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Discordant Secular Trends in Elevated Blood Pressure and Obesity in Children and Adolescents in a Rapidly Developing Country

Arnaud Chiolero, MD, MSc; Gilles Paradis, MD, MSc; Georges Madeleine, RN; James A. Hanley, PhD; Fred Paccaud, MD, MSc; Pascal Bovet, MD, MPH

Background—The effect of the increasing prevalence of obesity on blood pressure (BP) secular trends is unclear. We analyzed BP and body mass index secular trends between 1998 and 2006 in children and adolescents of the Seychelles, a rapidly developing island state in the African region.

Methods and Results—School-based surveys were conducted annually between 1998 and 2006 among all students in 4 school grades (kindergarten and 4th, 7th, and 10th years of compulsory school). We used the Centers for Disease Control and Prevention criteria to define obesity and elevated BP. The same methods and instruments were used in all surveys. Some 25,586 children and adolescents 4 to 18 years of age contributed 43,867 observations. Although the prevalence of obesity in boys and girls increased from 5.1% and 6.0%, respectively, in 1998 to 2000 to 8.0% and 8.7% in 2004 to 2006, the prevalence of elevated BP decreased from 8.4% and 9.8% to 6.9% and 7.8%. During the interval, mean age-adjusted body mass index increased by 0.57 kg/m² in boys and 0.58 kg/m² in girls. Mean age- and height-adjusted systolic BP decreased by 3.0 mm Hg in boys and 2.8 mm Hg in girls, whereas mean diastolic BP did not change substantially in boys (−0.2 mm Hg) and increased slightly in girls (0.4 mm Hg).

Conclusion—At a population level, the marked increase in the prevalence of obesity in children and adolescents in the Seychelles was not associated with a commensurate secular rise in mean BP. (Circulation. 2009;119:558-565.)

Key Words: blood pressure ■ epidemiology ■ hypertension ■ obesity ■ pediatrics

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Children with elevated blood pressure (BP) have an increased risk of end-organ damage such as ventricular hypertrophy and increased carotid intima-media thickness, as well as an increased risk of hypertension in adulthood. Because of the strong causal association between obesity and elevated BP, the increasing prevalence of obesity is expected to lead to a parallel increase in mean BP at the population level in adults and in children.

However, the consequences of the obesity trends on BP may not be easily predicted. In many countries, mean BP and the prevalence of hypertension in adults have not increased concomitantly with the obesity epidemic. In children and adolescents, obesity also is strongly associated with elevated BP, but the few available studies on secular trends have not consistently shown parallel increases in the prevalence of obesity and elevated BP in populations. Furthermore, few large population-based studies have been conducted, and methods for BP measurement have changed over time in some of these studies, making interpretation of trends difficult. Reliability of BP measurement methods is a key aspect because changes in mean BP are expected to be moderate over time at the population level and readings depend strongly on how BP is measured. No study has reported joint BP and body mass index (BMI) trends in populations outside North America and Europe.

On the basis of school-based surveys conducted between 1998 and 2006 among 25,586 children and adolescents, we report the trends in BMI and BP in Seychelles, a rapidly developing country in which the prevalence of obesity has increased rapidly in the last decade.

Methods

The study took place in the Republic of Seychelles, an island state in the Indian Ocean situated 1800 km east of Kenya (African region). A large majority of the population is of African descent. Seychelles has experienced rapid socioeconomic development over the last decades, and national gross domestic product per capita increased in...
Table 1. Anthropometry and BP of the 25 586 Participants Contributing 43 867 Observations

