Arterial hypertension in overweight and obese Algerian adolescents: Role of abdominal adiposity

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Abstract

Objective. – This study aimed to estimate the prevalence of hypertension in Algerian overweight and obese adolescents to assess the risk factors associated with hypertension and an increase in arterial stiffness.

Subjects and methods. – This cross-sectional study included 305 adolescents (133 boys and 172 girls) aged 12–19 years, who were either overweight or obese (IOTF criteria). Their body weight, height, BMI, waist circumference (WC), WC-to-height ratio and blood pressure were also measured.

Results. – Hypertension and prehypertension were found in 19.7 and 16.1%, respectively, of the study population, with significantly more hypertensives among the obese than among the overweight adolescents. The prevalence of hypertension was also twice as high in boys as in girls (27.1% vs 14%; \( P = 0.004 \)), and WC and WC-to-height ratios were significantly higher in hypertensives than in normotensives. The risk of hypertension was also significantly higher in boys and associated with WC, independent of age and severity of weight excess (whether overweight or obese). Mean pulse pressure (PP) was significantly higher in boys versus girls, in obese versus overweight adolescents and in hypertensives versus normotensives, and was correlated with WC and WC-to-height ratio. PP >45 mmHg was associated with WC and hypertension only in boys, independent of age.

Conclusion. – The prevalence of hypertension is high in overweight and obese adolescents, and higher in boys than in girls. Hypertension and arterial stiffness, as determined by high PP levels, were associated with abdominal adiposity. It is recommended that prehypertension be identified in overweight adolescents and that lifestyle changes be made to avoid its evolution towards obesity and hypertension.

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Keywords: Hypertension; Blood pressure; Pulse pressure; Adolescents; Obesity; Waist circumference; Algeria
1. Introduction

Arterial hypertension affects one in four adults around the world and 30% of Algerian adults, according to the 2003 World Health Organization (WHO) report, based on a survey carried out in two pilot regions, Sétif and Mostaganem [1]. The prevalence of hypertension is far lower in children and adolescents, around 1–5%, but the hypertension-related complications may be just as important [1–6].

The pathophysiology of hypertension is different before puberty and during adolescence. Before puberty, hypertension is mostly secondary to a curable cause. During adolescence, hypertension is mostly essential, with major roles being played by overweight, the metabolic syndrome (MetS) and familial factors of hypertension [6]. However, the mechanisms that link hypertension and obesity in children and adolescents are poorly known. Childhood obesity may be responsible for the premature onset of hypertension, insulin resistance and lipid disorders in adolescents, and the increased risk of type 2 diabetes, the MetS and cardiovascular disease in adults over the subsequent decades of life [7–10]. On the other hand, an increase in arterial stiffness, a surrogate marker of cardiovascular risk, has been reported in children who are extremely obese [11].

Obesity is among the most serious global health problems today. In 2007, the WHO estimated that 22 million children under 5 years of age were overweight around the world, and more than 75% of these overweight or obese children are now living in low- or middle-income countries [12]. Also, recent reports suggest that 1.11 million (21.8%) of obese children and adolescents, aged 5–18 years and living in European Union, are hypertensive [8,13]. In Algeria in 2002, a study carried out in Khroub (Constantine area) reported prevalences of 10.9 and 4% of overweight and obesity, respectively, in children and adolescents aged 6–16 years [14].

The aim of our present study was to estimate the prevalence of hypertension in Algerian overweight and obese adolescents, and to examine the risk factors associated with hypertension and an increase in arterial stiffness.

2. Patients and methods

Our sample population was recruited during the school year 2006–2007 from adolescent pupils living in Constantine (Algeria) with the collaboration of general practitioners (GPs) and school doctors who referred those who were overweight or obese to our university department of endocrinology–diabetology. The sample included 305 adolescents, comprising 133 boys (43.6%) and 172 girls (56.4%) aged 12–19 years (15.1 ± 2.0 years). According to International Obesity Task Force (IOTF) criteria [15], 204 of these adolescents were overweight and 101 were obese, including 16 who had a body mass index (BMI) >35 kg/m² (two of which were ≥40 kg/m²).

