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Research Article

Association between obesity and the severity of ambulatory hypertension in children and adolescents

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Abstract

The goal of our study was to analyze the association between obesity and the severity of ambulatory hypertension in obese children. A total of 109 patients with primary obesity ages 7 to18 years (mean ± SD age 14.1 ± 3.1) were enrolled. Patients were divided into three groups according to body mass index (BMI) Z-scores: group 1 (n = 27): BMI >1.65 and < 3.28 standard deviation scores (SDS); group 2 (n = 55): BMI >3.29 and <4.91 SDS; group 3 (n = 27): BMI >4.92 SDS. Definition and staging of ambulatory hypertension was based on blood pressure (BP) levels and BP load, obtained from ambulatory BP monitoring (ABPM). Only 24% had ambulatory normotension, 25% had ambulatory prehypertension, 3% had hypertension, and 48% had severe ambulatory hypertension. The severity of hypertension increased significantly with the degree of obesity ($P = .0027$). Daytime systolic, diastolic, and mean arterial BPs increased significantly with increased BMI, whereas the nighttime pressure remained elevated regardless of the degree of obesity. Isolated nighttime hypertension was observed in 25% of patients and 38% were classified as nondippers. Almost 50% of children with obesity and hypertension detected on ABPM suffer from severe ambulatory hypertension. BMI is associated with the severity of ambulatory hypertension and the increase of daytime BP. J Am Soc Hypertens 2012;6(5):356–363.

Keywords: Blood pressure; children and adolescents; hypertension; obesity.

Introduction

Obesity has a major adverse impact on the cardiovascular health of children and adolescents.[1] Given the existence of a tracking phenomenon of obesity and hypertension,[2,3] it is likely that obese and hypertensive children and adolescents will stay obese and hypertensive into their adulthood. It seems therefore logical to assume that both obesity and hypertension have their roots in childhood and adolescence, thus emphasizing the pediatrician's role toward primary prevention of obesity and hypertension early on in a child's life.

In contrast to obesity, which can be easily diagnosed by an elevated body mass index (BMI), the abnormal blood pressure (BP) can be frequently undetected.[4] The ambulatory blood pressure monitoring (ABPM) enables a more accurate detection of arterial hypertension in children with a separate assessment of BPs during daytime and nighttime periods. However, the interpretation of ABPM in children is complicated by a multitude of variables (systolic/diastolic BP, mean arterial pressure) measured at various time periods, while further requiring a comparison of obtained results with age- and gender-specific normative values. In addition, the ABPM enables the assessment of BP load, which in combination with blood pressure levels, can be used for the assessment of hypertension severity (staging).[5]

Because obese children are at an increased risk for the development of hypertension, an early and accurate assessment of abnormal BP is of the utmost importance in this population. Moreover, many obese children have only isolated nighttime hypertension,[6,7] which further emphasizes the need for ABPM.[8] Increased ambulatory BPs in obese

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children and adolescents have been previously reported.[7,9–13] However, these literature reports focused on the prevalence of increased systolic BP (SBP) or diastolic BP (DBP) levels or BP loads without classification of patients into normotensives/hypertensives and lack assessment of severity (staging) of ambulatory hypertension.

The goal of our study was to perform a comprehensive assessment of ABPM in obese children and adolescents, with classification of patients into ambulatory normotension and various stages of ambulatory hypertension. We also aimed to analyze the impact of obesity on the severity of ambulatory hypertension.

Methods

Patients

White children ages 6 to 18 years referred by community physicians to our university hospital between May 2005 and December 2010 for assessment of obesity (BMI >95th percentile) were enrolled in the study. None of the patients suffered from known chronic illness nor received antihypertensive medications at the time of assessment. All patients maintained regular diet and physical exercise as recommended by their referring physicians. Patients with secondary obesity and patients with acute illnesses were excluded.

A total of 109 patients met the inclusion criteria and were included in the final analysis.

All enrolled patients had their weight and height measured, underwent ABPM and had blood drawn for serum creatinine, serum uric acid, fasting lipid profile, insulin and glucose levels; 24-hour urine collection was analyzed for albumin excretion. All these tests were performed within 1 week of the assessment period. All included patients had a minimum of 40 blood pressure readings over 24 hours and a minimum of 8 readings between midnight and 6:00 AM.