<table>
<thead>
<tr>
<th>Grade</th>
<th>n</th>
<th>Age, y</th>
<th>Height, cm</th>
<th>Weight, kg</th>
<th>BMI, kg/m²</th>
<th>Systolic BP, mm Hg</th>
<th>Diastolic BP, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>5071</td>
<td>5.5 (0.4)</td>
<td>112.8 (5.6)</td>
<td>19.4 (3.5)</td>
<td>15.2 (2.0)</td>
<td>95.1 (10.4)</td>
<td>59.7 (9.4)</td>
</tr>
<tr>
<td>4</td>
<td>5842</td>
<td>9.2 (0.4)</td>
<td>134.1 (6.4)</td>
<td>29.8 (7.4)</td>
<td>16.4 (3.1)</td>
<td>101.0 (10.7)</td>
<td>62.5 (9.1)</td>
</tr>
<tr>
<td>7</td>
<td>5757</td>
<td>12.6 (0.4)</td>
<td>152.0 (8.4)</td>
<td>42.6 (11.2)</td>
<td>18.3 (3.7)</td>
<td>104.5 (11.3)</td>
<td>64.3 (8.7)</td>
</tr>
<tr>
<td>10</td>
<td>5332</td>
<td>15.6 (0.5)</td>
<td>169.4 (7.7)</td>
<td>57.4 (11.6)</td>
<td>20.0 (3.5)</td>
<td>115.9 (12.3)</td>
<td>68.1 (8.8)</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>4844</td>
<td>5.5 (0.4)</td>
<td>112.0 (5.6)</td>
<td>19.1 (3.4)</td>
<td>15.2 (2.1)</td>
<td>94.6 (10.7)</td>
<td>60.4 (9.5)</td>
</tr>
<tr>
<td>4</td>
<td>5654</td>
<td>9.2 (0.4)</td>
<td>134.1 (6.8)</td>
<td>30.5 (8.0)</td>
<td>16.8 (3.4)</td>
<td>101.1 (10.9)</td>
<td>63.7 (9.1)</td>
</tr>
<tr>
<td>7</td>
<td>5748</td>
<td>12.5 (0.4)</td>
<td>154.3 (7.2)</td>
<td>46.3 (11.6)</td>
<td>19.3 (4.1)</td>
<td>106.0 (11.0)</td>
<td>66.7 (8.5)</td>
</tr>
<tr>
<td>10</td>
<td>5619</td>
<td>15.6 (0.4)</td>
<td>160.3 (6.3)</td>
<td>54.8 (11.8)</td>
<td>21.3 (4.2)</td>
<td>109.6 (10.9)</td>
<td>69.3 (8.3)</td>
</tr>
</tbody>
</table>

K indicates kindergarten. Values are mean (SD).

real terms from US $2927 in 1980 to US $5239 in 2004. A high prevalence of cardiovascular disease risk factors, including hyper-
tension, and obesity has been documented in adults and children.13,24–26

Data for this study came from a school-based national surveillance system that consists of annual surveys of all children and adolescents attending all public and private schools in Seychelles in 4 selected school grades: kindergarten and 4th, 7th, and 10th years of obligatory school (see the online Data Supplement).24,25 Nearly 100% of children attend school, ~96% in public schools and 4% in private schools. This study included all students examined between 1998 and 2006. Therefore, each year, we obtained population-based data on all children of the same specified 4 school grades, allowing analyses of secular trends. Some students were screened several times as they moved across subsequent grades; eg, a child examined in kindergarten could be examined again when he/she was attending grade 4 and later in grade 7.

Data were collected during routine medical visits at school by more than a dozen trained school nurses. BP was measured according to a standardized protocol with clinically validated oscillometric automated devices (Omron M527) that meet the international validation protocol criteria for BP measurement.28 The average systolic/diastolic BP difference between the oscillometric device and mercury sphygmomanometer readings was -.05/-.08 mm Hg (SD, 5.8/4.8 mm Hg).29 BP was measured in the sitting position after a rest of at least 5 minutes on the right arm with a cuff of appropriate size based on arm circumference. Two readings were obtained at a 1-minute interval and averaged. Z scores and corresponding percentiles of BP were generated using the Centers for Disease Control and Prevention (CDC) reference tables.29,30 Elevated BP was defined as systolic BP and/or diastolic BP equal to or above the referent sex-, age-, and height-specific 95th percentile.30

Weight was measured with precision electronic scales (Seca 870, Seca, Hamburg, Germany); height was measured with fixed stadiometers (Seca 208, Seca). BMI was calculated as weight divided by height squared. Z scores and corresponding percentiles of BMI were generated with the CDC reference tables.29 Overweight and obesity were defined using the sex- and age-specific BMI criteria of the CDC, ie, BMI ≥85th and ≥95th percentiles, respectively.

