

## Prevalence, Persistence, and Clinical Significance of Masked Hypertension in Youth

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**Abstract**—Masked hypertension, an elevated daytime ambulatory blood pressure in the presence of a normal office blood pressure, confers an increased cardiovascular risk to adults. We investigated the prevalence, persistence, and clinical significance of masked hypertension in children and adolescents. We enrolled 592 youths (6 to 18 years old). Youths with masked hypertension (n=34) and a random sample of the normotensive participants (n=200) were followed-up. In a nested case-control study, we compared echocardiographic left ventricular mass among cases with persistent masked hypertension and normotensive controls. At baseline, mean age was 10.2 years; 535 youths were normotensive on office and daytime ambulatory blood pressure measurement (90.4%), and 45 had masked hypertension (7.6%). Compared with normotensive controls, participants with masked hypertension had a higher ambulatory pulse rate, were more obese, and were 2.5-times more likely to have a parental history of hypertension. Among 34 patients with masked hypertension (median follow-up 37 months), 18 became normotensive, 13 had persistent masked hypertension, and 3 had sustained hypertension. Patients with persistent masked hypertension (n=17) or who progressed from masked to sustained hypertension (n=3) had a higher left ventricular mass index (34.9 versus 29.6 g/m<sup>2.7</sup>; *P*=0.023) and a higher percentage with left ventricular mass index above the 95th percentile (30% versus 0%; *P*=0.014) than normotensive controls. In children and adolescents, masked hypertension is a precursor of sustained hypertension and left ventricular hypertrophy. This condition warrants follow-up and, once it becomes persistent, is an indication for blood pressure-lowering treatment. (*Hypertension*. 2005;45:493-498.)

**Key Words:** blood pressure monitoring, ambulatory ■ hypertension ■ hypertrophy

Cardiovascular complications in adults often find their roots in risk factors operative early in life. Independent of age, high blood pressure prominently figures among the precursors of an adverse prognosis.<sup>1</sup> In children, the diagnosis of hypertension is defined relative to the 95th percentiles of the office blood pressure in various strata, which account for sex, age, and body height.<sup>2,3</sup> In young and older people alike, blood pressure variability, the white-coat effect and observer bias limit the reliability of office measurements.<sup>4</sup> Automated techniques of blood pressure measurement may overcome these limitations. After pediatricians agreed on operational thresholds, ambulatory monitoring became an established instrument for the diagnosis of hypertension in children and adolescents.<sup>5</sup>

White-coat hypertension or isolated clinic hypertension is the transient elevation of a patient's blood pressure in response to the observer measuring the blood pressure.<sup>6-8</sup> The opposite phenomenon, masked hypertension or isolated ambulatory hypertension, consists of an elevated daytime or awake ambulatory blood pressure in the presence of a normal

blood pressure on conventional blood pressure measurement at the office.<sup>9,10</sup> In adults, masked hypertension is associated with increased left ventricular mass<sup>11</sup> and a worse cardiovascular prognosis.<sup>12</sup> To the best of our knowledge, no previous study addressed the prevalence, persistence, and clinical significance of masked hypertension in children and adolescents. Here, we report cross-sectional findings in 592 children, of whom 234 were followed-up. Youth with persistent masked hypertension or who progressed to sustained hypertension during follow-up were matched with normotensive controls. Cases and controls underwent echocardiography.

### Methods

From November 1990 until December 2003, we enrolled 592 youth from 6 to 18 years old, who attended the pediatric outpatient clinic of the General Hospital of the University of Valencia for a preventive health check-up. We excluded concomitant disease by physical examination, blood biochemistry, and analysis of a urine sample. The Institutional Committee for the Protection of Human Subjects approved the study. All parents and participants older than 12 years gave informed written consent. We measured blood pressure in the nondominant arm with cuff and bladder size adjusted to upper-arm