Methods

Weight and height were measured with a digital device (TONAVA TH200, Tonava a.s., Czech Republic); the measurements were performed by a trained clinic nurse according to a standard protocol. BMI was calculated as body weight in kilogram/square root of height in meters; absolute BMI values were subsequently transformed into standard deviation scores (SDS) based on normative values obtained from a Slovak child population.[14]

Serum creatinine, uric acid, lipid profile, insulin, glucose levels and urine albumin were measured by a Cobas Integra 800, Roche device (IL, USA). The glomerular filtration rate was estimated using serum creatinine and height.[15] The homeostatic model assessment (HOMA) was calculated as follows: (fasting glucose [mmol/L] × fasting insulin [mIU/L])/22.5.[16] The metabolic syndrome was defined according to the modified International Diabetes Federation criteria.[17]

Office BP

Office BP was measured only once on the day of the ABPM using a sphygmomanometer device (Tonometer 40, Chirana 400, Slovak Republic) on a nondominant arm with an appropriate cuff size. Obtained values in mm Hg were subsequently transformed into BP percentiles using the normative values.[18]

ABPM

ABPM was measured using the validated oscillometric monitor Meditech-04 (SunTech Medical Instruments, Inc., NC, USA). A cuff of an appropriate size was placed on a nondominant arm as per current guidelines.[5] The device was programmed to measure BP every 20 minutes during the day and every 30 minutes during the night. To compare our results with the most recent ABPM normative values in children,[19] we defined the nighttime period as the time between midnight and 6:00 AM; the daytime period was defined as 8:00 AM to 8:00 PM. All ABPM raw data were screened for obvious errors; values falling outside of the range recommended by guidelines[5] were manually excluded.

The obtained and verified ABPM results were subsequently imported into Chronos-Fit software (Zuther P et al. Chronos-Fit 1.06. http://www.ma.uni-heidelberg.de/inst/phar/lehre/chrono.html; 2009). The following parameters were analyzed: average SBP, DBP and mean arterial pressure (MAP) levels, their respective loads, day to night differences and average heart rates. All these parameters were calculated for 24 hour, daytime and nighttime periods separately. Absolute BP values were subsequently transformed into Z-scores based on ABPM normative values.[19] BP load for 24 hours, daytime and nighttime SBP, DBP, and MAP was defined as the number of BP values exceeding the 95th percentile of a given blood pressure during a given period.

Classification of Patients Based on BMI

To analyze our results in relation to the severity of obesity, BMI Z-scores (SDS) of all patients were divided into quartiles; the resulting values of the 25th and 75th percentiles were chosen as threshold values for the division of all patients into three groups: group 1 (n = 27): BMI SDS above +1.65 and below +3.28; group 2 (n = 55): BMI SDS above +3.29 and below +4.91; and group 3 (n = 27): BMI SDS above +4.92.

Classification of Ambulatory Hypertension

Classification of patients into ambulatory normotension or various stages of ambulatory hypertension was based on previous recommendations by Lurbe et al and Urbina et al,[5,20] but we only used the ambulatory BP results regardless of the office BP. Our classification was as follows.

Patients were considered to have ambulatory normotension if their 24-hour daytime and nighttime average SBP, DBP, and MAP were below the 95th percentile and their respective BP loads were below 25%. If all the BP levels were below the 95th percentile, but one or more of their BP loads (either SBP or DBP or MAP load) were between 25% and 50%, patients were classified as having ambulatory prehypertension.

If one or more of the BP parameters (either SBP or DBP or MAP) was above the 95th percentile and their BP loads were between 25% and 50%, patients were considered to have ambulatory hypertension. If patients with ambulatory hypertension had a BP load >50% (either SBP, DBP, or MAP), they were considered to have severe ambulatory hypertension.

Patients were considered to have isolated nighttime hypertension if either SBP, DBP, or MAP exceeded the 95th percentile at nighttime, but all other BP levels remained below the 95th percentile during the day. Consequently, patients with either SBP, DBP, or MAP above the 95th percentile during the day but below the 95th percentile during the night were considered to have isolated daytime hypertension. Patients with nighttime and any other hypertension (daytime or 24 hour) were considered to have combined daytime and nighttime hypertension.

Patients were further classified as nondippers if their day to night BP difference was below 10% (either SBP, DBP, or MAP).