Nurses were trained by one of the investigators (G.M.). The equipment was checked annually for accuracy. Equipment and methods for BP measurement were kept identical throughout all surveys. The study was approved by the research committee of the Ministry of Health after scientific and ethical reviews. Informed consent was obtained from parents or guardians, and children were free to participate.

Statistical Analyses

Secular trends in BMI and BP were analyzed both by calendar years and by 3-year periods (1998 to 2000, 2001 to 2003, and 2004 to 2006). The latter categorization yields more stable estimates of BP across sex, age, and grade strata. Within each 3-year period, children were examined only once.

For the analyses of trends based on all observations, we used generalized estimating equations (GEEs) (function xtgee of Stata, Stata Corp, College Station, Tex) to account for the correlation between several observations on the same children. An exchangeable correlation structure was assumed. In addition, we modeled trends using random-effect models (function xtmixed, allowing for a random effect for students’ ages. Both modeling techniques gave similar results; we report only findings obtained with GEEs. We estimated mean age-adjusted BMI each year between 1998 and 2006.

To account for differences in mean age and mean height between surveys, we estimated mean age- and height-adjusted BPs each year between 1998 and 2006. The following models were used: (1) $BMI = \alpha + \beta_1 \times \text{survey year} + \beta_2 \times \text{age}$ and (2) $BP = \alpha + \beta_1 \times \text{survey year} + \beta_2 \times \text{age} + \beta_3 \times \text{height}$. The value of $\beta_1$ in model 1 is the estimated mean change in BMI per survey year. The value of $\beta_1$ in model 2 is the estimated mean change in BP per survey year.

Because no child had repeated measurement within each 3-year period and within each sex- and grade-specific stratum, we used linear regression to estimate mean age-adjusted BMI and mean age- and height-adjusted BP within these strata.

To examine how BMI and BP were associated at the individual level in 1998 to 2000, 2000 to 2003, and 2004 to 2006, we plotted mean systolic and diastolic BP across BMI categories within each sex and grade stratum and for each 3-calendar year period. To test whether the strength of the association between BMI and BP changed over time, we used sex-specific GEE models with BP as the dependent variable and with BMI, survey year, age, and the interaction term BMI-by–survey year as the independent variables. A positive coefficient suggests a stronger association between BMI and BP over calendar years (ie, a decrease in the slope). A negative coefficient for the interaction term BMI-by–survey year suggests a weaker association between BMI and BP.

For the analyses of trends based on all observations, we used generalized estimating equations (GEEs) (function xtgee of Stata, Stata Corp, College Station, Tex) to account for the correlation between several observations on the same children. An exchangeable correlation structure was assumed. In addition, we modeled trends using random-effect models (function xtmixed, allowing for a random effect for students’ ages. Both modeling techniques gave similar results; we report only findings obtained with GEEs. We estimated mean age-adjusted BMI each year between 1998 and 2006. To account for differences in mean age and mean height between surveys, we estimated mean age- and height-adjusted BPs each year between 1998 and 2006. The following models were used: (1) $BMI = \alpha + \beta_1 \times \text{survey year} + \beta_2 \times \text{age}$ and (2) $BP = \alpha + \beta_1 \times \text{survey year} + \beta_2 \times \text{age} + \beta_3 \times \text{height}$. The value of $\beta_1$ in model 1 is the estimated mean change in BMI per survey year. The value of $\beta_1$ in model 2 is the estimated mean change in BP per survey year.