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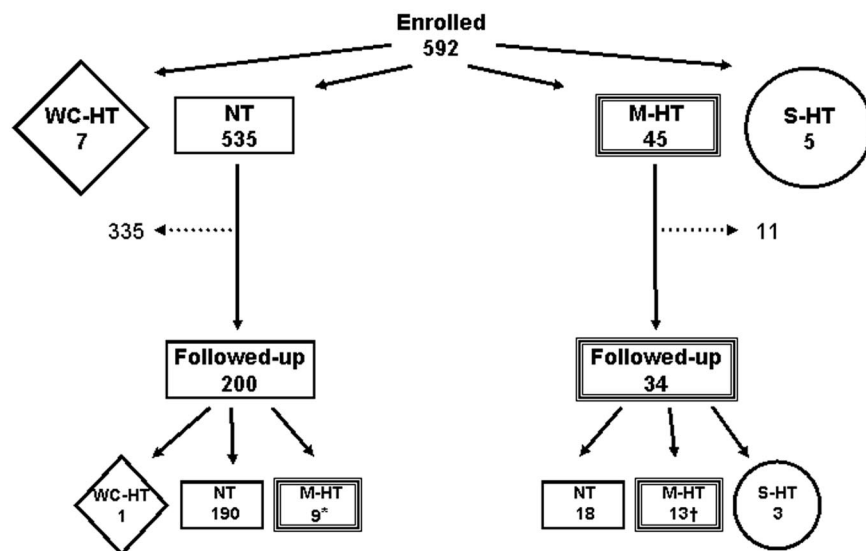
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**Figure 1.** Study profile. NT, WC-HT, M-HT, and S-HT indicate normotension, white-coat hypertension, masked hypertension, and sustained hypertension, respectively. \*Includes 4 patients with persistent masked hypertension. †All 13 patients had persistent masked hypertension. All patients with persistent masked hypertension and those with sustained hypertension constituted the 20 cases in the echocardiographic study.

girth.<sup>2</sup> We initiated the ambulatory recordings on regular school days between 8:30 AM and 9:00 AM. On monitoring days, the participants did not engage in vigorous exercise. We programmed oscillometric SpaceLabs 90207 monitors (SpaceLabs Inc, Redmond, Wash) to obtain blood pressure readings at 20-minute intervals from 6:00 AM until midnight and at 30-minute intervals from midnight until 6:00 AM. During the day, an acoustic signal warned the subjects to keep their arm relaxed during inflation and deflation of the cuff. Measurements were automatically repeated when readings were outside the ranges of 70 to 220 mm Hg systolic or 40 to 140 mm Hg diastolic. We did not otherwise edit the ambulatory recordings, from which we calculated time-weighted blood pressure means for the whole day, daytime (10:00 AM to 8:00 PM) and nighttime (midnight to 6:00 hour). These short fixed clock-time intervals closely corresponded to the awake and asleep parts of the day in all subjects and excluded the transition periods in the morning and evening, during which the blood pressure rapidly changed.

On monitoring days, the study nurses used a standard mercury sphygmomanometer to measure the office blood pressure 3 times consecutively, after the subjects had rested in the sitting position for at least 5 minutes. Diastolic blood pressure was determined at Korotkoff phase 4 in children younger than 13 years and at phase 5 in older adolescents. The 3 measurements of each office visit were averaged for analysis. Published diagnostic thresholds for the conventional<sup>2</sup> and daytime ambulatory<sup>13,14</sup> blood pressures delineated 4 conditions. In normotensive and hypertensive youth, both the conventional and the daytime ambulatory blood pressures were consistently normal or elevated. Masked hypertension was an increased daytime blood pressure in the presence of a normal office blood pressure, whereas white-coat hypertension was a normal daytime ambulatory blood pressure in the presence of an elevated conventional blood pressure.

All available participants with masked hypertension and a random sample representing approximately one-third of the subjects with normotension at baseline were followed-up and underwent repeat blood pressure measurements at one or more occasions. For the prospective follow-up, children with multiple blood pressure measurements during follow-up were classified according to the blood pressure status at the last contact. We administered a standardized questionnaire to obtain information on the parental history of hypertension.

