.2% in girls. Overweight (including obesity) could account for 18% of cases of elevated BP in boys and 26% in girls. Further studies should examine the impact of the relationship between BMI and elevated BP on the burden of hypertension in the context of the epidemic of paediatric obesity.
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Introduction

In addition to be a leading cause of the disease burden worldwide in adults,[1,2] hypertension is a matter of concern in children as well.[3] Children with elevated blood pressure (BP) can develop target organ damage, for example, increased carotid intima-media thickness[4] or ventricular hypertrophy,[5] and they are also at increased risk of cardiovascular disease in adulthood.[6] Moreover, BP tracks from childhood to adulthood.[7–9] Consequently, detection and management of elevated BP at an early age may be an important mean for limiting the disease burden due to hypertension.[10]

It is difficult to estimate the prevalence of elevated BP in children because there is no universally accepted definition of paediatric hypertension and because BP physiologically relates to sex, age and height during childhood.[11] The latter factor implies that BP cutoff values to define hypertension need to be age-, sex- and height specific[11] and prevalence studies in children must subsequently include large numbers of children.

Notwithstanding these limitations, several large population-based studies have recently assessed the prevalence of elevated BP in children in western countries and prevalence typically ranged from 7 to 19% based on measurements taken on one visit.[12–14] In contrast, few population-based studies have been conducted in children in developing countries[15–18] and several of them have relied on small sample sizes with subsequent limited power to estimate the prevalence of elevated BP with precision.[16–18] Continuous assessment of elevated BP in children (as well as in adults) is important in the view of changing distribution of determinants of hypertension (e.g. nutrition, obesity) and to provide information in regions that lack such data (e.g. developing countries) in order to guide health-care policy and prevention strategies.[1]

Childhood obesity has taken epidemic proportions worldwide.[19,20] Many studies have shown that BP is associated with overweight in children.[12–14,21] However, few data are available in non-western

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countries and in non-caucasian populations.[15–18] Furthermore, although some studies indicated that mean BP in children has recently increased in parallel to the obesity epidemic,[22,23] other studies have shown that BP has decreased over time in spite of upwards obesity trends.[24,25] The question of the strength of the relationship between BP and body weight in children in different populations has important implications for predicting trends in the burden of hypertension attributable to excess body weight, especially in the context of the extension of the obesity epidemic worldwide.[20,26]

The purpose of this study was (1) to estimate the prevalence of elevated BP in a large sample of children of the Seychelles, a country in the African region in which the prevalence of obesity has recently rapidly increased,[26] (2) to investigate the relationship between BP and body mass index (BMI), and (3) to estimate the proportion of children with elevated BP in the population that could be attributable to excess body weight (overweight or obesity).

Methods

The study took place in the Republic of Seychelles, an island state in the African region located 1800 km east of Kenya in the Indian Ocean. The large majority of the population is of African descent. Seychelles has experienced rapid socioeconomic development over the last three decades and the national gross domestic product per capita rose in real terms from US$ 2927 in 1980 to US$ 5239 in 2004. High levels of cardiovascular risk factors, including hypertension, were documented in the adult population in 1989 and 2004.[27,28]

Data for this study came from a school-based national surveillance system including surveys every year of all children attending all public and private schools of Seychelles in four selected school grades: kindergarten (G0), fourth (G4), seventh (G7) and 10th year (G10) of obligatory school.[26] Data were collected during routine medical visits at school by more than a dozen of school nurses. Nearly 100% of children attend school with approximately 96% attending public schools and 4% attending private schools. This study included students examined in 2002–2004. As the same student cannot be seen more than once every 4 years as he/she moves across subsequent grades, the selection of a 3-year period in this study (2002–2004) ensured that all students could be seen only once.[26]

BP was measured with clinically validated oscillometric automated devices (Omron M5, Omron Healthcare Europe BV, The Netherlands).[29] The width of the cuff (paediatric, normal, large) was adapted to the arm circumference. BP was measured in the sitting position, after a rest of at least 5 min, on the right arm. Two readings were obtained at a 1-min interval and the average was used to define BP. Weight was measured using precision electronic scales (Seca 870, Seca, Hamburg, Germany) and height was measured with fixed stadiometers (Seca 208). School nurses were regularly trained in measurement techniques and equipment was checked every year for accuracy. In addition, children of the upper grades (G4, G7 and G10) were asked questions about their average daily walking time to and from school (expressed in minutes per day) and frequency of leisure physical exercise outside of school (less than once per month; at least once per month but less than once per week; once per week; twice per week; three times or more per week). The survey was approved by the research committee of the Ministry of Health after technical and ethical reviews. Written consent was sought from the parents for the participation of their children and children were free to participate.

