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Correlation between electronic wrist blood pressure with auscultatory blood pressure in children

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Abstract. – OBJECTIVE: The increasing prevalence of obesity in children and adolescents has turned hypertension into an important public health issue. In the current literature, auscultatory blood pressure measurement is recommended for the diagnosis of hypertension. The number of studies comparing electronic blood pressure measurement and auscultatory blood pressure measurement is limited. This study aimed to compare auscultatory blood pressure measurement with electronic blood pressure measurement in the children population group aged 5-15 years.

PATIENTS AND METHODS: A total of 72 patients aged between 5-15 years without chronic disease were included in the study. Anthropometric measurements (height, weight, body mass index, wrist circumference, mid-upper arm circumference) were performed. Systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were first measured electronically from the wrist using an Omron Rs7 Intelli It HEM-6232T device, and then auscultatory measurements were performed. Each type of measurement was performed 3 times intermittently.

RESULTS: The mean wrist circumference was 14.43±0.22 cm and the mean mid-upper arm circumference was 21.43±0.55 cm. Mean SBP, DBP and MAP measured electronically on the wrist were 104.1±1.5, 65.6±1.3 and 78.1±1.3 mmHg, respectively, and mean SBP, DBP and MAP measured via auscultation were 99.3±1, 61.4±0.7 and 73.6±0.7 mmHg, respectively. Electronically-measured wrist MAP had significantly moderate correlations with mid-upper arm and wrist circumference (r:0.547, r:0.559, $p<0.01$).

CONCLUSIONS: Since the differences were less than 4 mmHg in both systolic and diastolic pressures between electronic wrist blood pressure (EWBP) measurement and auscultatory measurement, it appears that electronic measurement may be important in first line of blood pressure screening. Since it is easy and practical to use in the early period, it may be an alternative approach to auscultatory measurement among non-critical pediatric patients.

Key Words:
Blood pressure measurement, Wrist monitor, Pediatrics.

Introduction

With the increasing obesity prevalence, hypertension in children and adolescents has become a public health problem with increasing frequency[1]. Since hypertension is almost always asymptomatic unless there is severe organ damage, blood pressure measurement is the only method for early diagnosis[2]. Hypertension guidelines agree on the recommendation for blood pressure measurement once a year in children over 3 years of age[3]. While invasive blood pressure measurement is used in pediatric intensive care units, non-invasive blood pressure measurement is widely used in stable inpatients and in non-hospital settings[4].

Auscultatory blood pressure measurement is recommended in the current literature for the diagnosis of hypertension in children[3]. When an electronic oscillometric blood pressure monitor detects increased blood pressure, it should be confirmed by auscultatory blood pressure measurement[5]. However, children's anatomical and physiological characteristics may pose an obstacle to auscultatory measurement. The limitations of the auscultatory method in children include smaller arm circumferences, narrower and more elastic arteries, large differences between peripheral and central blood pressures, low amplitude of Korotkoff sounds, and difficulties identifying the sounds as they are not easily audible[6]. Household electronic blood pressure measurement is recommended for automated measurements since ambulatory blood pressure monitoring is not easy to apply in most cases[2]. The ease of use and the elimination of human errors in blood pressure measurement (e.g., mishearing, surrounding noises) make automated

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blood pressure measurement advantageous[7]. The number of studies comparing electronic wrist blood pressure measurement with auscultatory measurement is limited; therefore, the aim of this single-center prospective study was to compare electronic wrist blood pressure measurement with auscultatory measurement in children.

Patients and Methods

Study Population

The study was conducted in patients hospitalized with different diagnoses in the Department of Pediatrics of Niğde Ömer Halisdemir University Training and Research Hospital in the period between September 2022 and February 2023. A total of 72 patients between the ages of 5 and 15 years were randomly included in the study. Patients were divided into two subgroups according to age groups as 5-10 years and 10-15 years old.

This research has been approved by the Ethics Committee of Niğde Ömer Halisdemir University (decision No. 2022/78). Patients with cerebral palsy, chronic renal failure, asthma, congenital heart disease or arrhythmia and patients treated with beta-2 agonists and/or antihypertensives were excluded. Informed consent was obtained from the families of the participants.

Clinical and sociodemographic data including age, sex, anthropometric measurements (height, weight, body mass index (BMI), wrist circumference, mid-upper arm circumference), and family history of hypertension were recorded. Height was calculated by Harpenden stadiometer. Weight was calculated by mechanical adjustable scale. Wrist and mid-upper arm circumference were calculated by non-flexible paper tape measure. Height was taken to the nearest 0.1 cm and weight was taken to the nearest 0.1 kg. Mid-upper arm circumference was measured by marking the midpoint between the acromion and olecranon processes with the arm bent at 90°. The arm was then straightened at the participant's side and the circumference was measured at the marked midpoint with the measuring tape parallel to the floor. BMI was calculated by dividing weight by the square of height (kg/m^2).

