Original article

Usefulness of ambulatory blood pressure monitoring in diagnosis of arterial hypertension in children and adolescents

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Abstract

Background: Arterial hypertension in children and adolescents is an important medical problem with a prevalence rising over the last ten years from 1 to 4.5%.

Aim: To assess the usefulness of ambulatory blood pressure monitoring (ABPM) in diagnosis of arterial hypertension in children and adolescents.

Methods: Two hundred and twelve children with elevated blood pressure (BP) and 81 healthy controls participated in this study. In all children from the study and control groups standard BP measurement and ABPM were performed.

Results: With the use of standard BP measurement, 168 (79.2%) children were diagnosed as hypertensive and the remaining 44 (20.8%) as prehypertensive. When the ABPM was used, arterial hypertension was diagnosed in 143 (67.4%) cases and white coat hypertension in the remaining 69 (32.6%) subjects. In 7 (8.7%) control children elevated BP in ABPM was detected, and masked hypertension were diagnosed.

Conclusions: 1. Ambulatory blood pressure monitoring is a useful tool in diagnosis of arterial hypertension in children and adolescents. 2. Systolic hypertension is a major form of hypertension in childhood. 3. Ambulatory blood pressure monitoring is helpful to identify patients with white coat hypertension. 4. Further studies are necessary to establish uniform indications, standards and rules for interpretation of ABPM in children and adolescents.

Key words: ABPM, children, adolescents, hypertension

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Introduction

Hypertension, as a civilisation disease, has become a significant clinical problem in children and adolescents. The prevalence of primary hypertension in this group of patients has increased from 1% to 4.5% over the past 10 years [1]. The basic test that has become a gold standard in diagnosing hypertension in children and adolescents, as in adults, is blood pressure (BP) measurement using Korotkov's method and a mercury sphygmomanometer. In recent years, 24-hour ambulatory BP monitoring (ABPM) has been more frequently used for the diagnosis of hypertension in children as it allows BP assessment during normal physical activity [2]. The standards of BP measurement and the criteria of hypertension diagnosis using Korotkov's method in children and adolescents were specifically prepared and presented in the 4th Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents [3]. However, widely accepted rules of performing and interpreting the ABPM examination are still not available; thus its usefulness is significantly limited in this group of patients.

The aim of the study was to assess the usefulness of 24-hour ABPM in the diagnosis of hypertension in children and adolescents.

Methods

Study group

The patient group included 212 children (147 boys and 65 girls) referred to the Department of Paediatric Cardiology and General Paediatrics in the years 2005--2007, in whom increased values of BP were detected in

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at least two independent measurements conducted by primary care physicians and, additionally, on admission to the hospital. The age of examined children varied from 7.23 to 17.38 years, mean 13.46±3.57 years, and height varied from 121.2 to 194.3 cm, mean 157.46±21.12 cm. The control group included 81 children (53 boys and 28 girls) with normal values of BP, without family history of hypertension, who were age- and height-matched with children with hypertension.

In all hypertensive children and controls three measurements of BP were performed using a Riester Diplomat mercury sphygmomanometer, following the measurement standards presented in the 4th Report on the Diagnosis, Evaluation and Treatment of Hypertension in Children and Adolescents. On the basis of these measurements the group with hypertension and the group with prehypertension were selected. In both groups the prevalence of increased values of systolic BP (SBP), diastolic BP (DBP) and both SBP and DBP were assessed.

The ABPM measurements were done at home using a SpaceLab 90207 recorder, after advising normal physical activity, excluding exercises that might lead to damage of the recorder or measurement errors. The measurements were started at around 10 a.m. and continued for the following 24 hours. Measurements were taken during the day every 15 minutes, and during sleep every 30 minutes. The duration of day and night periods was established individually for each child on the basis of the diaries they kept with the time of falling asleep and waking up written down. Only those records in which the percentage of the artefact measurements did not exceed 15, were selected for the analysis; otherwise the measurements were repeated after at least 2 weeks.

In the ABPM measurements the following parameters were analysed: mean SBP and DBP for the whole measurement period, mean value of daytime SBP (DSBP) and daytime DBP (DDBP), mean value of nighttime SBP (NSBP) and nighttime DBP (NDBP), mean 24 hour load – the percentage of measurements exceeding the upper reference value for SBP and DBP (SPL – systolic pressure load and DPL – diastolic pressure load), and the mean value of systolic (SND) and diastolic (DND) nocturnal dip. Finally, the prevalence of hypertension was established on the basis of ABPM in both analysed groups, including the prevalence of increased SBP, DBP or both. Children with normal BP in standard measurements and with abnormal ABPM measurements were diagnosed with masked hypertension.