BMI was calculated as weight divided by height squared (kg/m^2). 'Overweight' and 'obesity' were defined using the sex- and age-specific BMI criteria of the International Obesity Task Force.[19] The category 'overweight' is generally meant to also include the category 'obesity', unless specified otherwise. *Z*-scores and corresponding percentiles of systolic and diastolic BP were generated using US reference tables.[30] 'Elevated BP' was considered for systolic BP and/or diastolic BP equal to or above the reference sex-, age- and height-specific 95th percentile (i.e. a *z*-score of $\geqslant 1.64$).[11]

Prevalence, standard error and 95% confidence interval (95% CI) were calculated for categories of sex and school grade. The shape of the relationship between BMI and BP was assessed using the LOWESS method, a scatterplot smoothing technique based on robust locally weighted regression.[31] Smoothed curves were generated for systolic and diastolic BP, according to sex and school grade. Logistic regression was used to assess the relationship between BMI categories and elevated BP. We calculated the population attributable fraction (PAF)[32] of elevated BP cases that could be attributed to excess body weight (overweight or obesity). CIs of PAF were based on asymptotic approximation.[33] Calculation of PAF assumes a causal relationship between the variables of interest (body weight and elevated BP).[32] Statistical analyses were performed with Stata 8.2.

Results

From an eligible total of 18 119 children seen in 2002–2004, data on weight, height and BP were available in 15 612 (86%) aged 5–16 years. Table 1 shows mean BMI, systolic and diastolic BP and the prevalence of overweight, obesity and elevated BP by sex and school grade. Overall, 13.0% (95% CI: 12.3–13.8) of boys and 18.8% (17.9–19.6) of girls

Table 1 Mean age, BMI and BP and prevalence of overweight, obesity and elevated BP, by sex and school grade, Seychelles, 2002–2004

Sex	*Grade*	N	*Age (year)*	*BMI (kg/m²)*	*Systolic BP (mm Hg)*	*Diastolic BP (mm Hg)*	*Overweight or obese (%)*	*Obese (%)*	*Elevated systolic BP (%)*	*Elevated diastolic BP (%)*	*Elevated BP (%)*
Boys	G0	1889	5.4 (0.4)	15.3 (2.2)	95.7 (11.2)	60.8 (10.0)	11.3 (10.0–12.8)	4.7 (3.8–5.7)	5.8 (4.8–6.9)	9.1 (7.8–10.4)	11.6 (10.2–13.1)
	G4	2150	9.1 (0.4)	16.5 (3.2)	100.7 (11.0)	62.6 (9.2)	14.1 (12.6–15.6)	5.6 (4.6–6.6)	5.6 (4.7–6.7)	4.1 (3.3–5.0)	7.9 (6.8–9.1)
	G7	2059	12.6 (0.4)	18.4 (3.8)	104.0 (11.4)	64.3 (8.6)	15.2 (13.7–16.8)	4.8 (3.9–5.8)	3.4 (2.7–4.3)	2.9 (2.2–3.7)	5.3 (4.4–6.4)
	G10	1704	15.6 (0.4)	19.9 (3.4)	117.3 (12.6)	69.3 (8.7)	11.0 (9.6–12.6)	3.2 (2.4–4.1)	10.3 (8.9–11.9)	4.5 (3.6–5.6)	12.6 (11.1–14.3)
	All	7802					13.0 (12.3–13.8)	4.6 (4.2–5.1)	6.1 (5.6–6.7)	5.1 (4.6–5.6)	9.1 (8.5–9.8)
Girls	G0	1749	5.4 (0.4)	15.2 (2.1)	94.7 (10.8)	61.1 (9.8)	13.9 (12.3–15.6)	5.0 (4.1–6.2)	6.6 (5.5–7.9)	10.1 (8.7–11.6)	12.5 (11.0–14.2)
	G4	2078	9.1 (0.4)	16.8 (3.5)	101.2 (11.1)	64.1 (9.1)	19.5 (17.8–21.3)	6.4 (5.4–7.5)	7.0 (5.9–8.2)	7.1 (6.0–8.3)	10.8 (9.5–12.2)
	G7	2059	12.5 (0.4)	19.5 (4.2)	105.8 (11.0)	67.1 (8.4)	20.9 (19.1–22.7)	5.9 (4.9–7.0)	5.2 (4.3–6.3)	5.1 (4.1–6.1)	8.5 (7.3.9.7)
	G10	1924	15.6 (0.3)	21.4 (4.2)	110.1 (10.8)	70.0 (8.3)	20.1 (18.3–22.0)	5.7 (4.7–6.8)	5.4 (4.4–6.5)	5.8 (4.8–6.9)	8.9 (7.7–10.3)
	All	7810					18.8 (17.9–19.6)	5.8 (5.3–6.3)	6.0 (5.5–6.6)	6.9 (6.3–7.5)	10.1 (9.5–10.8)