An appropriate size cuff was selected following the measurement of the patient's arm circumference in auscultatory blood pressure measurement. The cuff size of the electronic blood pressure measurement device was standard. The patient was in a seated position with the arm at heart level. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured, and the mean arterial pressure (MAP) was calculated using the following formula: (systolic blood pressure + 2 × diastolic blood pressure) / 3. Non-invasive electronic wrist blood pressure [EWBP] measurement was performed using the Omron Rs7 Intelli It HEM-6232T (Omron Healthcare, Inc., Kyoto, Japan) device. First, EWBP was measured 3 times at 5-minute intervals. Auscultatory blood pressure measurements were begun 15 minutes after the non-invasive electronic measurement, and these were also performed 3 times at 5-minute intervals after selecting the appropriate cuff for the patient.

Statistical Analysis

Continuous variables were tested for normal distribution using the Shapiro-Wilk test. Normally distributed variables are presented as mean ± SD. The correlations between measurements were calculated using the Pearson correlation coefficient. A prior power analysis was executed by using G*Power 3.1. The difference between two dependent means (paired-*t*-test) was used as a statistical test. For detecting a medium effect size, which equals 0.5, with alpha (α err prob) of 0.05 and 1-β err prob of 0.95, a minimum sample size of 54 individuals was sufficient to achieve an actual power of 95%. A *p*-value less than 0.05 (<0.05) was considered statistically significant. Statistical analysis was performed by using the statistical package SPSS version 24.0 (IBM Corp., Armonk, NY, USA) for Windows.

Results

Seventy-two patients were included in the study. Forty (55.6%) of the patients were female and 32 (44.4%) were male. The mean age of the patients was 115.89 ± 4.80 months. Thirty-four children were aged between 5-10 years, and thirty-six children were aged between 10-15 years. Fourteen (19.4%) of the patients had a family history of hypertension. Patients were hospitalized with different diagnoses. Five patients were diagnosed with a Familial Mediterranean Fever (FMF) episode, 7 with pneumonia, 12 with tonsillopharyngitis, 8 with a febrile seizure, 25 with acute gastroenteritis, and 5 with arthritis. None of the patients were hypertensive. Mean weight was 37.2 ± 0.43 kg, mean height was 137.76 ± 2.64 cm, mean wrist circumference was 14.43 ± 0.22 cm, mean mid-upper arm circumference was 21.43 ± 0.55 cm, and mean body mass index was 18.28 ± 0.64 kg/m^2.

Ages 5-10 years old, mean SAP, DAP and MAP values of auscultatory blood pressure (ABP) were 95.5±7.2, 59.4±5.7, 71.4±5.5 mmHg, respectively. Mean SAP, DAP and MAP values of EWBP were respectively 98.3 ±10.1, 61.4 ±10.01, and 73.3±9.6 mmHg on ages 5-10 years old. For ages 10-15 years old, the mean SAP, DAP and MAP values of ABP were 104.4±7.4, 63.9±6.3, and 76.4±5.7 mmHg, respectively. For ages 10-15 years old, mean SAP, DAP and MAP values of EWBP were 111.8±12.6, 71.2±11.7, and 84.5±11.4 mmHg, respectively.

For ages 5-10 years, there was a significant moderate positive correlation between electronic wrist systolic blood pressure and auscultatory systolic blood pressure (r:0.50, *p*:0.001), a significant poor correlation between electronic diastolic blood pressure and auscultatory diastolic blood pressure (r:0.29, *p*:0.04). Moreover, there was a significant moderate positive correlation between electronic wrist systolic blood pressure and auscultatory systolic blood pressure (r:0.51, *p*:0.006), a significant poor correlation between electronic diastolic blood pressure and auscultatory diastolic blood pressure (r:0.43, *p*:0.01).

The comparisons of the mean SAP, DAP and MAP values of EWBP and ABP, and paired *t*-test results are shown in Table I. There was a significant correlation between mean SAP, DAP and MAP values of EWBP and ABP.

There was a significant, strong positive correlation between electronic wrist systolic blood pressure and auscultatory systolic blood pressure (r:0.623, $p<0.01$), a significant moderate correlation between electronic wrist diastolic blood pressure and auscultatory diastolic blood pressure (r:0.462, *p*:0.01), and a significant moderate correlation between electronic wrist mean arterial pressure and auscultatory mean arterial pressure (r:0.437, *p*:0.01) as shown in Figure 1, Figure 2, and Figure 3.