Results

Of 55 615 eligible screening visits among all children and adolescents attending school in the selected grades between 1998 and 2006, data on weight, height, and BP were available in 43 867 visits (79%), which corresponded to 25 586 different students 4 to 18 years of age. Some 12 467 participants were examined once, 8664 were examined twice, 3748 were seen 3 times, and 707 were examined 4 times. In both sexes, size, weight, and BP were associated with age (Table 1).
Although age-adjusted mean BMI increased monotonically between 1998 and 2006 in both sexes (Figure 1), mean age- and height-adjusted systolic BP changed minimally up to 2002 to 2003 and decreased in subsequent years. Mean age- and height-adjusted diastolic BP remained fairly constant during the entire study period.

Mean age-adjusted BMI increased markedly across the consecutive 3-year periods in all sex and grade strata (Table 2). The largest increase in BMI over these 3-year categories was observed in children of grades 4 and 7. Mean age-adjusted height increased across the consecutive 3-year periods in all sex and grade strata (data not shown). There was no substantial change in mean age- and height-adjusted BP between 1998 to 2000 and 2001 to 2003. However, systolic BP was lower by −1 to −3 mm Hg between 2004 to 2006 and 1998 to 2000 across all sex and grade strata. No substantial change was observed for diastolic BP between 1998 to 2000 and 2004 to 2006, except for a slight increase (≈1 mm Hg) in younger children (boys in kindergarten; girls in kindergarten and grade 4).

In both sexes, the prevalence of overweight and obesity increased markedly across the 3-year periods (see the Data Supplement). Although the prevalence of overweight was 4.9% higher in 2004 to 2006 than in 1998 to 2000 (a 38% relative increase) and the prevalence of obesity was 2.8% higher (a 50% relative increase), the prevalence of elevated BP did not increase over time commensurately. Compared with 1998 to 2000, the prevalence of elevated BP was slightly higher in 2001 to 2003 but lower in 2004 to 2006 in both sexes. The prevalence of elevated BP was 7.4% in 2004 to 2006 compared with 9.1% in 1998 to 2000 (a 19% relative decrease). Similar trends were found for both elevated systolic and diastolic BPs, although the trends for diastolic BP were of weaker amplitude.

Figure 2 shows the distribution of the z scores of BMI and z scores of systolic and diastolic BPs in 1998 to 2000 and in 2004 to 2006. A marked upward shift in the distribution of the BMI z scores occurred between 1998 to 2000 and 2004 to 2006. This shift was most apparent in the upper half of the distribution. In contrast, the entire distribution of the systolic BP z scores shifted to lower values of the distribution between the same periods in both boys and girls. The distribution of the diastolic BP z score tended to be narrower in 2004 to 2006 than in 1998 to 2000, with a shift of the lower values toward more centered values, especially in girls.

![Table 2. Trends in Mean Age-Adjusted BMI and Mean Age- and Height-Adjusted Systolic and Diastolic BPs in Children and Adolescents in the Seychelles Between 1998 and 2006](circ.ahajournals.org)

Although age-adjusted mean BMI increased monotonically between 1998 and 2006 in both sexes, (Figure 1), mean age- and height-adjusted systolic BP changed minimally up to 2002 to 2003 and decreased in subsequent years. Mean age- and height-adjusted diastolic BP remained fairly constant during the entire study period.

<table>
<thead>
<tr>
<th>Grade</th>
<th>BMI, kg/m²</th>
<th>Systolic BP, mm Hg</th>
<th>Diastolic BP, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>15.2 (0.1)</td>
<td>15.2 (0.0)</td>
<td>15.3 (0.0)</td>
</tr>
<tr>
<td>4</td>
<td>16.0 (0.1)</td>
<td>16.5 (0.1)</td>
<td>16.7 (0.1)</td>
</tr>
<tr>
<td>7</td>
<td>17.9 (0.1)</td>
<td>18.3 (0.1)</td>
<td>18.6 (0.1)</td>
</tr>
<tr>
<td>10</td>
<td>19.8 (0.1)</td>
<td>19.8 (0.1)</td>
<td>20.2 (0.1)</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>15.1 (0.1)</td>
<td>15.2 (0.0)</td>
<td>15.3 (0.1)</td>
</tr>
<tr>
<td>4</td>
<td>16.5 (0.1)</td>
<td>16.8 (0.1)</td>
<td>17.0 (0.1)</td>
</tr>
<tr>
<td>7</td>
<td>18.9 (0.1)</td>
<td>19.5 (0.1)</td>
<td>19.4 (0.1)</td>
</tr>
<tr>
<td>10</td>
<td>21.2 (0.1)</td>
<td>21.4 (0.1)</td>
<td>21.3 (0.1)</td>
</tr>
</tbody>
</table>