Abbreviations: BMI, body mass index; BP, blood pressure.
In brackets: s.d. for continuous variables or 95% confidence interval for proportions.

were either 'overweight' or 'obese'. BP increased with school grade, hence with children's age.

Approximately one child out of 10 had elevated BP (systolic and/or diastolic BP). Overall, the prevalence of elevated BP was not largely different in boys than in girls. In boys, the prevalence of elevated BP tended to be higher in the first and last school grades (G0, G10) than in the intermediate grades. In the lowest grade (G0), more children (boys and girls) had elevated diastolic BP than elevated systolic BP. In the other grades, boys and girls tended to have elevated systolic BP more often than elevated diastolic BP.

Figure 1 shows smoothed curves of the relation between systolic/diastolic BP and BMI. BP was associated directly with BMI. The relationship was steeper for children of higher than lower grades. Except for children of the lowest grade (G0), the relationship tended to flatten in the upper range of BMI. In additional analyses stratified by height-for-age (i.e. small, and tall children), the curves relating BMI with BP were parallel but significantly higher in taller than smaller children (data not shown; available on request). This indicates that the relationship between BP and BMI was not confounded by children's height.

Table 2 illustrates the relationship between the prevalence of elevated BP and BMI categories. In both boys and girls, and for each school grade, the proportions of children with elevated BP (systolic and/or diastolic) increased sharply across categories of BMI. Among obese children, one boy out of four and one girl out of three had elevated BP. For elevated systolic BP, the proportions across BMI categories were 4.9% (4.4–5.5), 12.6% (10.2–15.4) and 16.0% (12.4–20.3) in normal weight, overweight and obese boys, and 4.3% (3.9–4.9), 9.6% (7.8–11.6) and 21.9% (18.2–26.0) in girls. For elevated diastolic BP, the proportions were 4.2% (3.8–4.8), 8.5% (6.5–10.9) and 15.0% (11.4–19.1) in boys, and 5.0% (4.5–5.6), 11.1% (9.2–13.2) and 23.7% (19.8–27.9) in girls.

Table 3 indicates the odds ratios of elevated BP (systolic and/or diastolic) in boys and in girls associated with overweight and obesity compared to normal weight. As elevated BP is adjusted for age, sex and height and excess body weight is adjusted for age and sex, the odds ratios in this table are inherently adjusted for these variables. The association tended to be stronger in girls than in boys, and weaker in younger than older age (grade 0 vs grades 4, 7 and 10). Odds ratios tended to be higher for obesity than overweight. The proportions of all children with elevated BP that could be attributed to excess weight (i.e. overweight and obesity) were 17% (14–21) among boys and 25% (22–29) among girls. The attributable fraction for overweight (excluding the obese category) was 9% (6–11) among boys and 11% (8–14) among girls. The attributable fraction for obesity was 9% (7–11) among boys and 15% (12–17) among girls. Hence, overweight and

