

The relationship between BMI and blood pressure in children aged 7–12 years in Ankara, Turkey

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Abstract

Objective: Recent studies have reported an increasing prevalence of childhood hypertension. Obesity is probably the most important risk factor. The relationship between hypertension and BMI in children has not been studied in Ankara, which is the second largest city in Turkey.

Design: Cross-sectional study analysing direct data on height, weight and blood pressure of students.

Setting: Population-based study in Ankara, the capital city of Turkey.

Subjects: In three schools, 2826 students aged 7–12 years.

Results: The overall prevalence of hypertension was 7.9%. Among the 222 hypertensive children, 124 (56%) were boys and ninety-eight (44%) were girls ($P=0.40$). In the whole group, 3.6% had only systolic hypertension, 0.7% had only diastolic hypertension and 3.5% had both systolic and diastolic hypertension. The prevalences of overweight and obesity were both 13.9%. BMI was significantly correlated with blood pressure ($P<0.001$). Overweight and obesity were more common in boys ($P<0.001$).

Conclusions: Hypertension was more common than has been reported in other studies. Blood pressure measurement should be routine and frequent in children, especially obese children.

Keywords
Children
Blood pressure
BMI
Hypertension
Obesity

Hypertension (HT) is the worldwide number-one risk factor for preventable death. In Turkey the overall prevalence of HT is 31.8%, and only 40.7% of those with HT are aware that they have it⁽¹⁾. HT is believed to result from obesity, which is exacerbated by a high-energy, high-fat and high-salt diet, inadequate exercise and stress^(2–4). Childhood HT risk factors increase the risk of HT in adulthood^(5,6). Systolic blood pressure (SBP) elevation in childhood predicts arterial stiffness in young adults^(7,8). Increased carotid intima-medial thickness predicts cardiovascular events⁽⁹⁾. Diastolic blood pressure (DBP) is particularly important in monitoring blood pressure (BP) in younger individuals⁽¹⁰⁾.

The prevalence of obesity has increased rapidly in all age groups⁽¹¹⁾. From 1980 to 2005, in the USA the prevalence of obesity has increased by 40% in children and adolescents^(12,13). Overweight predisposes children to the health problems of obesity in adulthood, including HT, dyslipidaemia, impaired glucose metabolism, hyperinsulinaemia, obstructive sleep apnoea, and orthopaedic and psychosocial problems⁽¹⁴⁾. High childhood BP predicts CVD in adulthood, and HT plus high BMI predicts even worse CVD in adulthood⁽¹⁵⁾. The risk of obesity is related to factors in the antenatal environment, the early postnatal years, the adiposity rebound (at 5–6 years of age) and puberty⁽¹⁶⁾.

The relationship between HT and BMI in children has not been studied in Ankara, which is the second largest and the capital city in Turkey. We measured height, weight and BP in 2826 students, aged 7–12 years, in Ankara, Turkey.

Method

The study was approved by the Provincial Health Directorate of Ankara and the Ethics and Research Committee of Diskapi Yıldırım Beyazıt Training and Research Hospital, Ankara, Turkey.

We collected the data between March and June of 2012. We expected a frequency of HT of 10% in 7–12-year-old children, so to achieve $\alpha=0.01$ we calculated that we would need 2396 subjects. The Provincial Health Directorate of Ankara selected, with a simple random-sampling method, three primary schools, in three different socio-economic regions of Ankara. There were a total of 3165 students in the three schools. Our data-collection days were predetermined and the data collectors were trained medical staff. We aimed to collect data from all 3165 students, but some students declined to participate and some were absent on our data-collection days. Response

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rate was 89.3% and data on height, weight, SBP and DBP of 2826 children were recorded.

With a device that combined a weight scale and a stadiometer (DR-MOD-85 scale) we measured height to the nearest centimetre, weight to the nearest 0.5 kg, and SBP and DBP to the nearest mmHg. The weight scale/stadiometer was recalibrated before every data-collection day. The children were measured while wearing their undergarments. BP above the 95th percentile was deemed HT, according to the 2004 scheme of the High Blood Pressure Working Group⁽¹⁷⁾. Overweight and obesity were defined according to the year 2000 Centers for Disease Control and Prevention growth charts⁽¹⁸⁾. The 85th BMI percentile was considered overweight and the 95th BMI percentile was considered obese^(19,20).

