Prevalence of hypertension in schoolchildren based on repeated measurements and association with overweight

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Objective Most studies assess the prevalence of hypertension in pediatric populations based on blood pressure (BP) readings taken on a single visit. We determined the prevalence of hypertension measured on up to three visits in a Swiss pediatric population and examined the association between hypertension and overweight and selected other factors.

Methods Anthropometric data and BP were measured in all children of the sixth school grade of the Vaud canton (Switzerland) in 2005–2006. 'Elevated BP' was defined according to sex-specific, age-specific and height-specific US reference data. BP was measured on up to two additional visits in children with elevated BP. 'Hypertension' was defined as 'elevated BP' on all three visits.

Results Out of 6873 children, 5207 (76%) participated [2621 boys, 2586 girls; mean (SD) age, 12.3 (0.5) years]. The prevalence of elevated BP was 11.4, 3.8 and 2.2% on first, second and thirds visits, respectively; hence 2.2% had hypertension. Among hypertensive children, 81% had isolated systolic hypertension. Hypertension was associated with excess body weight, elevated heart rate and parents' history of hypertension. Of the children, 16.1% of boys and 12.4% of girls were overweight or obese (CDC criteria, body mass index ≥85th percentile). Thirty-seven percent of cases of hypertension could be attributed to overweight or obesity.

Conclusions The proportion of children with elevated BP based on one visit was five times higher than based on three measurements taken at few-week intervals. Our data re-emphasize the need for prevention and control of overweight in children to curb the global hypertension burden. *J Hypertens* 25:2209–2217 © 2007 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

Hypertension is a leading cause of the burden of disease worldwide [1]. Most prevention and control strategies target adults [2]. Blood pressure (BP) in children, however, tends to track from childhood into adulthood [3], and prevention and control of elevated BP in children might be an important strategy for limiting the global disease burden due to hypertension [4]. The development of such a strategy, however, requires more evidence on the link between BP and its associated factors in children of different populations, particularly in a context of a raging epidemic of pediatric obesity [5,6].

No outcome-based definition of hypertension in children is available. Instead, the most widely used cut-off values for defining elevated BP are based on BP percentiles specific for sex, age, and height determined in American children in the 1970s and 1980s (i.e. before the obesity epidemic) [7,8]. Owing to a large variability in repeated BP readings, the diagnosis of hypertension in adults should be based on repeated BP measurements made on several visits [9,10]. It was recently recommended that, similarly to adults, hypertension in children is defined if the BP is elevated on at least three separate occasions [7].

Few studies have assessed the prevalence of elevated BP in children populations based on measurements obtained on more than one visit [11–16]. We are aware of only two recent population-based studies that have estimated the prevalence of hypertension in children based on measurements taken at three separate visits and using the current US reference cut-off values [14,15]. Both studies were carried out among schoolchildren of Houston, Texas, USA, and the prevalence of elevated BP was more than halved based on the third visit versus the first visit [15]. To our knowledge, the prevalence of hypertension based on at least three sets of BP readings is unknown in other pediatric populations, and the prevalence of sustained hypertension in child populations is therefore largely unknown.

In the present study, we estimated the prevalence of hypertension in all schoolchildren of one school grade in one region of Switzerland (the canton of Vaud) based on readings obtained on up to three separate visits. In addition, we assessed the relationship between hypertension and excess body weight and other characteristics of the children and their parents.

Method

The study took place between September 2005 and May 2006 in the canton of Vaud, Switzerland [17]. The canton of Vaud is located in the west, French-speaking part of Switzerland and accounts for 9% of the total 7.5 million population of Switzerland. Children attend school up to the ninth grade, with 96% in public schools. In this survey, all children of the sixth grade of the public schools were invited to participate. The survey was approved by the ethical research committee of the Faculty of Biology and Medicine, University of Lausanne. Consent was sought from directors of all schools. Signed consent of one of the parents and of the child were obtained.