All patients with persistent masked hypertension, defined as masked hypertension on at least 2 consecutive examinations, including that of last contact, were enrolled in an echocardiographic case-control study. We matched cases with normotensive controls for sex, age, and body height. One experienced pediatric cardiologist (R.P.), blinded with regard to the blood pressure of the study participants, used an Acuson 128-XP echocardiograph (Acuson

Corporation, Mountain View, Calif) with a 2.5-MHz transducer to obtain M-mode recordings of the left ventricle at end-expiration from the parasternal long-axis view under control of the 2-dimensional image. Left ventricular internal diameter and interventricular septal and posterior wall thickness were measured at end-diastole according to the recommendations of the American Society of Echocardiography, using the leading edge-to-leading edge convention.<sup>15</sup> End-diastolic left ventricular dimensions were used to calculate left ventricular mass. For statistical analysis, the measurements of 3 cardiac cycles were averaged. The intra-observer reproducibility coefficient for left ventricular mass indexed to body height to the power 2.7 was 2.5%. Published criteria allowed us to classify subjects into those with normal left ventricular mass and those with moderate or severe left ventricular hypertrophy, if left ventricular mass indexed to body surface area was below the 90th percentile, within the 90th to 99th percentile interval, or above the 99th percentile, respectively.<sup>16,17</sup>

For statistical analysis, we used the SAS software package, version 8.2 (SAS Institute, Cary, NC). We compared means and proportions, using analysis of variance (ANOVA) with Scheffé test for multiple comparisons or Student *t* test and a  $\chi^2$  statistic, respectively. To study longitudinal changes in blood pressure, we used repeated measures ANOVA.

## Results

### Observations at Baseline

Of 592 subjects, 535 (90.4%) were normotensive, 45 (7.6%) had masked hypertension, whereas 7 (1.2%) and 5 (0.8%) had white-coat or sustained hypertension, respectively (Figure 1). All participants were white and 330 (55.7%) were female. Sex ratio and mean age (10.2 [SD 3.0] years) and height (142 cm<sup>16</sup>) were similar ( $P \geq 0.27$ ) across the 4 blood pressure groups. Body weight (40.9 [14.8] versus 59.1 [24.2] kg) and body mass index (19.6 [3.8] versus 25.5 [7.0] kg/m<sup>2</sup>) were lower ( $P < 0.001$ ) in normotensive subjects and those with masked hypertension than in youth with white-coat or sustained hypertension. Compared with normotensive subjects, participants with masked hypertension had higher ambulatory pulse rates over 24 hours, daytime, and nighttime (Table 1). They also more frequently reported a parental history of hypertension (17.8% versus 6.9%;  $P = 0.017$ ). Median age of all parents was 40.7 years (interquartile range, 37.7 to 43.9).

**TABLE 1. Clinical Characteristics by Blood Pressure Status at Baseline**

Characteristics	Normotension (n=535)	Masked Hypertension (n=45)	P
Number (%) of subjects with characteristic			
Girls	299 (56.3)	24 (53.3)	0.90
Parental history of hypertension	37 (6.9)	8 (17.8)	0.014
Anthropometry			
Height, cm	143 (16)	145 (17)	0.62
Weight, kg	41.2 (14.7)	45.6 (18.9)	0.79
Blood pressure in mm Hg			
Office systolic	97.8 (9.5)	106.1 (12.0)	0.001
Office diastolic	55.6 (7.3)	58.4 (7.7)	0.016
24-hour systolic	108.5 (7.5)	122.9 (6.5)	NC
24-hour diastolic	64.3 (4.3)	72.9 (4.4)	NC
Daytime systolic	111.9 (8.0)	127.8 (6.8)	NC
Daytime diastolic	68.2 (4.9)	78.1 (4.8)	NC
Nighttime systolic	100.5 (7.9)	112.2 (7.9)	NC
Nighttime diastolic	55.3 (5.3)	61.9 (6.1)	NC
Pulse rate in beats per minute			
24-hour	83.6 (9.3)	88.4 (10.2)	0.001
Daytime	88.7 (10.3)	93.3 (10.5)	0.004
Nighttime	72.5 (9.7)	77.7 (12.6)	0.001

Unless indicated otherwise, values are means  $\pm$  SD. NC indicates not computed, because office and daytime blood pressure values were used to categorize the subjects.