Statistical analysis

The data were analysed with the statistical software package PASW Statistics 18 and are presented as mean and standard deviation, range and frequency values. The χ^2 test was used for categorical variables and Student's *t* test was used for normally distributed data with equal variances. The effect of BMI on SBP and DBP of children was investigated with ANOVA. The Kruskal–Wallis test was used if the variables did not have a normal distribution. Statistical significance was set at $P < 0.05$.

Results

We collected data from 2826 children (89.3% of the 3165 total students in the three schools; Table 1). Of these, 1496 (52.9%) were male and 1330 (47.1%) were female. All the children were between 7 and 12 years old. The mean BMI, SBP and DBP all increased with age in both sexes ($P < 0.001$) and all were higher in boys than in girls.

HT was present in 222 children (7.9%): 124 boys (55.9%) and ninety-eight girls (44.1%; $P = 0.40$). In the

whole cohort, 101 (3.6%) had only systolic HT, twenty-one (0.7%) had only diastolic HT and 100 (3.5%) had both systolic and diastolic HT.

Overall, 2040 (72.2%) of the children had normal weight, 393 (13.9%) were overweight and 393 (13.9%) were obese. Obesity was significantly more common in boys (16.2%) than in girls (11.3%, $P < 0.001$ via χ^2 test; Table 2).

Among the children with normal BP, 264 (10.1%) were obese. Among the children with HT, 129 (58.1%) were obese (Table 3). There was HT in fifty (2.5%) of the normal-weight children, forty-three (10.9%) of the overweight children and 129 (32.8%) of the obese children. HT was significantly more common in the obese children ($P < 0.001$). As BMI increased, SBP and DBP also increased: $P < 0.001$ for the relationship between BMI and SBP, and $P < 0.001$ for the relationship between BMI and DBP.

Mean SBP and DBP of the boys were significantly higher than those of the girls (all $P < 0.001$; Table 4), and mean SBP and DBP increased with age ($P < 0.001$; Table 5).

Discussion

The overall prevalence of HT in our cohort was 7.9%. Previous studies in Turkey reported prevalence between 3.9% and 17.8%, but those studies had smaller sample sizes^(21–24). The range of reported overall prevalence of HT among children in the USA is 2.7% to 16.9%⁽²⁵⁾. Two studies in Japan found HT prevalences of 11.0% and 7.2%, and HT was more common in boys^(26,27).

In our cohort the HT was predominantly systolic. Systolic HT in children is associated with more than fourfold increased risk of coronary artery disease⁽²⁷⁾ and childhood systolic and diastolic HT predict CVD in adult life^(7–10), so our findings are important and concerning.

According to our study, the mean BP increased with age, but increasing age did not correlate with an increase in the number of hypertensive children. Other studies in

Table 1 Mean BMI, systolic blood pressure (SBP) and diastolic blood pressure (DBP) by sex and age in 2826 children aged 7–12 years, Ankara, Turkey, March–June 2012

Sex	Age (years)	<i>n</i>	BMI (kg/m ²)		SBP (mmHg)		DBP (mmHg)	
			Mean	SD	Mean	SD	Mean	SD
Male	7	320	16.9	2.3	103.2	11.9	61.1	12.7
	8	269	17.7	3.0	105.6	13.4	62.7	13.3
	9	305	18.4	3.0	106.1	14.3	62.0	15.5
	10	319	18.9	3.3	105.8	11.0	61.9	13.1
	11	243	19.6	3.5	111.3	14.7	65.8	14.6
	12	40	19.9	3.4	109.3	12.7	63.4	16.5
Female	7	242	16.7	2.2	100.5	11.9	59.7	12.4
	8	231	17.4	2.8	102.1	13.3	57.6	13.7
	9	268	17.9	3.1	105.1	14.5	60.9	14.1
	10	312	18.4	3.1	104.2	11.1	60.4	13.8
	11	256	19.1	3.5	108.9	14.7	64.3	15.4
	12	21	19.2	2.9	109.1	11.4	63.1	13.7

Table 2 BMI category by sex and age in 2826 children aged 7–12 years, Ankara, Turkey, March–June 2012