Measurements were performed in a quiet and tempered room by trained clinical officers at the initial visit. Weight and height were measured with precision electronic scales (at 0.1 kg) and fixed stadiometers (at 0.1 cm). Children were measured without shoes and in light garments. The mid-arm circumference was measured and the cuff width adapted accordingly (i.e. pediatric or normal cuff for a mid-arm circumference of 17.0–21.9 cm or 22.0–32.0 cm, respectively). At each visit, three measurements of BP and of heart rate were taken on the right arm at 1-min intervals after a rest of at least 3 min, in a seated position. Readings were obtained with a clinically validated oscillometric device (Omron M6; Omron Healthcare Europe BV, Hoofddorp, The Netherlands) [18]. Each device was checked for accuracy by comparing BP values obtained with a mercury sphygmomanometer using a Y tube connected to the automated device [19].

'Elevated BP' was defined according to the American reference data [7], which are generally considered the best available standard. Children with 'elevated BP' based on the last two BP readings at one visit had a second set of three readings measured at a separate visit 1–2 weeks later. Children who still had 'elevated BP' based on the last two readings on that second visit had a third set of three readings measured another 1–2 weeks later. Measurements at the second and third visits were performed by school nurses, who had been trained on the standardized BP measurement methods and using the same BP measurement devices.

Parents were asked to complete a mailed structured questionnaire about their educational level, nationality, and hypertension status. Parents' educational level was based on the highest degree completed by the mother or the father (primary, secondary, tertiary educational level). Nationality was considered as Swiss if at least one of the parents reported Swiss nationality. Parents were considered to have hypertension if they reported to have been ever told by a physician or a health professional that they had elevated BP.

The body mass index (BMI) was calculated as weight divided by the height squared (kg/m^2). 'No excess weight', 'overweight', and 'obesity' were defined respectively for a BMI less than the 85th percentile, between the 85th and 94th percentiles, and of at least the 95th percentile of the US reference data, which are often used to define excess body weight in children [20]. Based on these US percentiles, we also calculated BMI categories (percentiles <25, 25–74, 75–84, 85–94, and ≥ 95). In addition, we have also indicated 'overweight' and 'obesity' along the sex-specific and age-specific BMI criteria of the International Obesity Task Force [5] for the sake of comparison with studies that have used these criteria.

'Elevated BP' was based on the American reference data [7], which have been determined in American children examined in the 1970s and 1980s (i.e. before the obesity epidemic) [8]. 'Elevated BP' is defined for systolic or diastolic BP equal to or greater than the 95th sex-specific, age-specific and height-specific percentiles of these American normative data (or, equivalently, for a Z-score of this sex-specific, age-specific and height-specific distribution of BP ≥ 1.64). Sex-specific and age-specific percentiles of height — which are needed to assess elevated BP – were similarly derived from the Centers for Disease Control and Prevention (CDC) growth charts. 'Hypertension' was considered for children who had 'elevated BP' at all three visits based on the average of the last two of the three BP readings.

The prevalence and standard error were estimated for boys and girls. The difference in mean BP or mean heart rate between visits was evaluated using a paired t-test (two visits) or analysis of variance (three visits). The shape of the relationship between the BMI and BP was assessed using the LOWESS method, a scatterplot smoothing technique based on robust locally weighted regression [21]. Smoothed curves were generated for both systolic and diastolic BP. Logistic models were fitted to assess the association between 'hypertension' and various characteristics: BMI categories and tertiles of heart rate at the first visit of the children as well as educational level, nationality, and history of hypertension of the parents. We calculated the proportion of all hypertensive children that could be attributed to overweight or obesity (CDC criteria), the population attributable fraction [22]. Confidence intervals of the population attributable fraction were based on asymptotic approximation [23].