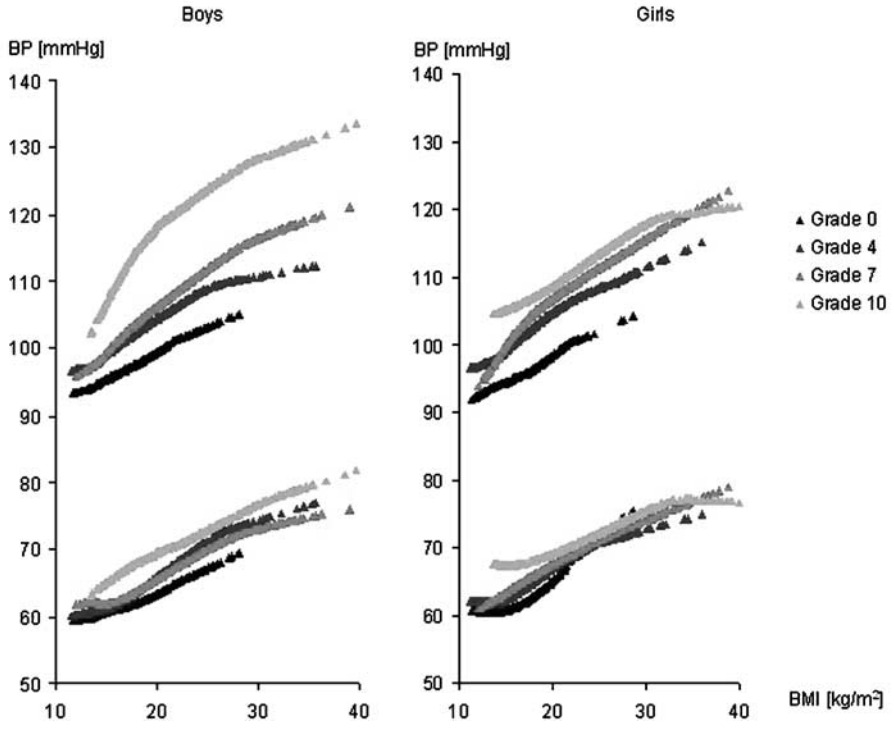

Figure 1 Smoothed curves of systolic (upper part) and diastolic BP (lower part) in relation to BMI, by sex and school grade.

Table 2 Prevalence of elevated BP among children with normal weight, overweight and obesity, by sex and school grade

Sex	*Grade*	*Normal weight (%)*	*Overweight and not obese (%)*	*Obese (%)*
Boys	G0	11.0 (9.4–12.6)	14.3 (8.2–20.4)	19.3 (11.1–27.5)
	G4	6.2 (5.0–7.4)	12.6 (7.7–17.5)	25.8 (18.0–33.6)
	G7	3.2 (2.4–4.0)	13.1 (8.6–17.6)	25.3 (16.7–33.9)
	G10	10.2 (8.6–11.8)	31.3 (23.5–39.1)	33.3 (20.6–46.0)
	All	7.5 (6.9–8.1)	16.9 (14.0–19.8)	25.2 (20.7–29.7)
Girls	G0	11.4 (9.8–13.0)	12.3 (7.2–17.4)	33.0 (23.2–42.8)
	G4	8.1 (6.7–9.5)	18.4 (13.7–23.1)	29.3 (21.5–37.1)
	G7	5.3 (4.1–6.5)	14.3 (10.4–18.2)	36.1 (27.5–44.7)
	G10	5.5 (4.3–6.7)	18.0 (13.5–22.5)	34.9 (25.9–43.9)
	All	7.5 (6.9–8.1)	16.1 (13.7–18.5)	33.2 (5.9–43.9)

Abbreviation: BP, blood pressure.
95% confidence interval in brackets.

Table 3 Association between elevated BP and categories of body mass index and proportions of all students with elevated BP that could be attributable to excess body weight ('attributable fraction')

Sex	*Grade*	*Overweight and not obese (OR)*	*Obese (OR)*	*Attributable fraction for overweight and obesity (%)*
Boys	G0	1.3 (0.8–2.3)	1.9 (1.1–3.4)	5 (1–10)
	G4	2.2 (1.3–3.5)	5.2 (3.3–8.2)	21 (13–28)
	G7	4.5 (2.8–7.3)	10.2 (6.0–17.2)	39 (28–49)
	G10	4.0 (2.7–6.0)	4.4 (2.4–7.9)	19 (13–35)
	All	2.5 (2.0–3.1)	4.1 (3.2–5.3)	18 (14–21)
Girls	G0	1.1 (0.7–1.8)	3.8 (2.4–6.2)	9 (4–15)
	G4	2.5 (1.8–3.6)	4.7 (3.1–7.1)	25 (17–32)
	G7	3.0 (2.0–4.4)	10.1 (6.6–15.5)	37 (28–46)
	G10	3.8 (2.6–5.5)	9.3 (5.9–14.5)	39 (30–47)
	All	2.4 (1.9–2.9)	6.1 (4.9–7.6)	26 (22–29)

Abbreviations: BP, blood pressure; OR, odds ratio.
95% confidence intervals in brackets.

obesity could account for an approximately same number of children with elevated BP. These attributable fractions tended to be lower in the youngest boys and girls (G0), consistent with the slightly lower odds ratio relating elevated BP to excess body weight in this age category.