In children taller than 140 cm, the reference values of ABPM in children according to Borowski et al. [4] were used, and in shorter children those according to Soergel et al. [5]. A proper nocturnal BP drop was defined as a drop of BP at night of at least 10% of daytime values. Systolic or diastolic pressure load was regarded as normal when its value did not exceed 25% [6].

Statistical analysis

The results are presented as mean ± SD or numbers and percentages. The results of BP measurements in the group of examined children were compared with values in the control group using Student's t-test for uncorrelated variables. The χ^2 test was used for the comparison of the frequency of hypertension occurrence in the examined and control group. A p value <0.05 was considered significant.

Results

Based on the BP measurements using Korotkov's method, 168 children out of all 212 examined were diagnosed to have hypertension (79.2%) and the remaining 44 children prehypertension (20.8%). In 192 (90.6%) patients, 156 with hypertension and 36 with prehypertension, an isolated increase of SBP was detected. In a further 17 (8%) patients, 9 with hypertension and 8 with prehypertension, an increase of both SBP and DBP was found. In the remaining 3 (1.4%) children with hypertension, an isolated increase of DBP was observed. All children from the control group presented with normal BP values.

Based on the ABPM measurement, hypertension was detected in 143 (67.4%) out of 212 examined children. In 7 (8.7%) out of 81 children from the control group an increased mean 24-hour value of SBP was detected and masked hypertension was diagnosed. The prevalence of hypertension was significantly higher than the prevalence of normal BP ($p < 0.001$) in the group of examined patients compared with controls, who were significantly more often ($p < 0.01$) found with normal BP values. Both in examined patients and in the control group the prevalence of increased SBP was significantly higher than the prevalence of increased DBP ($p < 0.01$) or both elevated SBP and DBP ($p < 0.01$). There were no significant differences in the prevalence of a specific type of hypertension (increased SBP, DBP or both SBP and DBP) between the examined group and controls ($p > 0.05$). The prevalence of hypertension, including increased values of SBP and DBP in examined children and in the control group, is presented in Figure 1. We found that out of 168 children who were diagnosed with hypertension on the basis of a measurement conducted using Korotkov's method, hypertension was confirmed with ABPM measurement in 139 (82.7%) of them, whereas hypertension was diagnosed using ABPM in 24 (54.5%) out of 44 children with prehypertension.

In all examined children and in all children from the control group who were diagnosed with hypertension based on the ABPM measurement, increased SPL and DPL were found. Out of 69 examined children with

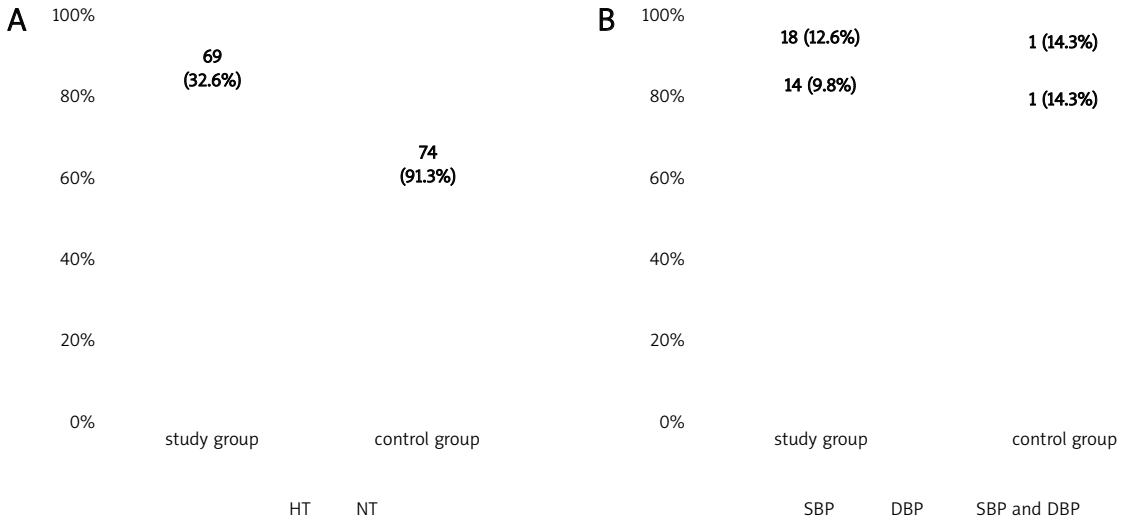

Figure 1. The prevalence of hypertension, including systolic and diastolic hypertension, in examined children and healthy controls. **A** – the prevalence of hypertension in the examined children and controls. **B** – the prevalence of increased values of systolic and diastolic blood pressure in examined children and controls