Table 1 Characteristics of the participants

	Boys	Girls	All
n	2621	2586	5207
Age (years), mean (SD) [range]	12.3 (0.5) [10.1–14.9]	12.3 (0.5) [10.3–14.8]	12.3 (0.5) [10.1–14.9]
BMI (kg/m^2), mean (SD) [range]	18.6 (2.9) [11.3–36.3]	18.7 (3.1) [12.4–39.5]	18.7 (3.0) [11.3–39.5]
IOTF BMI categories (%), mean (SE)			
No excess weight	85.0 (0.7)	87.6 (0.6)	86.3 (0.5)
Overweight (not obese)	13.3 (0.7)	10.7 (0.6)	12.0 (0.5)
Obesity	1.8 (0.3)	1.7 (0.3)	1.7 (0.2)
CDC BMI categories (%), mean (SE)			
No excess weight (< 85th percentile)	83.9 (0.7)	87.6 (0.6)	85.7 (0.5)
Overweight (85–94th percentile)	11.8 (0.6)	9.4 (0.6)	10.6 (0.4)
Obesity (≥ 95th percentile)	4.2 (0.4)	3.0 (0.3)	3.6 (0.3)
Parents' education (%), mean (SE)			
Tertiary	33.5 (0.9)	33.4 (0.9)	33.4 (0.6)
Secondary	48.6 (1.0)	47.8 (1.0)	48.2 (0.7)
Primary	10.3 (0.6)	10.9 (0.6)	10.6 (0.4)
Other/unknown	7.7 (0.5)	7.9 (0.5)	7.8 (0.4)
Parents' nationality (%), mean (SE)			
At least one parent is a Swiss national	75.2 (0.9)	74.8 (0.9)	75.0 (0.6)
No parent is a Swiss national	24.8 (0.9)	25.2 (0.9)	25.0 (0.6)
Parents with elevated blood pressure (%), mean (SE)			
None	76.6 (0.9)	76.2 (0.9)	76.4 (0.7)
Father	13.5 (0.7)	13.5 (0.7)	13.5 (0.5)
Mother	8.0 (0.6)	8.4 (0.6)	8.2 (0.4)
Both	2.0 (0.3)	1.8 (0.3)	1.9 (0.2)

BMI, body mass index; CDC, Centers for Disease Control and Prevention [20]; IOTF, International Obesity Task Force [5]; SD, standard deviation; SE, standard error.

Calculation of the population attributable fraction assumes a causal relationship between the variables of interest (body weight and hypertension) [22]. Statistical analyses were performed with Stata 8.2 (StataCorp LP, College Station, Texas, USA).

Results

All public schools of the canton of Vaud agreed to participate. Of the 6873 eligible children, 5207 were examined (participation rate, 76%).

Table 1 presents selected characteristics of the participants. Overweight was found in 15.0% (0.7) of boys and 12.4% (0.6) of girls (the overweight category includes the obesity category). Some associations are important to note (results not appearing in Table 1). Overweight (also including obesity; CDC criteria) was inversely associated with parents' educational level: the proportions of children who were overweight (including obesity) was 24.3% (1.8), 15.0% (0.7) and 9.8% (0.7) for parents with primary, secondary and tertiary educational levels, respectively ($P < 0.001$). Children whose parents were not Swiss nationals were more frequently overweight or obese compared with children who had at least one Swiss parent (22.7% (1.2) versus 11.3% (0.5); $P < 0.001$). The mean heart rate increased throughout BMI categories; respectively, 82.7 per min (0.2), 83.4 per min (0.5) and 84.2 per min (0.9) in lean, overweight (not obese), and obese children (trend, $P = 0.048$).