Sex	Age (years)	Normal (BMI < 85th percentile)		Overweight (BMI = 85th to 94th percentile)		Obese (BMI ≥ 95th percentile)		Total	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Male	7	234	73.1	40	12.5	46	14.4	320	100
	8	176	65.4	32	11.9	61	22.7	269	100
	9	198	64.9	44	14.4	63	20.7	305	100
	10	221	69.3	49	15.4	49	15.4	319	100
	11	184	75.7	35	14.4	24	9.9	243	100
	12	29	72.5	11	27.5	0	0.0	40	100
Total male		1042	69.7	211	14.1	243	16.2	1496	100
Female	7	187	77.2	27	11.2	28	11.6	242	100
	8	172	74.5	26	11.2	33	14.3	231	100
	9	198	73.9	36	13.4	34	12.7	268	100
	10	232	74.4	47	15.1	33	10.5	312	100
	11	192	75.0	42	16.4	22	8.6	256	100
	12	18	85.7	3	14.3	0	0.0	21	100
Total female		999	75.1	181	13.6	150	11.3	1330	100
Total		2041	72.2	392	13.9	393	13.9	2826	100

Table 3 Relationship between blood pressure (BP) category and BMI category in 2826 children aged 7–12 years, Ankara, Turkey, March–June 2012

BP category	Normal (BMI < 85th percentile)		Overweight (BMI = 85th to 94th percentile)		Obese (BMI ≥ 95th percentile)		<i>P</i>
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Normal	1991	76.5	349	13.4	264	10.1	<0.001
Hypertensive	50	22.5	43	19.4	129	58.1	

Table 4 Mean systolic blood pressure (SBP) by sex, age and BMI category in 2826 children aged 7–12 years, Ankara, Turkey, March–June 2012

Sex	Age (years)	Normal (BMI < 85th percentile)		Overweight (BMI = 85th to 94th percentile)		Obese (BMI ≥ 95th percentile)	
		SBP (mmHg)		SBP (mmHg)		SBP (mmHg)	
		Mean	SD	Mean	SD	Mean	SD
Male	7	100.8	10.3	105.6	10.6	113.4	14.6
	8	101.2	11.5	108.8	10.8	116.7	12.9
	9	101.0	10.9	107.8	11.3	120.9	15.2
	10	102.3	8.6	109.5	9.6	118.0	12.2
	11	107.0	11.2	119.0	12.8	132.9	18.1
	12	106.4	12.9	116.8	8.4	–	–
Female	7	98.6	11.2	103.9	12.7	109.6	10.5
	8	99.0	10.2	102.9	12.3	117.6	17.2
	9	101.1	11.0	110.3	13.5	122.9	18.1
	10	101.7	9.7	106.9	9.4	118.0	11.1
	11	105.1	12.4	117.7	14.1	125.5	16.0
	12	108.3	11.0	113.3	15.3	–	–

Turkey agree with these findings^(22,28,29). In contrast, our findings regarding the relationship of sex and HT do not agree with previous studies. Çetinkaya found that 9.4% of boys and 5.6% of girls in Ankara had HT⁽²⁴⁾. In the Van region of Turkey, Arslan found an equal prevalence of HT in boys and girls (9.4% *v.* 8.7%)⁽³⁰⁾. Contrary to our findings, two other studies in Turkey found a higher prevalence of HT in girls than boys

(20% *v.* 15%; 21% *v.* 15%)^(21,29). In our study HT was non-significantly more common in the boys.

In our children the prevalence of overweight and obesity were both 13.9%, and more boys than girls were obese. A study of 15–18-year-olds in Turkey found that 3% were overweight and 11% were at risk for being overweight⁽²⁹⁾. Another study, which included 1899 Turkish children aged 6–14 years, found that a higher percentage of boys

Table 5 Mean diastolic blood pressure (DBP) by sex, age and BMI category in 2826 children aged 7–12 years, Ankara, Turkey, March–June 2012