### Follow-Up of Blood Pressure

Of 535 normotensive children, 200 were randomly selected for follow-up (median follow-up, 34 months; range, 3 to 132). We collected repeat measurements of their office and ambulatory blood pressures: once in 119 children, twice in 54, and 3, 4, or 5 times in 20, 4, and 3 children, respectively.

Of the 45 patients with masked hypertension at baseline, 9 were unavailable for follow-up, because their family had migrated over a long distance (n=5) or because they had moved without leaving a contact address (n=4). Two children opted not to participate in the follow-up study. Among the remaining 34 children (75.6%), we performed 82 follow-up examinations: once in 8 children, twice in 13, and

3, 4, or 5 times in 7, 3, and 3 children, respectively. Median follow-up among the patients with masked hypertension at baseline was 37 months (range, 5 to 120).

### Change in Blood Pressure at 1 Year

Because in children and adolescents blood pressure changes with age, growth, and sexual maturation, we first studied the changes in blood pressure over 1 year. Of the children with normotension or masked hypertension at baseline, respectively, 90 and 28 had follow-up examinations at this interval ( $\pm$ 6 months). Among normotensive children, neither the office nor the daytime blood pressure changed, whereas among the patients with masked hypertension the daytime ambulatory blood pres-

**TABLE 2. Blood Pressure at Baseline and After 1 Year of Follow-up**

Blood Pressure	Normotensive (n=90)		Masked Hypertension (n=28)		P <sub>time</sub>	P <sub>int</sub>
	Baseline	1 Year	Baseline	1 Year		
Office systolic	98.9 (9.4)	99.7 (10.9)	104.2 (10.1)	107.5 (7.6)	0.49	0.18
Office diastolic	55.7 (7.0)	56.2 (7.2)	58.3 (7.3)	60.1 (8.2)	0.75	0.52
24-hour systolic	110.4 (8.0)	110.9 (7.7)	122.6 (5.8)	121.5 (7.6)	0.24	0.25
24-hour diastolic	64.6 (4.7)	64.6 (4.2)	73.4 (3.9)	71.6 (5.5)	0.19	0.08
Daytime systolic	113.7 (8.6)	114.7 (8.1)	127.5 (6.3)	125.4 (7.8)	0.05	0.05
Daytime diastolic	68.4 (5.2)	68.7 (4.7)	78.5 (4.3)	76.0 (5.4)	0.04	0.01
Nighttime systolic	102.5 (8.6)	102.0 (8.8)	112.5 (7.3)	113.1 (8.4)	0.46	0.50
Nighttime diastolic	55.8 (5.8)	55.1 (5.7)	63.3 (5.8)	62.5 (6.9)	0.73	0.92

All blood pressure values are expressed in mm Hg and are means (SD).

P<sub>time</sub> and P<sub>int</sub> were derived by repeated measures ANOVA and indicate the probabilities of an order effect (follow-up versus baseline) and the interaction between order and group.

**TABLE 3. Anthropometric Characteristics and Left Ventricular Mass in Patients With Persistent Masked or Sustained Hypertension vs Matched Normotensive Controls**

Characteristics	Controls (n=20)	Cases (n=20)	P
Anthropometry			
Girls, no.	12	10	0.53
Age, y	11.5 (3.5)	11.2 (3.2)	0.81
Weight, kg	47.9 (12.9)	52.7 (15.6)	0.30
Height, cm	1.50 (0.16)	1.49 (0.15)	0.94
Body mass index, kg/m <sup>2</sup>	21.2 (3.6)	23.2 (4.0)	0.09
Left ventricular mass			
Not indexed, g	90.1 (28.2)	107.7 (45.1)	0.15
Indexed to body surface area, g/m <sup>2</sup>	63.1 (12.5)	71.9 (20.6)	0.11
Indexed to height, g/m <sup>2.7</sup>	29.6 (4.8)	34.9 (8.8)	0.023