K indicates kindergarten. Values are mean (SE). Estimates are based on linear regression analyses. BMI is adjusted to represent values for boys or girls of mean age within each grade category. BP is adjusted to represent values for boys or girls of mean age and height within each grade category.
Table 3 shows mean age-adjusted changes in BMI and mean age- and height-adjusted changes in BP between 1998 and 2006 as determined by GEE. In both sexes, mean BMI increased and systolic BP decreased. Mean diastolic BP did not change in boys but increased slightly in girls. Additional adjustment with a quadratic term of height did not change our results.

In both sexes, BMI was strongly associated with both systolic and diastolic BPs (Figure 3A and 3B). Systolic BP tended to be lower across the entire distribution of BMI in 2004 to 2006 than in the previous 3-year periods, except among children of grade 7 (Figure 3A). Figure 3A and 3B also shows that the strength of the association (ie, the slope) between BP (either systolic or diastolic) and BMI did not change largely over calendar years. We tested whether the BMI-by-survey year interaction term was significantly associated with BP. No interaction was found in most sex- and grade-specific models, suggesting that the strength (ie, the slope) of the association between BP and BMI did not change.

Table 3. Mean Age-Adjusted Changes in BMI and Mean Age- and Height-Adjusted Changes in BP in Children and Adolescents in the Seychelles Between 1998 and 2006

<table>
<thead>
<tr>
<th></th>
<th>BMI, kg/m²</th>
<th>Systolic BP, mm Hg</th>
<th>Diastolic BP, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>0.57 (0.47 to 0.67)</td>
<td>−3.0 (−3.4 to −2.5)</td>
<td>−0.2 (−0.5 to 0.2)</td>
</tr>
<tr>
<td>Girls</td>
<td>0.58 (0.46 to 0.69)</td>
<td>−2.8 (−3.2 to −2.4)</td>
<td>0.4 (0.1 to 0.8)</td>
</tr>
<tr>
<td>Both sexes</td>
<td>0.57 (0.49 to 0.65)</td>
<td>−2.9 (−3.2 to −2.6)</td>
<td>0.2 (−0.1 to 0.4)</td>
</tr>
</tbody>
</table>

Estimates are based on GEE analyses (95% CI).
over time, except for boys in grade 7, for whom a negative interaction was found for systolic BP \( (P<0.001) \), and for girls in grade 4, for whom a positive interaction was found for diastolic BP \( (P=0.041) \).

**Discussion**

Despite a marked increase in the prevalence of obesity in children and adolescents of Seychelles between 1998 and 2006, the prevalence of elevated BP did not change to a commensurate extent. Mean systolic BP decreased but mean diastolic BP did not change substantially. In addition, the relationship between BMI and BP weakened slightly over time, essentially through a shift of systolic BP toward lower values across the entire distribution of BMI.