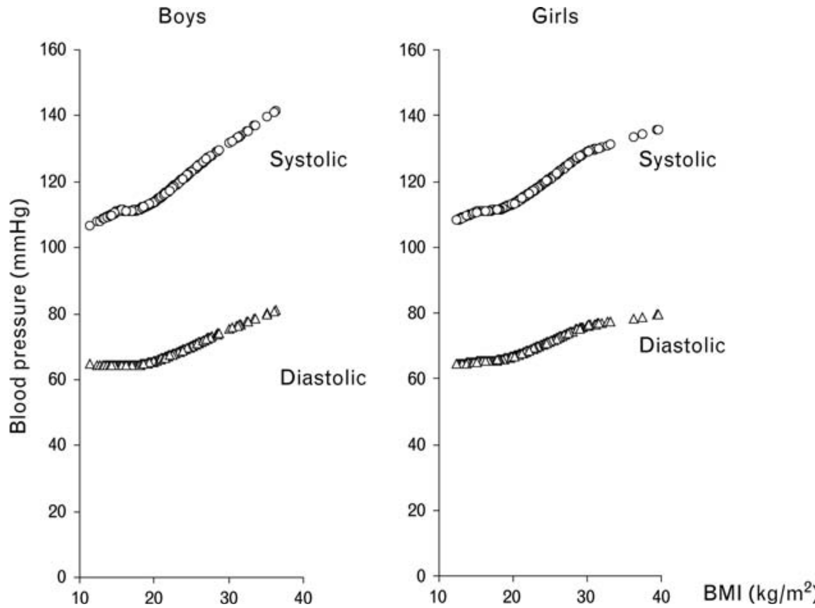
Table 2 presents the prevalence of 'elevated BP' at each of the three visits (based on the average of the last two of three BP readings). The figures were similar in boys and in girls. The prevalence of elevated BP decreased markedly over repeated visits. Among children with elevated BP, most of them had isolated systolic elevated BP; respectively, 84, 84, and 81% at the first, second, and third visits. Very few children had elevated diastolic BP.

Table 2 Mean blood pressure (BP) and prevalence of elevated BP at the first, second, and third visits

Sex	Visit	*n*	Systolic BP (mmHg), mean (SD)	Diastolic BP (mmHg), mean (SD)	Elevated systolic BP (%), (SE)	Elevated diastolic BP (%), (SE)	Elevated BP (%), (SE)
Boys	First	2621	113.1 (10.0)	65.2 (7.1)	9.9 (0.6)	1.4 (0.2)	10.5 (0.6)
	Second	249	123.0 (9.5)	68.7 (7.8)	3.7 (0.4)	0.7 (0.2)	4.0 (0.4)
	Third	100	127.5 (10.5)	72.2 (8.8)	2.2 (0.3)	0.5 (0.1)	2.3 (0.3)
Girls	First	2586	112.6 (9.8)	66.4 (7.0)	11.9 (0.6)	2.3 (0.3)	12.4 (0.6
	Second	293	120.3 (9.0)	69.9 (7.2)	3.5 (0.4)	0.6 (0.1)	3.7 (0.4)
	Third	91	125.4 (8.3)	72.2 (7.0)	2.0 (0.3)	0.3 (0.1)	2.0 (0.3)
All	First	5207	112.9 (9.9)	65.8 (7.1)	10.9 (0.4)	1.8 (0.2)	11.4 (0.4)
	Second	542	121.5 (9.3)	69.3 (7.5)	3.6 (0.3)	0.6 (0.1)	3.8 (0.3)
	Third	191	126.5 (9.6)	72.2 (7.9)	2.1 (0.2)	0.4 (0.1)	2.2 (0.2)

'Elevated BP' is defined according to American reference data [7]. SD, standard deviation; SE, standard error.

Fig. 1



Relationship between systolic blood pressure (upper part) and diastolic blood pressure (lower part) with the body-mass index (BMI), by sex.

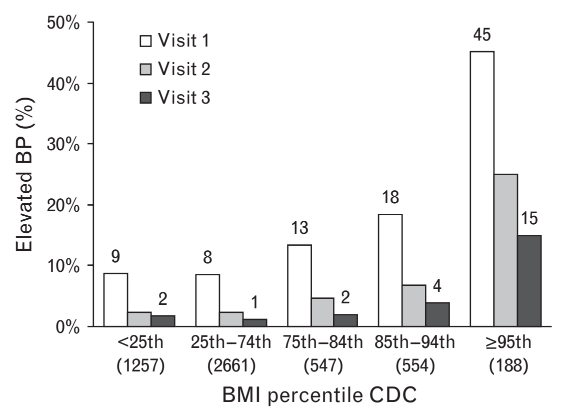
Among children whose BP was measured on two occasions ($n = 524$), the mean BP (SD) was 131.0 (6.6)/74.7 (6.8) mmHg at the first visit and 121.5 (9.3)/69.3 (7.5) mmHg at the second visit ($P < 0.001$ for difference with fist visit). The mean heart rate was, respectively, 88.5 (13.2) per min and 84.9 (12.6) per min ($P < 0.001$ for difference with first visit). Among children whose BP was measured on three occasions ($n = 191$), the BP was 132.5 (7.8)/75.8 (7.3) mmHg at the first visit, 131.5 (6.2)/73.9 (7.1) mmHg at the second visit, and 126.5 (9.6)/72.2 (7.9) mmHg at the third visit ($P < 0.01$ for a difference between visits). The mean heart rate was, respectively, 88.5 (13.1) per min, 87.4 (14.1) per min and 87.4 (14.1) per min ($P < 0.01$ for a difference between visits).