Cases and controls were matched for sex, age, and body height.

sure decreased by 2.1 mm Hg systolic and 2.5 mm Hg diastolic (Table 2). For the daytime systolic and diastolic blood pressures, the interaction between the initial blood pressure values and the order of the examinations was statistically significant (Table 2).

### Change in Blood Pressure Classification Throughout Follow-Up

Of the random subsample of 200 initially normotensive children, 190 (95.0%) remained normotensive, whereas 9 (4.5%) and 1 (0.5%) had masked hypertension or white-coat hypertension, respectively (Figure 1). Among the normotensive children who had masked hypertension, this condition was not confirmed by further follow-up in 5, but it was persistent in 4 children.

Among the 34 children who had masked hypertension at baseline, 18 (53.0%) became normotensive, 13 (38.2%) had persistent masked hypertension, and 3 (8.8%) progressed to sustained hypertension (Figure 1). Compared with the 200 normotensive controls, these 16 patients more frequently reported a parental history of hypertension (45.5 versus 7.1%;  $P<0.001$ ).

### Echocardiographic Study

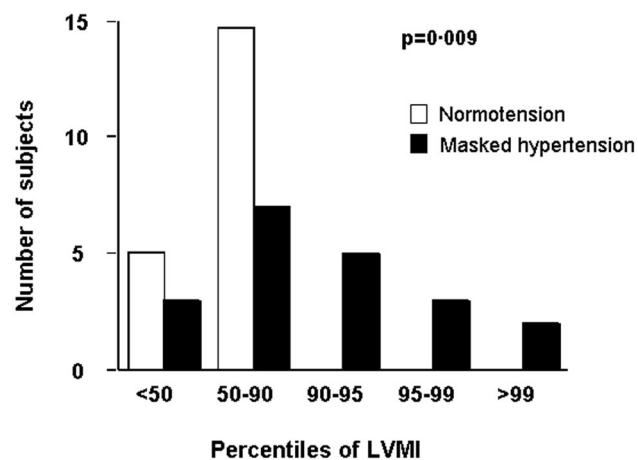
The cases in the echocardiographic study were 17 patients with persistent masked hypertension, of whom at baseline 4 were normotensive and 13 had already masked hypertension, as well as the 3 patients with masked hypertension at recruitment, who had progressed to sustained hypertension (Figure 1). We matched these cases by sex, age, and body height with 20 controls who remained normotensive throughout follow-up. Left ventricular mass indexed to body height<sup>2.7</sup> was significantly higher in cases than controls (Table 3). The distribution of left ventricular mass index also differed ( $P=0.014$ ) between cases and controls (figure 2). All controls had a normal left ventricular mass index (<90th percentile of the reference standard<sup>16,17</sup>). In contrast, among cases, 5 (20.0%) had a left ventricular mass index above the 95th percentile and 2 (10.0%) had severe left ventricular hypertrophy (>99th percentile<sup>16,17</sup>).

### Discussion

The key finding of our study was that masked hypertension occurred in ≈10% of children and adolescents. Follow-up

demonstrated that the abnormal elevation of the daytime ambulatory blood pressure persisted in nearly 40%. Furthermore, in youth, masked hypertension predisposed to the development of sustained hypertension and left ventricular hypertrophy, especially in children and adolescents with a parental history of hypertension. Because both hypertension and left ventricular hypertrophy are harbingers of adverse cardiovascular outcomes later in life, masked hypertension in childhood should be regarded as a condition that requires further follow-up and intervention in those in whom this disorder persists. Finally, white-coat hypertension characterized by an elevated office blood pressure in the presence of a normal daytime blood pressure occurs in only 1% of children and adolescents. The prevalence of office hypertension for the present study is as expected. The subjects are healthy children; blood pressure status is qualified using the average of 3 measurements and office blood pressure is measured by nurses to reduce the potential for alarm reaction.