In additional analyses performed in children of grades G4, G7 and G10 (for which data on physical exercise were available), elevated BP was associated with low frequency of physical exercise at leisure time and low walking time to/from school, independently of BMI categories (data not shown). However, the odds ratios for elevated BP with body weight categories reported in Table 3 were virtually identical upon inclusion of the physical exercise variables into the logistic regression models. These findings indicate that the considered physical exercise variables did not confound the association between excess weight categories and elevated BP.

Discussion

We found that both systolic BP and diastolic BP were strongly associated with BMI, independently of sex, age and height, in children of the Seychelles. Overweight and obesity could account for approximately one-fifth of all children with elevated BP. These findings in a middle-income country of the African region emphasize the role of excess body weight in children as a possible important determinant of hypertension in rapidly developing countries.

Comparison of the prevalence of elevated BP with other studies is limited due to differences in the procedures used for BP measurement across studies. Table 4 shows results of recent large population-based studies reporting the prevalence of elevated BP (using the US criteria) based on BP measured on one visit. Prevalence of elevated BP in Seychelles seemed to be similar to findings in developed countries such as Canada[13] or Italy.[14] The prevalence of elevated BP was however lower in Seychelles than in the USA, possibly consistent with the larger prevalence of overweight in the latter than in the former.[12] Inversely, the prevalence of elevated BP was higher in Seychelles than in urban South Africa, possibly consistent with a higher prevalence of paediatric overweight in Seychelles than in South Africa.[18]

Many studies have documented an association between BP and body weight in children and adolescents of western countries.[12–14,21] In American children, BMI was associated with systolic and diastolic BP, irrespective of sex, ethnic group or age.[34] In a recent large study of paediatric patients, an association was found for systolic and diastolic BP in all age groups, including in children aged less than 6 years.[35] Other studies indicate that BMI was associated more strongly with systolic BP than diastolic BP.[12,13] In a representative sample of youths aged 9, 13 and 16 years of Québec (Canada) in which the prevalence of excess body weight was 22–25% (based on BMI $\geqslant$85th percentile, the US reference tables), the prevalence of 'high normal' or 'elevated' systolic BP (i.e. BP $\geqslant$90th percentile, the US reference tables) was 12–30% in boys and 14–19% in girls, whereas the prevalence of 'high normal' or 'elevated diastolic' BP was $<$1% in both boys and girls.[13] In preschool American children, 19% of obese children had elevated BP vs 7.0% of the non-obese and the association between BP and BMI was stronger in non-obese than obese children.[36] The latter finding is consistent with our observation that the relation between BMI and BP flattened in the upper tail of the BMI distribution. Surprisingly, an inverse relationship between BMI and diastolic BP was recently reported in American adolescents.[37]

Few population-based data on the relation between BP and BMI are available in children in developing countries. In the Ashanti region of Ghana, BP was measured in 1277 children and adolescents aged 8–16 years.[17] Similarly to our results, a strong association was found between BP and BMI. In 118 children in Cameroon, BP was

Table 4 Comparison of the prevalence of elevated BP in children in Seychelles and in selected countries

Country	*Sample*	*Year*	*Age (year)*	*N*	*Mean BMI or prevalence of overweight*[a,b]	*Prevalence of elevated BP*
Pakistan[c15]	National	1990–94	5–14	5641	Boys/girls: 15.2/15.3 kg/m^2	Boys/girls: 15.8%/8.7%
Canada[d13]	Province of Quebec	1999	9, 13, 16	3589	9/13/16 years: 9%/9%/8%[a]	9/13/16 years: 7%/13%/17%
South-Africa[e18]	Regional (urban), Elisras	2000	6–13	1884	Boys/girls: 1–3%/1–5%[a]	Boys/girls: 1–6/3–11%
USA[f12]	City of Houston	2002	13.5$\pm$1.7	5102	20.0%[a]	19.4%
Italy[g14]	Province of Milan	2003–04	6–11	2416	Boys/girls: 24.7%/29.3%[b]	8.8%
Seychelles[h]	National	2002–04	5–16	15 612	Boys/girls: 13.0%/18.8%[b]	Boys/Girls: 9.1%/10.1%