Statistical Analysis

Data are shown as mean ± SD if normally distributed or the median and interquartile range (25th and 75th percentile) in cases of abnormal distribution. Normal/abnormal distribution of variables was tested with the D'Agostino and Pearson omnibus normality test. Continuous variables in patient groups were compared using the analysis of variance with Tukey correction for multiple comparisons (normally distributed data) or the Kruskal Wallis test with Dunn's multiple comparison correction (not normally distributed data). Categorical variables (proportion of patients between groups) were compared using a Fisher test or a chi-square test. The difference in proportions was analyzed using the chi-square test for trend. The cumulative frequency distribution graphs, showing relative frequencies as percent, were produced for daytime and nighttime SBP.

Results were considered statistically significant if the P value was below .05. All statistical analyses were performed with the GraphPad Prism software, version 5.0 (GraphPad Software, La Jolla, CA).

The study was approved by the local hospital ethics committee.

Results

Characteristics of Study Population

The demographic data are shown in Table 1. The mean ± SD age of all patients was 14.1 ± 3.1 years and did not differ among the three BMI groups (Table 1). There was also no difference between groups regarding gender distribution, renal function and urine albumin excretion. As a result of the division of patients into three groups based on their BMI Z-scores, the BMI was significantly different between groups with a median Z-score of 4.1 (range, 1.73–10.98)

Table 1
Demographic and laboratory data

Parameter	Group 1 BMI <3.28	Group 2 BMI >3.29, <4.91	Group 3 BMI >4.92	Total BMI 1.73–10.98
Number of patients	27	55	27	109
Age (y)	13.1 ± 3.3	14.2 ± 3.1	14.9 ± 2.9	14.1 ± 3.1
Gender (M:F)	11:16	40:15	17:10	68:41
BMI (kg/m^2)	28.1 (26.2–29.4)	32.5* (31.1–33.4)	36.9* (35.6–39.7)	32.4 (29.5–34.5)
BMI (SDS)	2.9 (2.4–3.1)	4.1 (3.8–4.4)*	5.4 (5.1–6.4)*	4.1 (3.3–4.9)
OSBP percentage	85.0 (65.3–97.3)	83.0 (69.3–98.0)	86.0 (66.0–97.0)	85.0 (69.0–97.0)
ODBP percentage	90.0 (66.8–93.0)	83.5 (64.0–83.3)	91.0 (80.0–95.0)	90.0 (68.0–94.0)
S-cr (μmol/L)	61.4 ± 14.7	62.2 ± 12.1	66.7 ± 11.1	63.1 ± 12.6
GFR (mL/min/1.73m^2)	96.4 ± 17.5	98.4 ± 14.1	94.4 ± 13.6	96.9 ± 14.8
S-uric acid (μmol/L)	310.5 (261.5–354.3)	377.0* (311.0–444.0)	417.0* (341.8–488.5)	357.0 (303.5–433.0)
Urine albumin (μg/min)	4.3 (2.7–8.6)	4.9 (3.0–9.4)	13.9 (3.7–21.6)	4.9 (3.0–10.7)
S-triglycerides	1.2 (1.0–1.4)	1.3 (1.0–1.9)	1.5 (1.2–2.1)	1.3 (1.0–1.8)
S-cholesterol	4.3 ± 0.8	4.3 ± 0.7	4.3 ± 0.8	4.3 ± 0.7
S-HDL-chol	1.1 (1.0–1.4)	0.9 (0.9–1.2)*	1.0 (0.8–1.2)*	1.0 (0.9–1.2)
HOMA	2.0 (1.3–2.4)	3.4 (1.9–8.9)*	5.1 (3.5–8.5)*	3.2 (1.9–6.0)

BMI, body mass index; GFR, glomerular filtration rate; HOMA, HOMA index; ODBP, office diastolic blood pressure; OSBP, office systolic blood pressure; S-cr, serum creatinine; S-HDL-chol, serum high-density lipoprotein cholesterol.

Values are given as mean ± standard deviation (if normally distributed) or median and interquartile range (if not normally distributed).

* Significantly different from group 1 ($P < .05$).