Previous studies in adults<sup>11,18</sup> and elderly men,<sup>12</sup> randomly recruited from the population<sup>11,12</sup> or via a university hospital or work sites,<sup>18</sup> noticed a prevalence of masked hypertension



**Figure 2.** Distribution of left ventricular mass index in 20 patients with masked hypertension and 20 matched normotensive controls. Cases and controls were matched for gender, age, and body height. LVMI indicates left ventricular mass indexed to height to the power 2.7.<sup>16</sup>



of 10% to 20% among subjects with normotension on conventional blood pressure measurement. None of these studies in adults<sup>11,12,18</sup> provided any information on the persistence of masked hypertension. However, in keeping with our findings, 2 cross-sectional studies found an association between left ventricular hypertrophy and masked hypertension.<sup>11,18</sup> A prospective study in men, aged 70 years at baseline, reported that masked hypertension in contrast to normotension clustered with other cardiovascular risk factors, including increases in plasma glucose, body mass index, and left ventricular wall thickness.<sup>12</sup> With adjustments applied for serum cholesterol, smoking, and diabetes mellitus, both masked hypertension and sustained hypertension independently predicted cardiovascular morbidity with hazard ratios of 2.77 and 2.94, respectively.<sup>12</sup> Among 871 never-treated stage 1 hypertensive patients followed-up for a mean duration of 62 months, Palatini et al<sup>19</sup> noticed a higher risk of sustained hypertension in 120 subjects (13.8%), who after 3 months of follow-up had masked hypertension, than in 124 subjects (14.2%) who after the same follow-up period returned to a normotensive state.

In the present study, patients with masked hypertension had a higher ambulatory pulse rate than normotensive subjects, were more obese, and were more than twice as likely to have a parental history of hypertension. These 3 characteristics, alone or in combination, predict the development of hypertension and increase cardiovascular risk later in life. Tachycardia and high body mass index are usually accompanied by stimulation of the sympathetic nervous system, which together with the elevated daytime blood pressure and obesity might underlie the development of left ventricular hypertrophy in youth with masked hypertension even before they proceed to sustained hypertension.<sup>20,21</sup> Approximately 50% of the youngsters with persistent masked hypertension had a positive parental history of hypertension. This is in agreement with previous epidemiological studies, which demonstrated that children with a positive familial history of hypertension had a higher blood pressure than those without such history.<sup>22</sup> This association was even more pronounced when parents became hypertensive early in their life,<sup>23</sup> as was the case in the present study.

The potential influence of office blood pressure values on the risk of having masked hypertension needs to be commented on. Although office blood pressure was significantly higher in the masked hypertension group than it was in the normotensive one, in the majority of masked hypertension subjects the percentile distribution was below the high-normal range, 90th to 95th percentile, for both systolic and diastolic blood pressure.

Our study has to be interpreted within the context of its limitations and strengths. Our hypothesis found its origin in clinical practice. Clinical indications and the time required to enroll the children explain why the number of follow-up visits and the interval between visits varied from one subject to another. Physical activity and stressful conditions increase the awake ambulatory blood pressure and pulse rate. We did not register physical activity. We identified subjects with masked hypertension at baseline based on an elevated daytime blood pressure. Over a 1-year follow-up period, regres-

sion to the mean occurred in this measurement. However, a substantial number of the youth with masked hypertension remained hypertensive on daytime ambulatory measurement or had sustained hypertension. Moreover, in comparison to the normotensive controls, patients with masked hypertension also had an elevated nighttime blood pressure and increased left ventricular mass, which suggest that on average their blood pressure was truly elevated. The diagnosis of office and ambulatory hypertension is, of course, inextricably tied to the operational blood pressure thresholds. Our normative data for the interpretation of ambulatory blood pressure readings in children and adolescents<sup>13,14</sup> are in close agreement with those proposed by a German Working Group on Pediatric Hypertension,<sup>24,25</sup> based on a multicenter study.