These adolescents completed a questionnaire including items on family history and tobacco use. They also underwent a clinical examination at school, during which anthropometric parameters were measured. Height without shoes was measured to the nearest 0.1 cm, using a portable stadiometer (Leicester Portable Height Measure, SECA Ltd, Birmingham, UK), and weight was measured to the nearest 0.1 kg, using a standard balance scale (SECA Ltd), with the subjects wearing light indoor clothing and no shoes. BMI (in kg/m²) was calculated from these values. Waist circumference (WC) was measured to the nearest 0.1 cm, according to the established guidelines [16], using a special measuring tape with automatic roll-up. Their WC-to-height ratios were then calculated.

Blood pressure was measured in accordance with international guidelines [17], using a sphygmomanometer and an adapted cuff, three times after 5 minutes of rest in a sitting position, and the three values were averaged. These measurements were all taken by three trained investigators and with the same sphygmomanometer. In adolescents aged <18 years, the North American criteria for hypertension and prehypertension (pre-HT) were applied, which take age, gender and height into account [17] whereas, in those aged ≥18 years, the guidelines of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7), 2003 [18], were applied (Supplementary data, table* S1).

This choice was justified by the inclusion of the pre-HT stage in both definitions, which is at variance with the 2007 European definitions, wherein the pre-HT stage is replaced by “normal” or “high normal blood pressure” [19]. Blood pulse pressure (PP) was calculated as the difference between the systolic (SBP) and diastolic (DBP) blood pressures.

The study protocol was approved by our institutional review board.

2.1. Statistical analyses

The data were analyzed using SPSS software (version 11), and the results were expressed as percentages and means ± SD values. Comparisons between groups were performed by analysis of variance (ANOVA) for continuous variables, and by Chi² and Fisher’s exact tests for non-continuous variables. Multivariate analyses were performed using logistic-regression models.
Table 1
Clinical characteristics of the study population, and prevalence of hypertension and prehypertension according to North American guidelines [17].

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Boys</th>
<th>Girls</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>305</td>
<td>133</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>15.1 ± 2.0</td>
<td>14.8 ± 2.0</td>
<td>15.4 ± 1.9</td>
<td>0.015</td>
</tr>
<tr>
<td>Overweight</td>
<td>204 (66.9%)</td>
<td>80 (60%)</td>
<td>124 (72%)</td>
<td>0.028</td>
</tr>
<tr>
<td>Obese</td>
<td>101 (33.1%)</td>
<td>53 (40%)</td>
<td>48 (28%)</td>
<td></td>
</tr>
<tr>
<td>Body mass index &gt;35 kg/m²</td>
<td>16 (5.2%)</td>
<td>7 (5.3%)</td>
<td>9 (5.2%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Tobacco use</td>
<td>13 (4.3%)</td>
<td>12 (9%)</td>
<td>1 (0.6%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Family history of obesity</td>
<td>135 (44.3%)</td>
<td>54 (40.6%)</td>
<td>81 (47.1%)</td>
<td>0.282</td>
</tr>
<tr>
<td>Family history of hypertension</td>
<td>35 (11.5%)</td>
<td>8 (6%)</td>
<td>27 (15.7%)</td>
<td>0.008</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>89.0 ± 11.9</td>
<td>90.5 ± 11.6</td>
<td>87.8 ± 11.9</td>
<td>0.042</td>
</tr>
<tr>
<td>Waist circumference/height</td>
<td>0.55 ± 0.06</td>
<td>0.55 ± 0.06</td>
<td>0.55 ± 0.07</td>
<td>0.9</td>
</tr>
<tr>
<td>Normotension</td>
<td>196 (64.3%)</td>
<td>73 (54.9%)</td>
<td>123 (71.9%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>49 (16.1%)</td>
<td>36 (21%)</td>
<td>13 (7.5%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Hypertension</td>
<td>60 (19.7%)</td>
<td>24 (14%)</td>
<td>36 (21%)</td>
<td></td>
</tr>
<tr>
<td>Grade 1</td>
<td>52 (17%)</td>
<td>31 (23.3%)</td>
<td>21 (12.2%)</td>
<td></td>
</tr>
<tr>
<td>Grade 2</td>
<td>8 (2.6%)</td>
<td>5 (3.8%)</td>
<td>3 (1.8%)</td>
<td></td>
</tr>
<tr>
<td>Hypertension in overweight</td>
<td>31 (15.2%)</td>
<td>18 (13.5%)</td>
<td>13 (7.5%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Hypertension in obese</td>
<td>29 (28.7%)</td>
<td>18 (13.5%)</td>
<td>11 (6.4%)</td>
<td>0.27</td>
</tr>
<tr>
<td>Prehypertension in overweight</td>
<td>37 (18.2%)</td>
<td>16 (12%)</td>
<td>21 (12.2%)</td>
<td>0.71</td>
</tr>
<tr>
<td>Prehypertension in obese</td>
<td>12 (11.9%)</td>
<td>8 (6%)</td>
<td>4 (2.3%)</td>
<td>0.36</td>
</tr>
<tr>
<td>Pulse pressure (mmHg)</td>
<td>44.9 ± 10.3</td>
<td>46.5 ± 11.4</td>
<td>43.7 ± 9.3</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Data are presented as n(%) or as means ±SD.