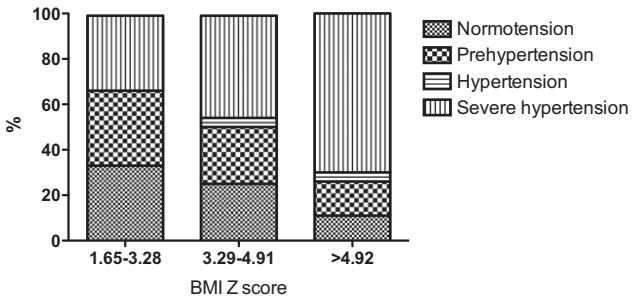

Figure 1. Proportion of patients with normotension and various degrees of hypertension in relation to the severity of obesity. BMI, body mass index.

for all patients. Serum uric acid levels and HOMA also increased significantly with the increasing BMI Z-score (Table 1). There was no difference in serum total cholesterol and triglyceride levels, but high-density lipoprotein cholesterol significantly decreased with the increasing BMI Z-score. A total of 64 patients (59%) suffered from metabolic syndrome.

ABPM Results: Patient-Oriented Approach/Staging of Ambulatory Hypertension

Based on the definition of ambulatory hypertension described in the Methods section, only 26 patients (24%) were normotensive on ABPM. The rest (n = 83, 76%) suffered from prehypertension or hypertension: 27 patients (25%) had ambulatory prehypertension, 3 (3%) had hypertension and 53 (48%) had severe ambulatory hypertension.

The severity of hypertension increased significantly with the degree of obesity (chi-square test for trend, $P = .0027$; Figure 1). The proportion of severe hypertension was 33% in group 1, 45% in group 2 and 70% in group 3 (Figure 1).

Of 109 patients, 27 patients (25%) suffered from an isolated nighttime ambulatory hypertension. The proportion of nighttime hypertension increased with the degree of obesity: 15% in group 1, 25% in group 2 and 33% in group 3, but did not reach statistical significance ($P = .11$).

Out of 109 patients, 41 patients (38%) were nondippers and the proportion of nondippers did not change across the BMI range: 41% in group 1, 35% in group 2, and 41% in group 3.

ABPM Results: BP Values-Oriented Approach

The absolute ambulatory BP data in mm Hg are shown in Table 2. The 24-hour, daytime, and nighttime SBP were significantly higher in group 3 (highest BMI) when compared with group 1. The nighttime SBP in group 2 was also significantly higher than in group 1, yet no other significant differences were found. The highest measured BP load in any of the calculated BP parameters is shown in Table 2 with the median load of 50.9% for all patients. A total of 41 out of 109 patients (38%) were classified as nondippers, but there were no differences in the day to night ratios (Table 2) or in the proportion of non-dipping/dipping SBP, DBP, and MAP values between BMI groups. Furthermore, no significant differences between the groups were observed in heart rates (Table 2).

The ABPM data in Z-scores are given in Table 3. The daytime SBP, DBP, and MAP increased significantly with

Table 2
Blood pressure (mm Hg), blood pressure load (%), and heart rate (beats/minute)

Parameter	Group 1 BMI <3.28	Group 2 BMI>3.29, <4.91	Group 3 BMI >4.92	Total BMI 1.73–10.98
SBP 24 hour	119.7 (111.9–124.1)	122.9 (117.6–128.8)	126.2* (122.2–136.3)	122.8 (117.2–128.4)
SBP day	123.1 (115.7–127.8)	125.4 (119.9–132)	128.6* (122.1–136.9)	125.4 (119.2–131.1)
SBP night	109.6 (105.2–113.7)	116.8* (107.5–123.7)	117.3* (113.1–126.4)	114.2 (108.0–122.3)
DBP 24 hour	66.1 (61.9–70.8)	66.2 (62.1–71.2)	69.8 (61.7–74.9)	66.2 (62.0–72.2)
DBP day	69.6 (63.3–73.2)	68.1 (64.2–73.5)	70.9 (63.7–77.2)	69.6 (63.8–74.9)
DBP night	57.3 (54.7–63.33)	59.6 (54.4–62.7)	61.0 (55.4–67.6)	59.3 (54.7–63.7)
MAP 24 hour	83.8 (78.7–87.7)	85.1 (81.0–92.4)	89.8 (81.6–93.6)	85.2 (81.1–91.6)
MAP day	86.1 (80.7–91.4)	88.1 (82.6–93.4)	92.8 (82.7–96.0)	87.8 (82.5–94.1)
MAP night	75.6 (70.9–80.5)	78.1 (72.7–83.7)	80.5 (75.8–86.7)	77.9 (73.1–83.6)
Max load (%)	36.4 (21.7–52.1)	50.0 (23.8–75.0)	60.0 (35.7–70.0)	50.9 (25.0–69.1)
D/N SBP	1.11 ± 0.08	1.09 ± 0.08	1.09 ± 0.08	1.10 ± 0.07
D/N DBP	1.18 ± 0.11	1.17 ± 0.10	1.16 ± 0.13	1.17 ± 0.11
D/N MAP	1.15 ± 0.09	1.13 ± 0.08	1.13 ± 0.09	1.14 ± 0.09
HR 24h	79.9 ± 9.7	77.9 ± 9.0	84.9 ± 11.7	79.4 ± 9.9
HR day	83.9 ± 10.9	81.1 ± 10.0	84.9 ± 11.7	82.7 ± 10.7
HR night	70.7 ± 8.9	70.3 ± 8.3	74.9 ± 12.9	71.5 ± 9.9