### Perspectives

If confirmed, our findings have important implications for the diagnosis and treatment of hypertension in children and adolescents and for future research. From a diagnostic point of view, our observations underline the diagnostic complementarity of ambulatory monitoring to conventional blood pressure measurement at the office. In pediatric subjects with normotension, ambulatory monitoring may be indicated in the presence of a parental history of hypertension, obesity, or other major cardiovascular risk factors, or when left ventricular hypertrophy is documented in the absence of office hypertension or other causal factors. From a therapeutic point of view, masked hypertension in pediatric patients is an indication for further follow-up and the institution of lifestyle measures, which promote cardiovascular health and have the potential to decrease the blood pressure or delay the development of hypertension. Once the persistence of masked hypertension is established, blood pressure-lowering therapy should be started in youth with left ventricular hypertrophy and might be considered for those without left ventricular hypertrophy, but with a familial predisposition to hypertension or a high cardiovascular risk profile. Finally, pediatric patients with masked hypertension are likely to carry the genetic variants that program an abnormal increase in blood pressure early in life. They might be a prime target for genetic studies, using either a case-control design or preferably a family-based approach, in which blood pressure as a continuous trait is related to the transmission of risk carrying alleles from parents to offspring. Masked hypertension in youth is a precursor of sustained hypertension and left ventricular hypertrophy. This condition warrants follow-up, and once persistent, may be an indication for blood pressure-lowering treatment, especially in children and adolescents with a positive familial history of hypertension.

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Drs Lurbe and Redon designed the study and analyzed the data with the help of Drs Nawrot and Staessen. Drs Lurbe and Staessen wrote the manuscript. Dr Paya performed the echocardiographic study. Drs Torro and Alvarez examined the children. All named authors critically reviewed the manuscript for scientific content, took part in the interpretation of the data, and approved the final version. The authors gratefully acknowledge the clerical assistance of Sandra Covens. None of the authors has a conflict of interest to declare. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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## References