a Boys versus girls.

3. Results

The main clinical characteristics of the study population are shown in Table 1. Of the 305 overweight or obese adolescents, 60 (19.7%) were hypertensive with mostly grade 1 hypertension (17%), and 49 (16.1%) had pre-HT. The percentage of hypertensives was twice as high in boys as in girls – 27.1% versus 14% (P = 0.004) – with no significant differences between boys and girls in pre-HT percentages.

However, the rates of hypertensives and pre-HT differed significantly between obese and overweight adolescents (P < 0.01). In the obese, hypertension was more prevalent than pre-HT (28.7 and 11.9%, respectively) while, in overweight adolescents, pre-HT was slightly more prevalent than hypertension (18.2 and 15.2%, respectively; Table 1). Also, SBP, but not DBP, was significantly higher in obese than in overweight adolescents (Supplementary data, table* S2).

In addition, the hypertensives and pre-HT were slightly older than the normotensives, and WC and WC-to-height ratios were significantly higher in hypertensives than in normotensives (P = 0.003 and P = 0.012, respectively). The percentage of smokers was also higher among hypertensives, with no significant differences in family history of hypertension (Table 2).

PP was ≥60 mmHg in 25 adolescents, two of whom were obese, with a BMI ≥35 kg/m². Mean PP was higher in boys than in girls (P = 0.02; Table 1), in obese compared with overweight adolescents (P = 0.007; Supplementary data, table* S2) and in hypertensives versus normotensives (P < 0.0001; Table 2). Also, the PP correlated with WC (r = 0.270, P < 0.0001; Supplementary
waist circumference (WC), tobacco consumption; Model 3: age, gender, severity of weight excess, WC, tobacco consumption; Model 4: age, gender, blood pressure

Independent variables included in the 6 models: Model 1: age, gender, severity of weight excess (overweight or obesity), tobacco consumption; Model 2: age, gender, waist circumference (WC), tobacco consumption; Model 3: age, gender, severity of weight excess, WC, tobacco consumption; Model 4: age, gender, blood pressure status: (normotension, pre-hypertension and hypertension), WC; Model 5: age, gender, severity of weight excess, blood pressure status.

Table 3
Models of multivariate analyses to explain hypertension and pulse pressure (PP).

<table>
<thead>
<tr>
<th>Significant variables</th>
<th>B</th>
<th>OR</th>
<th>CI95</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypertension vs normotension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1 Boys vs girls</td>
<td>0.75</td>
<td>2.12</td>
<td>1.18–3.80</td>
<td>0.012</td>
</tr>
<tr>
<td>Obese vs overweight</td>
<td>0.73</td>
<td>2.07</td>
<td>1.15–3.72</td>
<td>0.015</td>
</tr>
<tr>
<td>Model 2 Boys vs girls</td>
<td>0.77</td>
<td>2.16</td>
<td>1.19–3.89</td>
<td>0.011</td>
</tr>
<tr>
<td>WC</td>
<td>0.37</td>
<td>1.20</td>
<td>1.05–1.30</td>
<td>0.004</td>
</tr>
<tr>
<td>Model 3 Boys vs girls</td>
<td>0.91</td>
<td>2.49</td>
<td>1.35–4.59</td>
<td>0.003</td>
</tr>
<tr>
<td>WC</td>
<td>0.04</td>
<td>1.20</td>
<td>1.05–1.30</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Prehypertension vs normotension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3 Boys vs girls</td>
<td>0.67</td>
<td>1.96</td>
<td>1.01–3.77</td>
<td>0.04</td>
</tr>
<tr>
<td>Age</td>
<td>0.23</td>
<td>1.26</td>
<td>1.07–1.48</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Hypertension vs prehypertension</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3 WC</td>
<td>0.06</td>
<td>1.30</td>
<td>1.10–1.50</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>PP &gt;45 mmHg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 4 WC</td>
<td>0.04</td>
<td>1.20</td>
<td>1.10–1.30</td>
<td>0.0001</td>
</tr>
<tr>
<td>Obese vs overweight</td>
<td>0.67</td>
<td>1.9</td>
<td>1.1–3.1</td>
<td>0.016</td>
</tr>
<tr>
<td>Model 5 HT vs NT</td>
<td>0.71</td>
<td>2.03</td>
<td>1.1–3.7</td>
<td>0.024</td>
</tr>
</tbody>
</table>