Figure 1 shows the smoothed curves of the relationship between BP and BMI in all children. Both systolic BP and diastolic BP were associated directly and in a graded manner with the BMI.

Figure 2 shows the prevalence of elevated BP at each visit by the BMI percentile categories in all children. Elevated BP was increasingly frequent across categories of BMI percentiles (using CDC criteria).

Table 3 presents the univariate and multivariate associations between hypertension and selected characteristics of the children and of the parents. The prevalence of hypertension was associated with children's BMI and heart rate. The mean heart rate was 82.7 per min (0.2) in normotensive children and 90.3 per min (1.3) in hypertensive children ($P < 0.001$). Childrens' hypertension was associated with parent's history of hypertension (in particular, paternal history of hypertension) but not with parents' educational level or nationality. The proportions of all children with hypertension that could be attributable to overweight or obesity (CDC criteria) were 37% overall (95% confidence interval, 24–48), 40% (95% confidence interval, 26–52) in boys and 34% (95% confidence interval, 21–44) in girls.

Fig. 2



Prevalence of elevated blood pressure (BP) by categories of body-mass index (BMI) percentile [using Centers for Disease Control (CDC) criteria] and the number of separate visits on which elevated BP was estimated. Number of children in each BMI category indicated in parentheses.

Table 3 Factors associated with hypertension in children

		Normal blood pressure *n*	Hypertension *n*	Crude odds ratio (95% confidence interval)	*P* value	Adjusted* odds ratio (95% confidence interval)	*P* value
Body mass index categories (CDC)	No excess weight (< 85th percentile)	4401	64	1		1	
	Overweight (85–94th percentile)	533	21	2.7 (1.6–4.5)	< 0.001	2.7 (1.5–5.0)	0.001
	Obesity (≥ 95th percentile)	160	28	12.0 (7.5–19.3)	< 0.001	16.2 (9.1–28.9)	< 0.001
Heart rate at the first visit	< 77.5 per min	1672	21	1		1	
	77.5–86.9 per min	1715	25	1.2 (0.6–2.1)	0.62	1.1 (0.6–2.3)	0.73
	≥ 87.0 per min	1707	67	3.1 (1.9–5.1)	< 0.001	3.4 (1.9–6.2)	< 0.001
Parents' educational level	Tertiary	1711	30	1		1	
	Secondary	2453	56	1.3 (0.8–2.0)	0.25	1.0 (0.6–1.7)	0.91
	Primary	536	15	1.6 (0.9–3.0)	0.14	1.8 (0.8–4.2)	0.17
Parents' nationality	Swiss	3513	75	1		1	
	Foreign	1171	25	1.0 (0.6–1.6)	1.00	0.6 (0.3–1.1)	0.09
Parents with hypertension	None	3197	53	1		1	
	Father	549	25	2.7 (1.7–4.5)	< 0.001	2.4 (1.4–4.2)	0.001
	Mother	333	16	2.9 (1.6–5.1)	< 0.001	1.7 (0.9–3.4)	0.13
	Both	77	4	3.1 (1.1–8.9)	0.032	2.3 (0.8–7.1)	0.14

Hypertension is defined for elevated blood pressure on three visits. CDC, Centers of Disease Control [20]. *Adjustment for age, sex, and other variables in the table.