Few studies have assessed the joint secular trends of BMI and BP in children and adolescents,\(^7,17–23\) and direct comparisons between studies are difficult because the time periods and the secular BMI changes differ between studies. In most of these studies, BP changes over time were relatively small (between 3 and \(-3\) mm Hg over a decade), and parallel secular trends in BMI and BP were not systematically observed.\(^22\) However, recent studies in the United States suggest that mean BP is on the rise.\(^7,18,20\) On the basis of national surveys of US children and adolescents conducted in 1988 to 1994 and 1999 to 2002, systolic BP increased slightly (by \(1.3\) mm Hg), diastolic BP increased substantially (by \(8.4\) mm Hg), and prevalence of elevated BP increased from 2.7% to 3.7%, leading the authors to conclude that BP was on the rise as a result of the obesity epidemic.\(^7\) However, BMI may be more strongly associated with systolic BP than diastolic BP in children,\(^14–16,31\) and a smaller change in systolic BP than in diastolic BP is unexpected if the observed recent increase is driven by the obesity epidemic. Surprisingly, the same study showed that between 1963 and 1998 to 1994, mean BP decreased markedly (by \(\approx 15\) mm Hg) and the prevalence of elevated BP decreased from 37.2% to 2.7%.\(^7\) In the United States, childhood obesity did not begin to rise in the 1990s but rather in the 1970s,\(^32\) suggesting that during this earlier period, mean BP had decreased in youth despite an increasing prevalence of obesity. Din-Dzietham et al\(^7\) reported that a time lag may exist between the rise in obesity and the rise in BP. Although biological mechanisms could explain a time lag between the rise in obesity and type 2 diabetes (eg, long latency between an early stage of insulin resistance and the failure of insulin secretion by the pancreatic \(\beta\) cells\(^33\)), BP rapidly changes in response to weight change at the individual level.\(^34\)

Other epidemiological data in adults did not systematically reveal the expected relation between the obesity trends and mean BP. Despite a large increase in the prevalence of obesity, mean levels of BP decreased regularly between 1960 to 1970 and 1990 to 2000 in US adults\(^11\) and between the mid 1980s and mid 1990s in populations of several European countries.\(^12\) On the other hand, the prevalence of hypertension seems to have increased between 1988 to 1994 and 1999 to 2004 in the United States, presumably because of increasing BMI levels,\(^35\) but obese adults do have lower BP levels nowadays than 30 years ago.\(^11\) These trends could not be accounted for only by better and more frequently prescribed antihypertensive treatment.\(^12\) We also observed in adults in...
Seychelles that mean BP did not increase between 1989 and 2004 despite a marked increase in the prevalence of overweight and that the strength of the relationship between BP and BMI had substantially weakened within the 15-year interval, a phenomenon not explained by the increased use of antihypertensive drug treatment in the interval.13

Our study has several strengths relevant for the assessment of secular BP trends in children. First, this is the largest study ever published on secular trends in youths 4 to 18 years of age. Second, the study is unlikely to suffer from selection biases because nearly all children and adolescents of the considered grades attend school, all children and adolescents of 4 different grades were examined, and the participation rate was high. Third, equipment and methods for examining children and measuring BP were kept identical throughout all surveys. In addition, measurements were taken by trained nurses who tend to provide lower and more reliable BP estimates than measurements taken by physicians because of a minimization of the “white-coat” effect.36 BP was measured with clinically validated automated devices27 that are recommended for epidemiological studies.37,38

Our study also has some limitations. First, only 2 readings were obtained in a single visit, which may overestimate BP levels because BP decreases with repeated measurements over several visits.16 This systematic overestimation is unlikely to bias our trend results. Although nurses were trained annually for BP measurement and the same sphygmomanometers were used throughout the study period, we could not assess the interobserver and intraobserver reliability. Second, a 9-year span is a fairly short period to assess population trends. However, the prevalence of obesity increased markedly in our study during that period, and previous studies assessing BP trends had similar time spans.17–23 Third, because some children have undergone repeated BP screenings, familiarization with the BP measurement procedure may have resulted in lower BP readings in the older grades. Because repeated observations were obtained at 3- or 4-year intervals, any habituation is expected to be minimal.39 Moreover, the same trends over time were found in children of the lowest grade (kindergarten), who had only 1 BP measurement session, compared with older children who could have several BP measurement sessions. Finally, we used US reference data40 to define elevated BP. This reference may not be adequate when applied to other populations, but this will not bias trends analyses.