OR: odds ratios; CI95: 95% confidence interval; HT: hypertensives; NT: normotensives. ORs and CI95 for age and WC are given for 1 year and for a 5-cm increase, respectively.

Independent variables included in the 6 models: Model 1: age, gender, severity of weight excess (overweight or obesity), tobacco consumption; Model 2: age, gender, waist circumference (WC), tobacco consumption; Model 3: age, gender, severity of weight excess, WC, tobacco consumption; Model 4: age, gender, blood pressure status: (normotension, pre-hypertension and hypertension), WC; Model 5: age, gender, severity of weight excess, blood pressure status.

To explain hypertension in comparison to normotension, several multivariate models were tested (Table 3). In Model 1, which included age, gender, severity of weight excess (overweight or obesity) and tobacco use as independent variables, both male gender (odds ratio [OR]: 2.12, \( P = 0.012 \)) and obesity (OR: 2.07, \( P = 0.015 \)) were associated with a greater risk of hypertension (Supplementary data, Fig. S3), thus reflecting the combined influence of gender and severity of weight excess on hypertension. In Model 2, which replaced severity of weight excess (Table 3), the higher rate of hypertension in both boys and girls when WC is ≥90 cm. In Model 3, which included age, gender, severity of weight excess, WC and tobacco use as independent variables, the risk of hypertension was greater with male gender (OR: 2.49, \( P = 0.003 \)) and was associated with WC (OR: 1.20 for every 5-cm increase in WC, \( P = 0.004 \)), but not with age or severity of weight excess. In fact, there was a significant gender interaction with WC, as the risk of hypertension increased with WC in adolescent boys, but not in girls (data not shown).

Model 3 also looked at pre-HT compared with normotension. The risk of pre-HT was higher with male gender (OR: 1.96, \( P = 0.04 \)) and was associated with age (OR: 1.26, \( P = 0.006 \)), but not with severity of weight excess or WC. As for hypertension compared with pre-HT, the risk of hypertension was associated with WC (OR: 1.30, \( P = 0.007 \)), but not with age, gender or severity of weight excess (Table 3).

To examine the factors associated with high PP levels, age, gender, WC and blood-pressure (BP) status (normal, pre-HT and hypertension) were included as independent variables in two models of multivariate analyses (Table 3). PP >45 mmHg (mean level for the overall population) was associated with higher WC (OR: 1.04 [1.02–1.06], \( P < 0.0001 \)), but not with BP status or gender (Model 4). The percentage of adolescents with PP >45 mmHg was higher with WC >100 cm in normotensives and >80 cm for pre-HT and hypertensives (Fig. 1). In Model 5, wherein age, gender, severity of weight excess and BP status were considered independent variables, PP >45 mmHg was associated with obesity only (OR: 1.9, \( P = 0.016 \)) and with hypertension compared with normotension (OR: 2.03, \( P = 0.024 \)). In Model 6, including WC and hypertension versus normotension as independent variables, PP >45 mmHg was associated with WC and hypertension only in boys (\( P < 0.0001 \) for both; data not shown).