Abbreviations: HT – hypertension, NT – normal blood pressure, SBP – systolic blood pressure, DBP – diastolic blood pressure

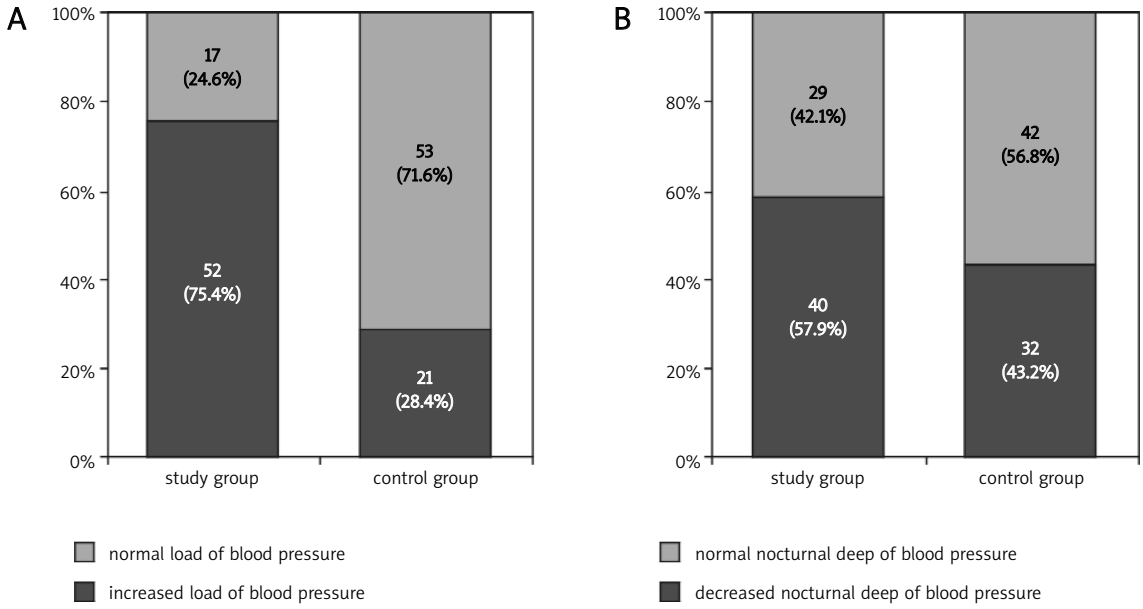

Figure 2. Increased load and decreased nocturnal deep of blood pressure in children with normal blood pressure in ABPM

normal BP revealed in ABPM, increased BP load was observed in 52 (75.4%), and, similarly, in 21 children out of 74 in the control group. The prevalence of increased BP load in patients with normal BP in ABPM was significantly higher in examined children than in the control group ($p < 0.01$) (Figure 2).

Out of 150 children (143 examined and 7 controls) with hypertension found in ABPM, decreased SND or DND was observed in 92 (64.3%) children from the examined group and in 5 (71.4%) children from the control group. No significant difference was found in the prevalence of decreased nocturnal BP dip between examined children and controls (Figure 2). The results of comparative analysis of all parameters of ABPM in examined children and in controls are presented in Table I.