Abbreviations: BMI, body mass index; BP, blood pressure.
Criteria for overweight definition: [a]'overweight' category according to CDC (i.e. BMI$\geqslant$95th percentile for age and sex); [b]'overweight' category according to IOTF (based on age- and sex-specific BMI values).
For all studies, elevated BP was based on the US reference data.[11] BP was measured on one single visit in all studies.
Method for BP measurement: [c]mercury sphygmomanometer; mean of two readings. [d]oscillometric device; mean of the last two of three readings; [e]oscillometric device, mean of three readings; [f]oscillometric device, mean of three readings; [g]mercury sphygmomanometer, one reading; [h]oscillometric device, mean of two readings.

higher in urban than rural boys and the latter tended to have higher BMI.[16] Interestingly, in the largest study performed on children of a developing country, BP was higher in Pakistani (5–14 years old; $N=5641$) than American children (5–14 years old; $N=4756$), despite lower BMI in the former than the latter (Table 4).[15] Both systolic BP and diastolic BP increased with BMI in these Pakistani children. In urban South African children aged 6–13 years, children with higher BMI had higher BP.[18]

We found a larger prevalence of elevated BP in younger than older children. Possible explanations can include a larger reaction alert in the former than the latter (i.e. white-coat effect) or a measurement bias with the automated device (e.g. smaller vs larger arms). More generally, thresholds for elevated BP are based on data collected in North American children[11] and may not necessarily apply to other populations. The validity of such normative data has not been assessed critically between populations and no other normative data have been commonly used so far.

Our population-based study design allowed us to estimate that approximately one-fifth of all children with elevated BP could be attributable to excess weight. We did not find other estimates of PAFs in children in the literature. However, in adults, the proportion of hypertension in a population that could be attributed to overweight or obesity (BMI $\geqslant 25\,kg/m^2$) ranged from 11% (Italy) to 28% (USA).[38,39]

Our study has some limitations. First, BP was measured on one single visit, whereas hypertension should be based on readings taken on several visits.[11] In two studies that assessed BP on several days in children, measurement of BP on two[14] or three different visits[12] more than halved the prevalence of elevated BP, a phenomenon also well known in adults.[40,41] Most other epidemiological studies of children BP also relied on readings taken on a single occasion.[13,15,33,35] Second, because of the scarcity of data linking BP in children and subsequent disease outcomes, the definition of 'elevated BP' largely relies on arbitrary normative values. The most frequently used reference values are derived from American children examined in the 1980s, that is before the epidemic of overweight.[11] These US reference data have the advantage to be adjusted for sex, age and height, which are the main known physiological determinants of BP in children.[11] Admittedly, generalization of such reference BP values to other populations is disputable, particularly if children's height-for-age is different. This caveat may bias our prevalence estimate of elevated BP but it is unlikely to have biased our findings on the relationship between BP and BMI. Third, our data were cross-sectional and the causal relationship between BMI and BP cannot be firmly established. However, the benefits of weight loss for BP reduction in children have been shown in both cohort studies and trials.[3] It was recently shown in a population-based study that children who were overweight at the age of 5 years and had normal weight at the age of 14 years had similar mean BP at the age of 14 years as compared to those with normal weight at both ages.[42] Finally, some factors not considered in this study, such as heart rate, family history of hypertension, birth weight or nutrition factors, could bias or modify the relationship between BMI and BP. Interestingly, our odds ratios relating BMI to elevated BP remained virtually identical upon adjustment for physical exercise variables.

The substantial prevalence of children with elevated BP emphasizes the need to consider appropriate screening and treatment programs of hypertension as early as in childhood.[11] Our findings further call for programs and policies to limit sedentary behaviours and promote physical activity and healthy nutrition among all children.[42,43] More generally, the association between overweight and elevated BP in children might announce an increased burden of hypertension-related diseases as the obesity epidemic further escalates. Prevention of cardiovascular risk factors as early as in childhood – also called *primordial prevention* – may be an important strategy to prevent non-communicable diseases in a life course perspective,[10] particularly in settings with scarce resources and limited health care capacity.

Conflict of interest:

None.

What is known on that topic
- The prevalence of elevated BP has been described in several western countries but few data are available in developing countries.
- Elevated BP is associated with overweight in children.
- We are not aware of studies that have estimated the proportion of children with elevated BP that can be attributed to overweight.

What this study adds
- This study based on a large representative sample shows a fairly high prevalence of elevated BP in children of a rapidly developing country in the African region.
- As many as one-fifth of children with elevated BP could be attributable to overweight.
- It is important to gather epidemiological data on the prevalence of elevated BP and the relationship with overweight in different pediatric populations to help predict trends and guide health policy in a context of an impeding pediatric obesity epidemic worldwide.

Abbreviation: BP, blood pressure.

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