Sex	Age (years)	Normal (BMI < 85th percentile)		Overweight (BMI = 85th to 94th percentile)		Obese (BMI ≥ 95th percentile)	
		DBP (mmHg)		DBP (mmHg)		DBP (mmHg)	
		Mean	SD	Mean	SD	Mean	SD
Male	7	58.9	11.5	62.1	12.4	71.7	13.6
	8	60.1	12.4	63.4	13.3	69.7	13.6
	9	56.9	13.0	65.5	13.9	75.7	14.8
	10	58.3	11.6	67.4	10.6	72.8	13.8
	11	62.2	12.7	73.6	11.2	82.7	16.4
	12	59.7	17.4	73.2	8.7	–	–
Female	7	58.5	12.1	61.3	11.6	66.6	12.9
	8	55.4	12.3	59.2	15.2	67.7	15.1
	9	57.8	11.9	65.4	15.1	74.3	16.3
	10	57.6	12.8	64.5	12.8	73.8	12.7
	11	60.3	13.6	74.6	13.4	78.9	16.1
	12	63.6	14.4	60.0	10.0	–	–

than girls were at or above the 85th percentile of BMI⁽³¹⁾. The 2007–2008 National Health and Nutrition Examination Survey (NHANES) in the USA found that 16.9% of 2–19-year-olds were obese⁽³²⁾. We also found a high incidence of obesity.

Our results showed a statistically significant relationship between obesity and HT. There was HT in 2.4% of the normal-weight children and 32.8% of the obese children. As BMI increased, SBP and DBP also increased. A study in Istanbul, Turkey found that obese children had higher SBP and DBP⁽³³⁾, and several studies in other countries had findings similar to ours^(34–39). In Italy, Di Bonito *et al.* found HT in 17.7% of obese children and 1.5% of normal-weight children aged 6–16 years⁽⁴⁰⁾. In the USA, a prospective study that included 22 071 individuals found a positive relationship between BMI and BP⁽³⁸⁾.

The impact of sex on the relationship between BMI and BP is controversial. A study of 7–18-year-olds in Iran found a stronger association between BMI and BP in boys than in girls⁽³⁵⁾. Two studies in Turkey found results similar to our study: BMI was higher in boys and there was a positive relationship between BMI and HT^(31,41). Overweight was a critical determinant of BP in both girls and boys^(42,43). On the other hand, Gundogdu found that sex had no effect on the relationship between BMI and BP⁽³¹⁾. The possible reasons for sex differences are not clear. The reported higher prevalence of HT in young and middle-aged men (than in women) and the higher prevalence of HT in older women (than in men) suggest that sex hormones may affect BP⁽⁴⁴⁾. SNP of oestrogen receptor genes was reported to be important in the development of HT. Men inheriting the 'a' allele of the oestrogen receptor α had significantly higher BP than did men with other genotypes⁽⁴⁵⁾, but there was no significant association between oestrogen receptor genes and BP in women. This suggests that sex differences affect BP via sex steroids⁽⁴⁶⁾. The effects of sex hormones on sodium excretion and renal haemodynamic response may explain the hormonal control of BP⁽³⁵⁾.

Limitations

Our study included only three schools. We tried to prevent selection bias with the Provincial Health Directorate of Ankara's randomized selection of schools from three different socio-economic levels. Since our study was not designed to determine the reasons for obesity, we do not think our results were importantly affected.

We did not collect data from 339 students (11%) who declined or were absent during the data-collection days. Refusal to participate may have been related to obesity, body image or self-esteem. However, we did reach our calculated necessary sample size, so we believe our results are valuable.

Future studies

We plan on multi-centre studies of BP and BMI in other cities in Turkey, which will provide percentile curves and important additional data on the relationship between BP, weight, age and sex.

Conclusions

Our study is the first study to be representative of Ankara with the highest number of sampling. In children aged 7–12 years in Ankara, Turkey, HT was more prevalent in the overweight and obese children and more prevalent in boys than in girls. As age, weight, height and BMI increased, the mean SBP and DBP increased. BP measurement should be routine and frequent in children, especially overweight children.