Discussion

The 24-hour ABPM is a diagnostic tool commonly used for detection of hypertension in children and adolescents. It is characterised by a far greater reproducibility compared

Table I. Results of ABPM obtained in the examined and control group

Parameter	Study group	Control group	p
SBP [mmHg]	120.67±8.67	113.72±8.16	<0.001
DBP [mmHg]	67.49±4.73	65.52±4.71	NS
DSBP [mmHg]	125.57±8.84	117.78±8.02	<0.001
DDBP [mmHg]	72.91±5.07	70.72±4.88	NS
NSBP [mmHg]	110.76±8.55	105.21±8.73	<0.05
NDBP [mmHg]	58.17±4.93	56.84±5.04	NS
SPL [%]	29.45±17.55	8.32±16.22	<0.001
SPL^{NT} [%]	22.47±15.32	7.69±14.97	<0.01
DPL [%]	13.33±7.02	5.77±6.13	<0.05
DPL^{NT} [%]	7.21±6.26	5.62±6.07	NS
SND [%]	7.83±5.07	12.19±4.14	<0.05
SND^{NT} [%]	9.24±4.88	12.73±3.91	<0.05
DND [%]	15.76±3.88	18.78±4.16	NS
DND^{NT} [%]	16.21±3.57	18.43±4.13	NS

Abbreviations: BP – blood pressure, ABPM – ambulatory blood pressure monitoring, NT – results referring to children with normal values of BP in ABPM, SBP – mean 24 hour diastolic BP, DBP – mean 24 hour diastolic BP, DSBP – mean day systolic BP, DDBP – mean day diastolic BP, NSBP – mean night systolic BP, NDBP – mean night diastolic BP, SPL – systolic pressure load, DPL – diastolic pressure load, SND – systolic nocturnal dip, DND – diastolic nocturnal dip

with standard BP measurement and better reflects the risk of peripheral complications of hypertension [7, 8].

In our study, ABPM revealed the SBP, SPL and DPL to be significantly higher and SND values lower in children with initial diagnosis of hypertension based on the measurement using Korotkov's method, compared with healthy children. The presented results are consistent with the observations of Reusz et al. [9].

Based on the 24-hour ABPM measurements, hypertension was detected in 67.4% of examined children, including 82.7% of children with initial diagnosis of hypertension based on standard BP measurement and in 54.5% of children diagnosed with prehypertension. Isolated systolic hypertension was the predominant type that was found in 77.6% of all children diagnosed with hypertension on the basis of ABPM measurement. In the study of Sorof et al. [10] including 71 children, systolic hypertension was also more frequently recognised; however, using ABPM, hypertension was confirmed only in 41% of patients. It should be noted that the frequency of hypertension being confirmed in ABPM is influenced by three factors: the accuracy of BP measurements based on Korotkov's method, white-coat hypertension (WCH), and the criteria used for the interpretation of the examination.

White-coat hypertension is a term used to describe a brief rise of BP, mainly SBP, caused by stress factors, such as contact with members of medical staff or the procedure of BP measurement itself. In the study presented herein, in the 32% of children in whom hypertension was not confirmed by ABPM, the presumed diagnosis of WCH should be made. According to available studies, the prevalence of WCH, assessed based on ABPM measurements, varies from 22 to 88% [11-13]. Kavey et al. [13] demonstrated that children with WCH present with increased hypertensive response to physical activity and with increased mass of the left ventricle. The authors suggest that these children should be considered to have prehypertension, and are at risk of hypertension development in the future. In the group of children with WCH in our study, significantly higher values of systolic pressure load and lower values of systolic pressure dip were observed, compared with healthy children with normal results of ABPM measurements, and these observations might indirectly suggest an increased risk of hypertension development as well as indicating the need for regular assessment of BP in this group of patients.

The prevalence of hypertension and WCH, detected based on ABPM measurement, depends on the criteria used for the interpretation of ABPM measurement, which have not been clearly established neither for adults nor for children and adolescents. In the majority of published reports, increased values of mean 24-hour SBP or DBP are considered the criterion for hypertension diagnosis [14]. It has been more often suggested that hypertension in children should be detected based on increased SPL and DPL in ABPM [15]. The normal value of BP load in ABPM has not been clearly established yet. There is a wide range of values that are considered normal and they vary from 20 to 50% [6, 11, 16, 17]. In our study, in which the upper reference value for BP load was 25%, the use of this parameter as a criterion for hypertension detection would cause a significant increase of the prevalence of hypertension, from 67.4 to 91.9%, and would lead to the necessity of expensive diagnostic procedures and possible introduction of pharmacological treatment in a larger group of children.