DBP, diastolic blood pressure; D/N, day to night ratio; HR, heart rate; MAP, mean arterial pressure; max load, highest blood pressure load in SBP or DBP or MAP; SBP, systolic blood pressure.

* Significantly different from group 1 ($P < .05$).

Table 3
Blood pressure data in Z-scores (SDS)

Parameter	Group 1 BMI <3.28	Group 2 BMI>3.29, <4.91	Group 3 BMI >4.92	Total BMI 1.73–10.98
SBP 24 hour	0.77 (0.18, 1.55)	0.65 (0.14, 1.31)	0.97 (0.36, 1.87)	0.99† (0.52, 1.93)
SBP day	0.32 (−0.08, 1.25)	1.24* (0.70, 2.06)	1.86* (1.25, 2.35)	0.65† (0.07, 1.45)
SBP night	0.92 (0.52, 1.56)	0.99 (0.52, 1.98)	1.72 (0.70, 2.52)	1.37† (0.69, 2.06)
DBP 24 hour	−0.02 (−0.87, 0.68)	−0.71 (−1.31, 0.25)	−0.35 (−1.46, 0.85)	−0.02 (−0.88, 0.79)
DBP day	−0.42 (−1.43, 0.00)	0.56* (−0.13, 1.13)	0.93* (0.02, 1.89)	−0.44‡ (−1.38, 0.33)
DBP night	0.23 (−0.12, 1.33)	−0.24 (−0.90, 0.69)	0.39 (−0.91, 1.44)	0.60† (−0.12, 1.35)
MAP 24 hour	0.39 (−0.19, 1.06)	0.14 (−0.65, 0.80)	0.37 (−0.73, 1.52)	0.42† (−0.23, 1.33)
MAP day	−0.01 (−0.61, 0.50)	0.85* (0.10, 1.76)	1.36* (0.51, 2.36)	0.13 (−0.65, 0.89)
MAP night	0.57 (0.14, 1.5)	0.41 (−0.28, 1.23)	0.85 (−0.23, 2.03)	0.91† (0.20, 1.90)

DBP, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.
* Significantly different from Group 1 ($P < .05$).
† Significantly higher than median of 0 (=50th percentile of normal population), $P < .05$.
‡ Significantly lower than median of 0 (=50th percentile of normal population), $P < .05$.

the degree of obesity, whereas no significant increase in nighttime BP between groups was observed. However, the nighttime SBP, DBP, and MAP were significantly elevated in all patients when compared with the 50th percentile of a normal population (Z-score = 0). The daytime SBP, 24-hour SBP, and 24-hour MAP were also higher than the 50th percentile of a normal population.

The highest number of BP readings exceeding the 95th percentile was noted in the SBP: 21% in daytime and 41% in nighttime SBP.

Daytime versus Nighttime Hypertension and Impact of Obesity

To further analyze the relation between daytime and nighttime hypertension, we assessed the cumulative distribution of the daytime and nighttime SBP Z-scores (Figure 2). When the SBP cumulative distribution reaches 50%, the daytime BP value is +0.65, whereas the nighttime BP Z-score is already +1.37 (Figure 2) (ie, the nighttime BP curve is shifted to the right). This shift to the right is directly proportional to the degree of obesity in both daytime and nighttime SBP; however, less expressed in the nighttime SBP (Figure 3). When the SBP cumulative distribution reaches 50%, the resulting SBP Z-scores across the BMI groups are +0.32, +1.24, and +1.86 for the daytime SBP and +0.92, +0.99, and +1.71 for the nighttime SBP (Figure 3). The change (shift to the right) in the nighttime SBP is less impacted by the degree of obesity, because the nighttime SBP Z-score (+0.92 SDS) is already higher than the daytime SBP Z-score (+0.32 SDS) in the lower BMI group. Therefore, the relative change in the median SBP Z-score (ie, shift to the right is only 0.79 [1.71–0.92] for the nighttime SBP compared with 1.54 [1.86–0.32] for the daytime SBP).