- Williams CL, Hayman LL, Daniels SR, Robinson TN, Steinberger J, Paridon S, Bazzarre T. Cardiovascular Health in childhood. A statement for health professionals from the Committee on Atherosclerosis, Hypertension, and Obesity in the Young (AHOY) of the Council on Cardiovascular Disease in the Young, Am Heart Association. *Circulation*. 2002;106:143–160.
- National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents. Update on the 1987 Task Force Report on High Blood Pressure in Children and Adolescents: A Working Group Report from the National High Blood Pressure Education Program. *Pediatrics*. 1996;98:649–658.
- National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents. *Pediatrics*. 2004;114:555–576.
- O'Brien E, Asmar R, Beilin L, Imai Y, Mallion JM, Mancia G, Mengden T, Myers M, Padfield P, Palatini P, Parati G, Pickering T, Redon J, Staessen J, Stergiou G, Verdecchia P; European Society of Hypertension Working Group on Blood Pressure Monitoring. European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. *J Hypertens*. 2003;21:821–848.
- Lurbe E, Sorof JM, Daniels SR. Clinical and research aspects of ambulatory blood pressure monitoring in children. *J Pediatr*. 2004;144:7–16.
- Cavallini MC, Roman MJ, Pickering TG, Schwartz JE, Pini R, Devereux RB. Is white coat hypertension associated with arterial disease or left ventricular hypertrophy? *Hypertension*. 1995;26:413–419.
- Sorof JM, Poffenbarger T, Franco K, Portman R. Evaluation of white-coat hypertension in children: importance of the definitions of normal ambulatory blood pressure and the severity of casual hypertension. *Am J Hypertens*. 2001;14:855–860.
- Hornsby JL, Mongan PF, Taylor AT, Treiber FA. 'White coat' hypertension in children. *J Fam Pract*. 1991;33:617–623.
- Pickering TG, Davidson K, Gering W, Schwartz JE. Masked hypertension. *Hypertension*. 2002;40:795–796.
- Mancia G. Reversed white-coat hypertension: definition, mechanisms and prognostic implications. *J Hypertens*. 2002;20:579–581.
- Sega R, Trocino G, Lanzarotti A, Carugo S, Cesana G, Schiavina R, Valagussa F, Bombelli M, Giannattasio C, Zanchetti A, Mancia G. Alterations of cardiac structure in patients with isolated office, ambulatory, or home hypertension: data from the general population (Pressione Arteriose Monitorate E Loro Associazioni [PAMELA] Study). *Circulation*. 2001;104:1385–1392.
- Björklund K, Lind L, Zethelius B, Andrén B, Lithell H. Isolated ambulatory hypertension predicts cardiovascular morbidity in elderly men. *Circulation*. 2003;107:1297–1302.
- Lurbe E, Redon J, Liao Y, Tacons J, Cooper RS, Alvarez V. Ambulatory blood pressure monitoring in normotensive children. *J Hypertens*. 1994;12:1417–1423.
- Lurbe E, Redon J. Ambulatory blood pressure methodology and norms in children. In: Portman R, Sorof JM, Ingelfinger JR, Eds. *Pediatric Hypertension*. Totowa, NJ: Humana Press; 2004:107–120.
- Sahn DJ, de Maria A, Kisslo J, Weyman A. Recommendations regarding quantitation in M-mode echocardiography: result of a survey of echocardiographic measurements. *Circulation*. 1978;58:1072–1083.
- Daniels SR, Meyer RA, Liang YC, Bove KE. Echocardiographically determined left ventricular mass index in normal children, adolescents and young adults. *J Am Coll Cardiol*. 1988;12:703–708.
- Daniels SR, Kimball TR, Morrison JA, Khoury P, Witt S, Meyer RA. Effect of lean body mass, fat mass, blood pressure, and sexual maturation on left ventricular mass in children and adolescents. Statistical, biological and clinical significance. *Circulation*. 1995;92:3249–3254.
- Liu JE, Roman MJ, Pini R, Schwartz JE, Pickering TG, Devereux RB. Cardiac and arterial target organ damage in adults with elevated ambulatory and normal office blood pressure. *Ann Intern Med*. 1999;131:564–572.
- Palatini P, Winnicki M, Santonastaso M, Mos L, Longo D, Zaetta V, Dal Follo M, Biasion T, Pessina AC. Prevalence and clinical significance of isolated ambulatory hypertension in young subjects screened for stage 1 hypertension. *Hypertension*. 2004;44:170–174.
- Palatini P, Julius S. Heart rate and the cardiovascular risk. *J Hypertens*. 1997;15:1–37.
- Julius S, Valentini M, Palatini P. Overweight and hypertension: a 2 way street? *Hypertension*. 2000;35:807–813.
- Lauer RM, Clarke WR. Childhood risk factors for high adult blood pressure: the Muscatine Study. *Pediatrics*. 1989;84:633–641.
- Hunt SC, Williams RR, Barlow GK. A comparison of positive family history definitions for defining risk of future disease. *J Chronic Dis*. 1986;39:809–821.
- Soergel M, Kirschstein M, Busch C, Danne T, Gellermann J, Holl R, Krull F, Reichert H, Reusz GS, Rascher W. Oscillometric twenty-four-hour ambulatory blood pressure values in healthy children and adolescents: a multicenter trial including 1141 subjects. *J Pediatr*. 1997;130:178–184.
- Wuhl E, Witte K, Soergel M, Mehls O, Schaefer F, Kirschstein M, Busch C, Danne T, Gellermann J, Holl R, Krull F, Reichert H, Reusz GS, Rascher W; German Working Group on Pediatric Hypertension. Distribution of 24-h ambulatory blood pressure in children: normalized reference values and role of body dimensions. *J Hypertens*. 2002;20:1995–2007.