In ABPM, an increased mean 24-hour value of SBP was found in 8.7% of control children who were considered healthy based on standard BP measurement using Korotkov's method. The presence of increased BP values in ABPM together with a normal result of BP measurement with Korotkov's method is called masked or unstable hypertension, and its prevalence in a paediatric population, according to different reports, varies from 7.6 to 11.0% [18, 19]. In our study, masked hypertension was caused by isolated increase of SBP revealed by ABPM. The criteria of masked hypertension detection in both adults and children have not been clearly established yet. In Mancia et al. [20] PAMELA study, conducted among 3200 adult volunteers, increased mean 24-hour SBP was the criterion used to diagnose masked hypertension, while Matsuoka et al. [19] made the diagnosis of masked hypertension in children and adolescents on the basis of increased values of both SBP and DBP in ABPM. Despite the initial results

indicating that patients with masked hypertension present with increased mass of a left ventricle and increased risk of hypertension development, standard procedures and care of patients have not been established so far in this group.

Decreased night BP drop in adults with hypertension is considered a risk factor for the development of end-organ damage, however no such data were found in literature regarding children and adolescents. In our study, significantly lower values of SND were found in the examined group compared with the control group; however, there was no significant difference in the frequency of improper night BP drop between children with hypertension and healthy controls. Kavey et al. [13] did not observe any significant differences in the night drop of SBP between children with hypertension and WCH. Our own experience demonstrates that many children wake up during the measurements at night and thus the night BP drop may be significantly decreased and the assessment of this parameter is unreliable.

In summary, we have demonstrated 24-hour ABPM to be a useful tool in the diagnosis of hypertension in children and adolescents; its real value will only be validated when the indications, reference values and criteria of results interpretation are established. Also, keeping in mind the low prevalence of hypertension in children, further multicentre studies are needed.

Conclusions

1. 24-hour ABPM is a useful tool in the diagnosis of hypertension in children and adolescents.
2. Isolated systolic hypertension is the predominant type of hypertension in children and adolescents.
3. ABPM allows the selection of children with white coat hypertension, which is a significant clinical and epidemiological problem in the paediatric population.
4. Further studies are needed to establish uniform indications, reference values and standard procedures of conducting and interpreting ABPM measurements in children and adolescents.

References

1. Diaz LN, Garin EH. Comparison of ambulatory blood pressure and Task Force criteria to identify pediatric hypertension. *Pediatr Nephrol* 2007; 22: 554-8.
2. Woroniecki RP, Flynn JT. How are hypertensive children evaluated and managed? A survey of North American pediatric nephrologists. *Pediatr Nephrol* 2005; 20: 791-7.
3. 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 (2 Suppl 4th Report): 555-76.
4. Borowski A, Wieteska-Klimczak A, Dorywalski T, et al. Dobowy pomiar ciśnienia tętniczego u zdrowych dzieci i młodzieży polskiej. *Pediatr Pol* 1998; 73: 1247-51.
5. Soergel M, Kirschstein M, Busch C, et al. Oscillometric twenty-four-hour ambulatory blood pressure values in healthy children and adolescents: a multicenter trial including 1141 subjects. *J Pediatr* 1997; 130: 178-84.
6. Wyszyńska T. Pomiary ciśnienia tętniczego i interpretacja ich wyników. In: Wyszyńska T, Litwin M. Nadciśnienie tętnicze u dzieci i młodzieży. *Wydawnictwo Lekarskie PZWL*, Warszawa 2002: 33-49.
7. Sorof JM, Portman RJ. Ambulatory blood pressure monitoring in the pediatric patient. *J Pediatr* 2000; 136: 578-86.
8. Cuspidi C, Macca G, Sampieri L, et al. Target organ damage and non-dipping pattern defined by two sessions of ambulatory blood pressure monitoring in recently diagnosed essential hypertensive patients. *J Hypertens* 2001; 19: 1539-45.
9. Reusz GS, Hóbor M, Tulassay T, et al. 24 hour blood pressure monitoring in healthy and hypertensive children. *Arch Dis Child* 1994; 70: 90-4.
10. Sorof JM, Poffenbarger T, Franco K, et al. Isolated systolic hypertension, obesity, and hyperkinetic hemodynamic states in children. *J Pediatr* 2002; 140: 660-6.
11. Sorof JM, Portman RJ. White coat hypertension in children with elevated casual blood pressure. *J Pediatr* 2000; 137: 493-7.
12. Sorof JM, Poffenbarger T, Franco K, et al. 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: 855-60.
13. Kavey RE, Kveselis DA, Atallah N, et al. White coat hypertension in childhood: evidence for end-organ effect. *J Pediatr* 2007; 150: 491-7.
14. Kennedy SE, Mackie FE, Rosenberg AR, et al. Agreement on reporting of ambulatory blood pressure monitoring in children. *Pediatr Nephrol* 2005; 20: 1766-68.
15. Lurbe E, Sorof JM, Daniels SR. Clinical and research aspects of ambulatory blood pressure monitoring in children. *J Pediatr* 2004; 144: 7-16.
16. Khan IA, Gajaria M, Stephens D, et al. Ambulatory blood pressure monitoring in children: a large center's experience. *Pediatr Nephrol* 2000; 14: 802-5.
17. Koshy S, MacArther C, Luthra S, et al. Ambulatory blood pressure monitoring: mean blood pressure and blood pressure load. *Pediatr Nephrol* 2005; 20: 1484-6.
18. Lurbe E, Torro I, Alvarez V, et al. Prevalence, persistence, and clinical significance of masked hypertension in youth. *Hypertension* 2005; 45: 493-8.
19. Matsuoka S, Awazu M. Masked hypertension in children and young adults. *Pediatr Nephrol* 2004; 19: 651-4.
20. Mancia G, Facchetti R, Bombelli M, et al. Long-term risk of mortality associated with selective and combined elevation in office, home, and ambulatory blood pressure. *Hypertension* 2006; 47: 846-53.