Discussion

The prevalence of hypertension based on three sets of triplicate BP readings was 2.2% in a large sample of Swiss children of the sixth grade (mean age, 12 years). Most children with hypertension had isolated systolic hypertension (ISH). The prevalence of 'elevated BP' decreased by approximately five times between the first and the third visits at few-week intervals. Hypertension was associated with children's excess weight, children's heart rate, and parents' history of hypertension, but not with parents' educational level and nationality. One-third of all children with hypertension could be accounted for by excess body weight.

The strengths of the study are the large sample size, the population-based study design, as well as a fair participation rate, which ensure that the results are representative of the general population. Clinical officers and school nurses were trained to perform standardized BP measurement and a clinically validated automated BP device was used, which confers a good level of accuracy and validity of the BP measurements. On the other hand, the study had some limitations. First, BP was not re-assessed in children with normal BP at the first visit. This may lead to some underestimation of the prevalence of hypertension if some of the children had low BP at that initial visit but high usual BP (i.e. masked hypertension). Only a few studies have so far assessed the prevalence of masked hypertension in children [24]. Masked hypertension could be a precursor of persistent hypertension and is more frequent among overweight youths [24], and could therefore be a potential issue in the context of the worldwide obesity epidemic [5]. Second, parents' data on hypertension status were self-reported. Both accuracy and validity of this information are limited, and this is likely to weaken the association with high BP among their children. School nurses reported occasional cases of children with excess weight who declined participation [17]. The prevalence of overweight/obesity may therefore be underestimated, and the population attributable fraction of hypertension related to excess weight may be correspondingly underestimated. Finally, a low BMI may relate in some instances to eating disorders (e.g. malnutrition or anorexia nervosa). We did not have the necessary additional information to identify such conditions but BP is typically low in adolescents with anorexia nervosa [25].

The population attributable fraction assumes causality between exposure (overweight) and outcome (hypertension) [22]. This cross-sectional study does not provide direct argument for this, but reverse causation is unlikely. Furthermore, our estimates have been adjusted for several potentially confounding variables.

Our finding of one-third of hypertension cases due to excess body weight in Swiss children is higher than figures (18% in boys and 25% in girls) found in a large study of school children in the Seychelles islands (African region) based on duplicate BP readings on one single occasion [26,27]. In adults, the proportion of hypertension attributable to overweight or obesity (BMI $\geq 25\,kg/m^2$) has been found to range from 11 to 28% [28,29]. In the Framingham, Heart Study, up to 60% of cases of hypertension could account for a BMI of at least $23\,kg/m^2$ [30].

Other studies also showed a substantial decrease of BP in children when measures were repeated on different occasions. In 1979, in 10 641 US children in Dallas [12], the prevalence of elevated BP was 8.9% at the first visit. At a third visit some days later, only 1.2% had systolic hypertension and 0.4% had diastolic hypertension. In the Muscatine Study [11], out of 6662 children, 13% had elevated BP at the initial screening visit while less than 1% had persistent elevated BP based on repeated measurements taken on separated occasions.

Only two studies [14,15] have estimated the prevalence of hypertension based on measurements taken on three separate visits and current US BP reference. The prevalence of elevated BP more than halved from the first to the third visits [15]. The decrease was even larger in our study, with an 80% decrease between the first and third visits.

Table 4 summarizes the few recent population-based studies in which BP was measured in children on more than one visit and in which elevated BP was based on the current US reference data [7]. The prevalence in our study (2.2% at the third visit) tends to be lower that what was observed in the available studies using the same methodology in the USA (5–9% at the third visit). When attempting to explain the low prevalence of hypertension in children in our study, it can be considered that the prevalence of overweight in children is substantially lower in Switzerland than in the USA [31] and that the prevalence of hypertension in adults is low in Switzerland by international standards; for example, similar to the prevalence in North America but substantially lower than in many other European countries [32].