Similar shifting of the cumulative distribution to the right in relation to daytime/nighttime periods and BMI groups can be observed for the DBP and MAP.

Discussion

The main findings of our study are: only 24% of children with obesity have normal BP on ABPM, whereas 76% suffer from either prehypertension or hypertension; almost 50% of children with obesity have severe ambulatory hypertension (BP >95th percentile and BP load >50%); and increasing BMI Z-score has a significant impact on the severity of hypertension and daytime BP.

Ambulatory hypertension was observed in 51% of patients in our study. This compares favorably with literature reports showing the prevalence of abnormal BP conditions on ABPM in obese children between 20% and 83%,[7,8,11,21] depending on the type of BP, the severity of obesity and the dipping status. Several authors reported only absolute SBP or DBP values in mm Hg,[8,9,12,22] few studies used older pediatric ABPM normative values[23] to calculate the 95th percentile,[6,7,21,24] only two studies used the most recent ABPM normative values[19] to obtain the blood pressure index,[11,25] and conversion to BP Z-scores was performed in only one study.[11] MAP has not been

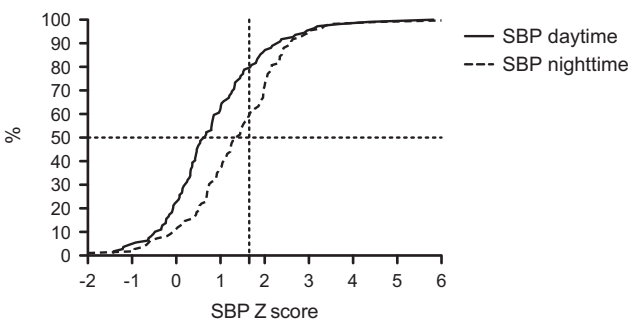

Figure 2. Cumulative distribution of daytime and nighttime systolic blood pressure (SBP) Z- scores. The horizontal interrupted line represents 50% of cumulative distribution; the vertical interrupted line shows the upper limit (+1.65 standard deviation scores) of the SBP.

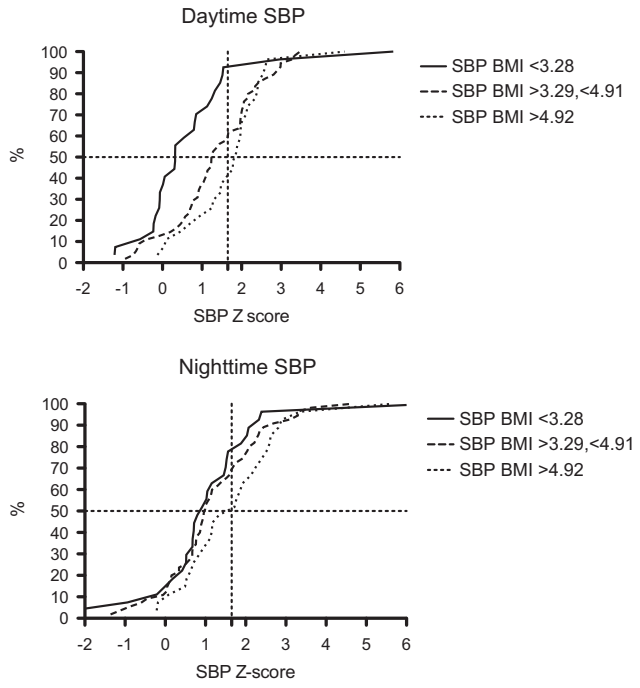

Figure 3. Cumulative distribution of systolic daytime (upper graph) and systolic nighttime (lower graph) blood pressure Z-scores in three body mass index (BMI) groups. The horizontal interrupted lines represent 50% of cumulative distribution, the vertical interrupted lines show the upper limit (+1.65 standard deviation scores) of the systolic blood pressure (SBP).

used in any of the studies. BP load was reported in only three studies,[7,9,13] but was not used for the definition of hypertension. Consequently, the severity of ambulatory hypertension in obese children was not examined thus far.