Ocena przydatności 24-godzinnego ambulatoryjnego monitorowania ciśnienia tętniczego w diagnostyce nadciśnienia tętniczego u dzieci i młodzieży

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Streszczenie

Wstęp: Nadciśnienie tętnicze u dzieci i młodzieży jest istotnym problemem klinicznym, jego częstość wzrosła w ciągu ostatnich 10 lat z 1 do 4,5%.

Cel: Celem pracy była ocena przydatności 24-godzinnego ambulatoryjnego monitorowania ciśnienia tętniczego (ang. *ambulatory blood pressure monitoring*, ABPM) w diagnostyce nadciśnienia tętniczego u dzieci i młodzieży.

Metodyka: W badaniu uczestniczyło 212 dzieci z podwyższonym ciśnieniem tętniczym w pomiarach prowadzonych przez lekarzy podstawowej opieki zdrowotnej. Grupę kontrolną stanowiło 81 zdrowych dzieci. U wszystkich dzieci z grupy badanej i kontrolnej przeprowadzono standardowy pomiar ciśnienia tętniczego metodą Korotkowa oraz badanie ABPM z oceną średniej wartości ciśnienia skurczowego i rozkurczowego dla całej doby, okresu dnia i nocy, ładunku i spadku nocnego ciśnienia skurczowego i rozkurczowego.

Wyniki: W standardowym pomiarze ciśnienia tętniczego w grupie badanej nadciśnienie tętnicze rozpoznano u 168 (79,2%) dzieci, a u pozostałych 44 (20,8%) stwierdzono stan przednadciśnieniowy. W 24-godzinnym ABPM rozpoznanie nadciśnienia tętniczego potwierdzono w 143 (67,4%) przypadkach, a w pozostałych 69 (32,6%) rozpoznano nadciśnienie białego fartucha. U 7 (8,7%) dzieci z grupy kontrolnej, u których w badaniu ABPM stwierdzono podwyższone ciśnienie tętnicze, rozpoznano nadciśnienie maskowane. W badaniu ABPM stwierdzono znamiennie statystycznie wyższe wartości ciśnienia skurczowego dla całej doby, okresu dnia i nocy, ładunku ciśnienia skurczowego i rozkurczowego oraz niższe wartości spadku nocnego ciśnienia skurczowego w porównaniu z grupą kontrolną. Nie stwierdzono natomiast statystycznie istotnych różnic w zakresie średniej wartości ciśnienia rozkurczowego dla całej doby, okresu dnia i nocy oraz spadku nocnego ciśnienia rozkurczowego pomiędzy grupą badaną i kontrolną.

Wnioski: 1. 24-godzinne ABPM jest przydatnym narzędziem w diagnostyce nadciśnienia tętniczego u dzieci i młodzieży. 2. W populacji pediatrycznej dominuje nadciśnienie skurczowe. 3. 24-godzinne monitorowanie ciśnienia tętniczego pozwala wyodrębnić grupę dzieci z nadciśnieniem białego fartucha. 4. Konieczne są dalsze badania w celu ujednolicenia wskazań, standardów i zasad interpretacji badania ABPM u dzieci i młodzieży.

Słowa kluczowe: ABPM, dzieci, młodzież, nadciśnienie

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