4. Discussion

Childhood obesity increases the risk of concomitant comorbidities, and the risk of persistent obesity and cardiometabolic complications during adulthood [8,9,20]. In the US, the prevalence of hypertension increased by 37% between 1988 and 1999 in children and adolescents. A recent analysis of US data from both the Third National Health and Nutrition Examination Survey (NHANES III) 1988–1994 and NHANES 1999–2000 estimated that obesity explained 30% of the increase in SBP observed in adolescents aged >12 years [21,22]. In addition, 50% of children aged 10 years with BP lev-
sures >45 mmHg according to blood-pressure status and waist circumference

Fig. 1. Percentages of adolescents in the total study population with pulse pres-

sion was twice as frequent in obese compared with overweight

children, thus supporting the role of severity of weight excess

was more frequent in overweight adolescents, and hyperten-

sion was associated with reduced arterial distensibility in the nor-

mal population [31], its predictive value should also be evaluated in adoles-

cents. In extremely obese children, arterial stiffness has been

reported in association with abdominal adiposity [11]. How-

ever, although the mechanisms contributing to hyperten-

sion in obese adolescents have not yet been clearly ascertained,

an excess of visceral adiposity, as suggested by a large WC, is

likely to play a major role in elevated BP in adolescents

as it does in adults [26,27]. Disorders associated with visceral

adiposity, such as insulin resistance, inflammatory mediators,

oxidative stress, endothelial dysfunction, renin–angiotensin sys-
tem activation and sleep apnoea syndrome may all account for

hypertension in adults via activation of the sympathetic ner-

vous system, vasoconstriction and augmentation of intravascular

fluids [28], and may well be similarly involved in adolescents.

Multivariate analyses indicated that the increased risk of

hypertension was associated with male gender, independent of

age, WC and severity of weight excess. Such a relationship with

gender was also reported in a US study [21], but its indepen-
dent role has not been found in other studies [7,22]. Our present

results are consistent with the well-established complex role of

androgens in BP regulation, which may act in adolescence by

inducing vasoconstriction through effects on thromboxane-A2
expression, norepinephrine synthesis, angiotensin-II expression

and endothelin-1 effects, by promoting vascular remodelling

and atherosclerosis, and by stimulating a renal prohypertensive pro-

cess involving the renin–angiotensin–aldosterone system and

oxidative stress [29].

As for the influence of a family history of hypertension, only

8.3% of our present hypertensive adolescents had such

antecedents, which is in accordance with the Canadian study

[7]. Furthermore, even if some of our adolescents had an

unknown family history of hypertension, these data are

nevertheless consistent with a role played by obesity and hypertension

independent of this factor.

PP was higher in obese than in overweight adolescents, and

significant correlations between PP and arterial stiffness have

frequently been reported in adults. Although such evidence is

not available for children in the literature so far, an increased

PP was associated with reduced arterial distensibility in the nor-
moglycaemic normotensive offspring of type 2 diabetic patients
[30]. Thus, our data suggest that arterial stiffness is higher in

obese compared with overweight adolescents. In addition, as PP

increases are a well-known cardiovascular risk factor in adults
[31], its predictive value should also be evaluated in adoles-
cents. In extremely obese children, arterial stiffness has been

reported in association with abdominal adiposity [11]. How-
ever, in our present study, only 2% of obese adolescents (0.7% of
the overall cohort) were severely obese. Nevertheless, PP corre-
lated significantly with WC and BP status, particularly in boys,
thereby suggesting a role for abdominal adiposity and probably insulin resistance in arterial stiffness in adolescents, as has already been seen in adults [32] and, recently, in children, too [33].

5. Conclusion

The prevalence of hypertension is high in overweight and obese adolescents, and the condition appears to be independent of a family history of hypertension. The present study found a higher prevalence of hypertension in boys, and a strong relationship between hypertension and abdominal adiposity and, for the first time in adolescents, a relationship between arterial stiffness, as evidenced by high PP levels, and abdominal adiposity. The excess abdominal adiposity is likely to play a major role in these disorders, just as it does in adults. Also, pre-HT needs to be identified in overweight adolescents and should lead to lifestyle changes to avoid its evolution towards obesity and hypertension.

Conflicts of interest statement

The authors declare no conflicts of interest.

Acknowledgements

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Appendix A. Supplementary data

Supplementary material (Figs. S1–S4, and Tables S1 and S2) associated with this article can be found at http://www.sciencedirect.com and at doi:10.1016/j.diabet.2010.10.010.

References