Our aim was to assess hypertension defined as an elevated BP sustained over three consecutive visits, along the recommendation of the National High Blood Pressure Education Program [7]. A limitation of this definition is that it cannot identify children with BP that is normal at a first visit but high at subsequent visits. We had previously shown, in adults, that the decrease in BP over subsequent visits occurred in both persons with high and normal initial BP [33], and we may anticipate that a similar decrease also occurs among children (i.e. that only few children with low initial BP would have elevated BP on further visits).

While hypertension typically refers to sustained elevated BP, elevated BP based on one visit should not be considered completely benign. BP measured on one occasion was shown to correlate with left ventricular hypertrophy [34] and with carotid intima–media thickness [35]. Repeated readings, however, improve the reliability of BP estimates and, for example, the carotid intima–media thickness was associated with ambulatory BP measurement but not with one set of office BP readings in another study in children [36]. Hence, sustained elevated BP is probably a better clinical indicator for guiding diagnosis and treatment.

Eighty percent of hypertensive children had ISH. This is consistent with higher prevalence of elevated ISH than elevated diastolic BP reported in most other surveys [14,15,37]. In Houston, Sorof *et al.* [14] found that 88% of hypertensive children had ISH. In adults, ISH is usually linked to increasing arterial stiffness with age [38]. In children, sympathetic nervous system

Table 4 Comparison of the prevalence of elevated blood pressure (BP) in children in studies in which BP was measured on more than one visit

Study	Sample	Year	Age (years)	n	Mean BMI or prevalence of overweight	Device	Definition of BP	Prevalence of elevated BP on first visit	Prevalence of elevated BP on second visit	Prevalence of elevated BP on third visit
Adrogué and Sinaiko, 2001 [13]	Schoolchildren of cities of St Paul and Minneapolis, USA	1986–1987	10–15	19 542	Boys: 20.5 kg/m^2 Girls: 19.9 kg/m^2	Mercury sphygmomanometer	Mean of two BP readings	sys/dia: 2.7%/2.0%	sys/dia: 0.8%/0.4%	–
Sorof *et al.*, 2002 [14]	Children of eight schools in Houston, USA	2000–2001	12–16	2460	Boys and girls: 23%[a]	Automated oscillometric SpaceLabs monitor	Mean of three BP readings	16.8% sys/dia: 16%/2%	11.1% sys/dia: 11%/1%	9.5% sys/dia: 8%/2%
Sorof *et al.*, 2004 [15]	Children of eight schools in Houston, USA	2002	13.5 ± 1.7	5102	Boys and girls: 20%[a]	Automated oscillometric SpaceLabs monitor	Mean of three BP readings	19.4%	9.5%	4.5%
Genovesi *et al.*, 2005 [16]	Children of the schools of five villages, province of Milan, Italy	2003–2004	6–11	241	Boys: 24.7%[b] Girls: 29.3%[b]	Mercury sphygmomanometer	One BP reading at first visit; mean of three BP readings at second visit	8.8%	4.2%	–
Chiolero *et al.*, 2007 (present study)	All children of sixth grade, canton of Vaud, Switzerland	2005–2006	10–14	5207	Boys: 15.0%[b] Girls: 12.4%[b]	Automated oscillometric Omron M5	Mean of the two last of three BP readings	11.4% sys/dia: 10.9%/1.8%	3.8% sys/dia: 3.6%/0.6%	2.2% sys/dia: 2.1%/0.4%

BMI: body mass index; sys/dia, systolic BP/diastolic BP. [a] Criteria for 'overweight' of the Centers for Disease Control and Prevention (BMI ≥ 95th percentile) [20]. [b] Criteria for 'overweight' of the International Obesity Task Force [5].

hyperactivity leads to a hyperdynamic hemodynamic state and may contribute to the pathogenesis of ISH: obese children with isolated systolic BP had increased heart rate and BP variability [14]. We also found that obese children had a higher resting heart rate and that children with hypertension had a higher resting heart rate, independently of BMI. The association between elevated BP and resting heart rate might also reflect a white-coat phenomenon [39]. The occurrence of a white coat effect in our study, however, might have been minimized by the facts that BP was measured with an automated device out of the physician's office [40,41] and BP was measured by nurses rather than doctors [42].