Our study lacks covariates (nutrition, salt intake, physical exercise, etc) that could have helped explain the BP trends. Although a general improvement in nutrition and socioeconomic development may explain favorable trends in BP over calendar years, the diet characteristics in the Seychelles, based largely on fish and rice, have not changed greatly in the past decade. Longo-Mbenza et al40 reported that BP was high in malnourished African children. However, undernutrition has not been a substantial problem in Seychelles in the past 2 or 3 decades. More generally, the effect of socioeconomic conditions on BP and BMI is complex.41 Upward trends in BMI on one hand and downward trends in BP and cardiovascular mortality on the other hand have been observed in adults of high- or middle-income countries during the past decades, consistent with findings in Seychelles.13 Accordingly, the lack of increase in Seychelles of BP over time among children and adults13 is compatible with decreased age-standardized stroke and heart attack mortality rates during the past 20 years.42

We did not track salt intake, but another study showed that salt intake was not particularly high in adults in Seychelles.43 Physical activity has decreased in children,57 but this trend would not favor a BP decrease. It has been shown that birth weight can be inversely associated with BP,41 but in our study, mean birth weight was similar in children regardless of their year of examination (see the Data Supplement). Finally, as in other trend studies, we used BMI, a crude indicator for adiposity in children and a correlate of both fat and lean mass.44 We observed for a given level of BMI that BP was lower, which could be explained by changes in the distribution of body fat (abdominal versus subcutaneous) or in the proportion of fat versus lean mass.45 This finding also suggests that obesity may be associated with a lower cardiovascular risk than previously.11 The mechanisms at stake remain highly speculative, and studies are needed to provide further evidence.

Our data, consistent with those of others,22 suggest that the increasing prevalence of obesity can result in a less than commensurate increase in population BP levels. Although in many countries the prevalence of type 2 diabetes is increasing in adults46 and maybe in adolescents,47 it remains unclear to what extent the increasing prevalence of obesity increases the burden of hypertension in populations. The prevalence of obesity may need to reach a very high level (eg, as in the United States57) before an effect on BP can be measured at a population level. However, consistent with findings in other populations,14–16 we have previously reported a quasilinear relationship between BMI and BP at the individual level among children in the Seychelles,24 which argues against a threshold in the relation between BMI and BP in the population.

Our results do not imply that the upward trend in mean BMI in children of Seychelles had no consequences on mean BP; it is likely that mean BP would have been lower had the upward prevalence of overweight/obesity been prevented. The strength of the association between BMI and BP at the individual level has remained substantial throughout all surveys in our study, and obesity likely accounts for a substantial proportion of cases of elevated BP.24 However, our findings underline another important message: Some potential modifiable determinants may have mitigated a rise in BP in response to a rise in BMI in the population, and their identification could have important significance for the prevention of hypertension. More generally, our findings contribute to the current debate on the scope and scale of the associations between the obesity epidemic and cardiometabolic outcomes in populations.

Acknowledgments

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Sources of Funding

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Disclosures

None.

References


**CLINICAL PERSPECTIVE**

The effect of the increasing prevalence of obesity on blood pressure (BP) levels in the population is complex. In children, some studies in the United States suggest that BP increased recently, likely because of the obesity epidemic, but other studies in the United States and elsewhere show no increase in BP levels in the last decades despite increasing average body mass index. In a population-based study of 25 586 children 4 to 18 years of age in the Seychelles (a rapidly developing country in the Indian Ocean, African region), the prevalence of obesity increased largely between 1998 and 2006, yet systolic and diastolic BPs did not increase. During this period, systolic BP shifted toward lower values across the entire distribution of body mass index. Our study was not designed to investigate factors underlying these divergent trends in BP and obesity. However, the identification of potential preventable determinants that may mitigate the effect of increasing body mass index on BP trends might help develop new strategies for the primary prevention of hypertension and related diseases. Our findings also contribute to the current debate on the scope and scale of the association between the obesity epidemic and cardiometabolic outcomes in populations.