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References

- Altun B, Arıcı M, Nergizoğlu G *et al.* (2005) Prevalence, awareness, treatment and control of hypertension in Turkey (the PatenT study) in 2003. *J Hypertens* **23**, 1817–1823.
- Sorof JM, Lai D, Turner J *et al.* (2004) Overweight, ethnicity, and the prevalence of hypertension in school-aged children. *Pediatrics* **113**, 475–482.
- Bagga A, Jain R, Vijakumar M *et al.* (2007) Evaluation and management of hypertension. *Indian Pediatr* **44**, 103–121.
- Flyn JT (2001) What's new in pediatric hypertension? *Curr Hypertens Rep* **3**, 503–510.
- Raj M, Sundaram KR, Paul M *et al.* (2010) Body mass index trend and its association with blood pressure distribution in children. *J Hum Hypertens* **11**, 1–7.
- Ataei N, Hosseini M & Iranmanesh M (2009) The relationship of body mass index and blood pressure in Iranian children <7 yr old. *J Trop Pediatr* **55**, 313–317.
- Li S, Chen W, Srinivasan SR *et al.* (2004) Childhood blood pressure as a predictor of arterial stiffness in young adults: the Bogalusa Heart Study. *Hypertension* **43**, 541–546.
- Raitakari OT, Juonala M, Kahonen M *et al.* (2003) Cardiovascular risk factors in childhood and carotid artery intima-media thickness in adulthood: the Cardiovascular Risk in Young Finns Study. *JAMA* **290**, 2277–2283.
- Davis PH, Dawson JD, Riley WA *et al.* (2001) Carotid intimal-medial thickness is related to cardiovascular risk factors measured from childhood through middle age: the Muscatine Study. *Circulation* **104**, 2815–2819.
- Elkasabany AM, Urbina EM, Daniels SR *et al.* (1998) Prediction of adult hypertension by K4 and K5 diastolic blood pressure in children: the Bogalusa Heart Study. *J Pediatr* **132**, 687–692.
- Nielsen GA & Andersen LB (2003) The association between high blood pressure, physical fitness, and body mass index in adolescents. *Prev Med* **36**, 229–234.
- Lasserre AM, Chiolero A, Paccaud F *et al.* (2007) Worldwide trends in childhood obesity. *Swiss Med Wkly* **137**, 157–158.
- Prineas RJ (1991) Measurement of blood pressure in the obese. *Ann Epidemiol* **1**, 321–336.
- Işık P & Naçar N (2000) Complications of obesity. *Katki Pediatri Dergisi* **21**, 587–597 (in Turkish).
- Rademacher ER, Jacobs DR, Moran A *et al.* (2009) Relation of blood pressure and body mass index during childhood to cardiovascular risk factor levels in young adults. *J Hypertens* **27**, 1766–1774.
- Velasquez-Mieyer P, Perez-Faustini S & Cowan PA (2005) Identifying children at risk for obesity, type 2 diabetes, and cardiovascular disease. *Diabetes Spectrum* **18**, 213–220.
- National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2004) The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* **114**, 555–576.
- Kuczmariski RJ, Ogden CL, Guo SS *et al.* (2002) 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat* **11**, issue 246, 1–190.
- Neyzi O, Günöz H, Furman A *et al.* (2008) Weight, height, head circumference and body mass index references for Turkish children. *Çocuk Sağlığı ve Hastalıkları Dergisi* **51**, 1–14 (in Turkish).
- Centers for Disease Control and Prevention, National Center for Health Statistics (2007) Hypertension among persons 20 years of age and over according to sex, age, race and Hispanic origin: United States, 1988–1994 and 1999–2000. <http://www.cdc.gov/nchs/data/hus/07.pdf> (accessed June 2013).
- Dişçigil G, Aydoğdu A, Başak O *et al.* (2008) Prevalence of hypertension and related factors in primary school students in Aydın. *Turkish J Fam Med* **12**, 70–74 (in Turkish).
- Irgil E, Erkenci Y, Aytekin N *et al.* (1998) Prevalence of hypertension among school children aged 13–18 years in Gemlik, Turkey. *Eur J Public Health* **8**, 176–178.
- Coskun Y & Bayraktaroğlu Z (1997) Coronary risk factors in Turkish schoolchildren: report of a pilot study. *Acta Paediatr* **86**, 187–191.
- Çetinkaya F (1999) Prevalence of asymptomatic hypertension in school aged children. PhD Thesis, Ankara Training and Research Hospital (in Turkish).
- Falkner B (2010) Hypertension in children and adolescents: epidemiology and natural history. *Pediatr Nephrol* **25**, 1219–1224.
- Matsuoka S & Awazu M (2004) Masked hypertension in children and young adults. *Pediatr Nephrol* **19**, 651–654.
- Zhang CX, Tse LA, Deng XQ *et al.* (2008) Cardiovascular risk factors in overweight and obese Chinese children: a comparison of weight-for-height index and BMI as the screening criterion. *Eur J Nutr* **47**, 244–250.
- Sarıkan I (2007) Prevalence and risk factors of hypertension among 7 to 17 year-old school aged children in Isparta. PhD Thesis, University of Süleyman Demirel (in Turkish).
- Diñç G, Saatli G, Baydur H *et al.* (2009) Hypertension and overweight among Turkish adolescents in a city in Aegean region of Turkey: a strong relationship in a population with a relatively low prevalence of overweight. *Anadolu Kardiyoloji Dergisi* **9**, 450–456.
- Arslan D (2007) Prevalence of asymptomatic hypertension in school aged children in Van. PhD Thesis, University of Van Yüzüncü Yıl (in Turkish).
- Gundogdu Z (2008) Relationship between BMI and blood pressure in girls and boys. *Public Health Nutr* **11**, 1085–1088.
- Ogden CL, Carroll MD, Curtin LR *et al.* (2010) Prevalence of high body mass index in US children and adolescents, 2007–2008. *JAMA* **303**, 242–249.
- Öktem F (2010) Results of ambulatory arterial blood pressure monitoring in children with obesity. *Dicle Tıp Dergisi* **37**, 353–357 (in Turkish).
- Wolff C, Hoang S, Flannery D *et al.* (2006) A preliminary study of diet, overweight, elevated blood pressure, and acanthosis nigricans among K–9th grade native American students. *Calif J Health Promot* **4**, 77–78.
- Hosseini M, Ataei N, Aghamohammadi A *et al.* (2010) The relation of body mass index and blood pressure in Iranian children and adolescents aged 7–18 years old. *Iran J Public Health* **39**, 126–134.
- Brion MA, Ness AR, Davey Smith G *et al.* (2007) Association between body composition and blood pressure in a contemporary cohort of 9-year-old children. *J Hum Hypertens* **21**, 283–290.
- Cook NR, Gillman MW, Rosner BA *et al.* (1997) Prediction of young adult blood pressure from childhood pressure, height, and weight. *J Clin Epidemiol* **50**, 571–579.
- Gelber RP, Gaziano JM, Manson JE *et al.* (2007) A prospective study of body mass index and the risk of developing hypertension in men. *Am J Hypertens* **20**, 370–377.