The large difference in the prevalence of diastolic and systolic hypertension raises concerns about the validity of cut-off values used to define childhood hypertension. Sorof *et al.* [14,15] found that, in population-based studies of US children, less than 5% of children had elevated diastolic BP at the first visit while more than 10% of children had elevated systolic BP. Similarly, the prevalence of isolated diastolic hypertension was less than 1% in a population-based study of children in Canada [37]. Should we conclude that since the 1970s–1980s, diastolic BP has decreased while systolic BP has increased? Trend studies do not seem to confirm such secular changes in BP [8,43–45]. Furthermore, the dominance of ISH in childhood is difficult to reconcile with the observation that isolated diastolic hypertension is more prevalent than ISH in young adults [46]. As BP tends to track while children get older [4], one would expect ISH to be the dominant type of hypertension in young adulthood. These nonconsistent findings may also reflect changes in BP measurement methods and devices used for BP measurement, or a changing relation between elevated BP and overweight in the context of the obesity epidemic [8].

One could argue that cut-off BP values to assess hypertension among children should be based on distributions found in the target populations; for example, in view of possibly higher systolic BP among European than US children [47]. Such cut-off values have been proposed for children in Italy [48] and in the United Kingdom [49]. This issue, however, raises several fundamental epidemiological questions. Compared with 'universal' norms, population-specific distributions might have higher internal validity but they would have lower external validity [50].

In addition, it is probable that the definition of elevated BP in children should depend on height – in addition to age and sex – so that data-sets to generate population-specific distributions will need to include very large numbers of children to account for the many age-specific, sex-specific and height-specific strata (the US data included 63 227 American children aged 1–17 years surveyed in the 1970s and 1980s [7]). Another issue in defining hypertension in children is the need to account for secular trends in the prevalence of overweight in children and their effect on BP over time. American norms are based on data collected largely before the obesity epidemic. Overall, and in contrast to adults, few prospective studies or trials have linked BP among children with cardiovascular disease outcomes. Pending conclusive evidence, it may be useful to use the American pediatric reference data, which does not necessarily exclude a concomitant use of population-specific norms.

As BP was measured with an oscillometric device, the diastolic BP might have been underestimated. We did, however, use a device from a leading company in the area that was clinically validated in adults [17]. Furthermore, we checked all devices for accuracy by comparing BP values obtained with a mercury sphygmomanometer using a Y tube connected to the automated device: auscultatory and oscillometric readings for systolic BP as well as diastolic BP were comparable.

Our findings have several implications. First, they further emphasize the need for measuring BP on several separated visits before ascertaining the diagnosis of hypertension. Such an approach is clearly needed for children as it was already shown for adults [9]. Just as for adults, however, the clinical significance of transiently elevated BP among children should also be researched.

A second implication is related to screening of elevated BP among children. Figures provided by this study show limited robustness of measurement BP measured on one visit to predict sustained elevated BP and a low prevalence of sustained elevated BP in the studied population. Hence, systematic screening based on BP readings on a single visit is likely to mislabel as hypertensive a substantial number of children, with the potential harm associated with wrong labeling and unneeded complementary investigations. Hence, universal screening for elevated BP in children may not be advisable, at least in populations with low prevalence of hypertension, bearing in mind the important resources needed for screening programs and the uncertainty on long-term consequences of childhood BP [3,7]. On the other hand, systematic BP screening may provide a welcome opportunity for health education related to healthy lifestyle and nutrition. This entry point may be particularly relevant in the context of the impending obesity epidemic.

Owing to the higher prevalence of elevated BP among overweight children, a screening strategy limited to those overweight could be suggested. Weight reduction, however, which is the primary therapeutic goal for obesity-related hypertension [7], is advised in obese children irrespective of BP level [6] – and screening of hypertension among obese children might further stigmatize these children. Further studies should evaluate the pros and cons of different BP screening strategies targeting all children or specific subgroups. More generally, our data re-emphasize the need for prevention of overweight in children as a means to curb the global hypertension burden.

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