In contrast to previous studies, we focused our analysis on patients rather than BP values. We attempted to summarize BP parameters obtained from ABPM reports and classify patients (rather than BP values) into normotensives or hypertensives based on ambulatory BP levels and BP loads. We believe that this combined/comprehensive evaluation of ABPM focused on the patient offers a more accurate assessment of hypertension and allows for the assessment of severity of ambulatory hypertension.

Using the combination of SBP, DBP, and MAP levels and their respective BP loads, we found that only 24% had normotension, whereas an additional 25% of patients suffered from prehypertension (normal BP levels but increased BP load) (ie, are potentially at risk for developing hypertension later on in life, as suggested by Falkner et al).[26] More importantly, almost 50% of patients with hypertension detected on ABPM (either SBP, DBP, or MAP) already suffered from a severe form of hypertension with a high BP load >50%. This has not been reported in the literature so far and may have a major impact on further management of obese patients.

Obesity has a significant and added impact on hypertension in children, as already suggested by Lurbe et al.[12] In this study, 87 patients with overweight and obesity were divided into three groups based on their HOMA index. Individuals with the highest HOMA tertile had higher systolic BP and heart rate values during the 24-hour and sleep periods.[12] In our study, an increased degree of obesity (BMI Z-score) did not have any impact on the heart rate, but had a significant impact on the severity of ambulatory hypertension (Figure 1). Similarly to Lurbe's findings, obesity increased the daytime, nighttime, and 24-hour systolic BP if absolute values were used (Table 2). However, the conversion of absolute values into Z-scores shows that the most significant impact of obesity is on daytime systolic BP (progressive increase with the increasing BMI Z-score), whereas the nighttime BP remains elevated throughout various degrees of obesity.

The effect of obesity on daytime BP is further illustrated by a significant shift of the cumulative distribution of the daytime BP in relation to the BMI Z-score, whereas the change in the cumulative distribution of the nighttime BP remains relatively small (Figure 3). This is a novel finding, not previously reported in the literature.

Our study has several limitations. First, only obese patients were analyzed without a control group of normal, non-obese children; however, the conversion of absolute BP values into BP Z-scores enabled an indirect comparison with a healthy child population. Second, we did not use the office BP for classification of hypertension because it was measured only once on a single occasion and may not therefore represent a reliable assessment of the office BP. Consequently, we did not analyze the prevalence of white coat or masked hypertension, nor did we study end-organ damage in our patients. Third, we did not analyze the distribution of body fat and its impact on ambulatory hypertension as an isolate change in abdominal obesity, without any changes in total obesity (ie, BMI). This may have a significant impact on hypertension and target organ damage regression.[27] We can only speculate that abdominal obesity would have a similar impact as the BMI on the severity of ambulatory hypertension, which needs to be proven in future studies.

A relatively small homogenous one-site population sample in our study may be a limiting factor for generalization of results. However, with replication of results in larger more diverse samples, the results of our study may impact on the management of obese children and adolescents. If indeed the daytime BP is increasing proportionally to the degree of obesity, one can hypothesize that the office BP (measured during the daytime) remains normal throughout the early stages of obesity. This may result in underdetection of hypertension (by office BP) in patients with a mildly increased BMI. Those patients may only have an elevated nighttime BP, and this can only be detected during the 24-hour BP monitoring. Our findings therefore further

emphasize the need for ABPM in patients with even mildly increased BMI and normal office BP. Future research may focus on these patients with early stages of hypertension in whom the development of a more severe hypertension can be prevented. A longitudinal follow-up of obese patients with BP, end-organ damage, and vascular stiffness assessments would allow for a better characterization of patients at risk for cardiovascular complications.

In conclusion, our study shows that a significant proportion of obese children with ambulatory hypertension already suffer from severe hypertension at the time of diagnosis. Furthermore, there is a significant association between obesity and the severity of ambulatory hypertension in children and adolescents. The daytime SBP seems to be directly related to the degree of obesity, whereas the nighttime BP remains elevated throughout the wide range of BMI Z-scores.

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