39. Moore WE, Stephens A, Wilson T *et al.* (2006) Body mass index and blood pressure screening in a rural public school system: the Healthy Kids Project. *Prev Chronic Dis* **3**, A114.
40. Di Bonito P, Forziato C, Sanguigno E *et al.* (2009) Prehypertension in outpatient obese children. *Am J Hypertens* **22**, 1309–1313.
41. Şimşek F, Ulukol B, Berberoğlu M *et al.* (2005) Obesity prevalence in a primary school and a high school in Ankara. *Ankara Üniversitesi Tıp Fakültesi Mecmuası* **58**, 163–166 (in Turkish).
42. Kawabe H, Shibata H, Hirose H *et al.* (2000) Determinants for the development of hypertension in adolescents: a 6-year follow-up. *J Hypertens* **18**, 1557–1561.
43. Paradis G, Lambert M, O'Loughlin J *et al.* (2004) Blood pressure and adiposity in children and adolescents. *Circulation* **110**, 1832–1838.
44. Martins D, Nelson K, Pan D *et al.* (2001) The effect of gender on age-related blood pressure changes and the prevalence of isolated systolic hypertension among older adults: data from NHANES III. *J Gend Specif Med* **4**, 10–13.
45. Ellis J, Infantino T & Harrap S (2004) Sex-dependent association of blood pressure with oestrogen receptor genes ER α and ER β . *J Hypertens* **22**, 1127–1131.
46. Dasgupta K, O'Loughlin J, Chen S *et al.* (2006) Emergence of sex differences in prevalence of high systolic blood pressure: analysis of a longitudinal adolescent cohort. *Circulation* **114**, 2663–2670.