There was a significant moderate correlation between anthropometric measurements, such as arm circumference and wrist circumference, and electronic wrist mean arterial pressure (r:0.547, r:0.559, $p<0.01$). Auscultatory mean arterial pressure demonstrated significant moderate correlations with arm circumference, wrist circumference, and body mass index as shown in Table II.

Discussion

In our study, SBP, DBP and MAP values measured by the EWBP method were significantly higher compared to the ABP method. Differences between blood pressure values may occur depending on whether the measurement is performed in the radial or brachial region. Blood pressure values measured on the brachial region tend to be closer to the central blood pressure values than the radial region. Incorrect cuff size and rapid evacuation of air may cause inconsistencies in auscultatory blood pressure measurement[8].

In studies carried out in schools, it was found that systolic blood pressure measured by the

Table I. Comparison of blood pressure values measured by EWBP and ABP

Pressures	EWBP Mean (SD) (mmHg)	ABP Mean (SD) (mmHg)	EWBP-ABP Mean (SD) (95%CI) (mmHg)	*p*-value
Systolic (mmHg)	104.1 (1.5)	99.3 (1.0)	4.7 (10.2) (2.3; 7.1)	<0.001
Diastolic (mmHg)	65.6 (1.3)	61.4 (0.7)	4.2 (10.4) (1.7; 6.6)	0.001
Mean (mmHg)	78.1 (1.3)	73.6 (0.7)	4.5 (10.6) (2.0;7.0)	0.001

EWBP: electronic wrist blood pressure; ABP: auscultatory blood pressure.

Table II. Correlation between anthropometric measurements with mean blood pressure.

	AMBP mean (r)	EWBP mean (r)	*p*
Arm circumference	0.547	0.581	<0.01
Wrist circumference	0.559	0.486	<0.01
Body mass index	0.612	0.528	<0.01

AMBP: Auscultatory mean blood pressure.

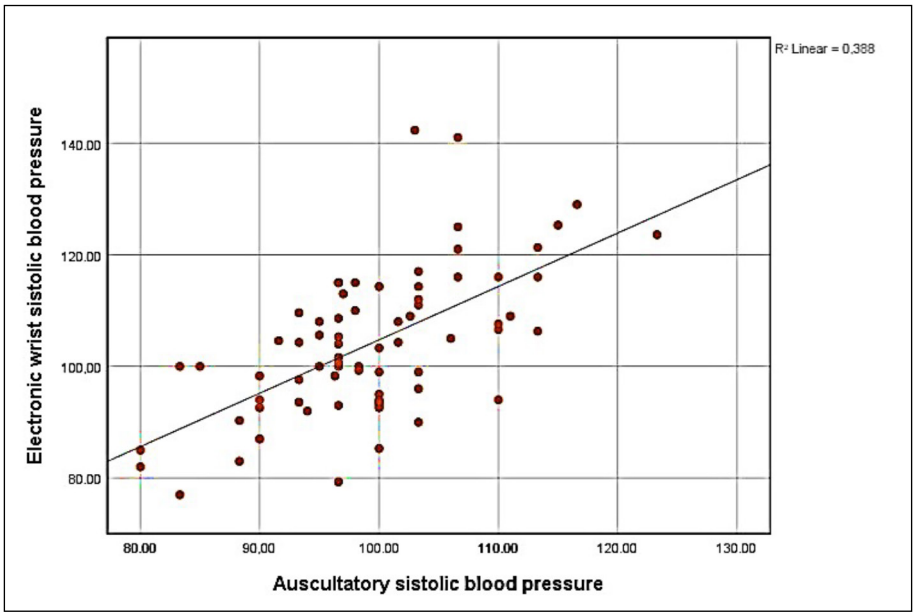

Figure 1. Correlation between electronic wrist systolic blood pressure and auscultatory systolic blood pressure. (Correlation coefficient r: 0.623, $p<0.01$).

oscillometric method yielded higher values compared to measurements with mercury sphygmomanometers. In individual studies, considerable heterogeneity was observed when the oscillometric method and mercury sphygmomanometer were compared in systolic blood pressure measurement[9]. Differences between systolic blood pressures were found to range between -4.95 and 11.6 mmHg in the literature. In a study by Ringrose et al[10], systolic blood pressure was found to be significantly lower and diastolic blood pressure was found to be significantly higher in electronic wrist measurement compared to oscillometric measurement. In our study, systolic blood pressure was found to be 4.7 ± 10 mmHg higher with electronic wrist measurement compared to au-

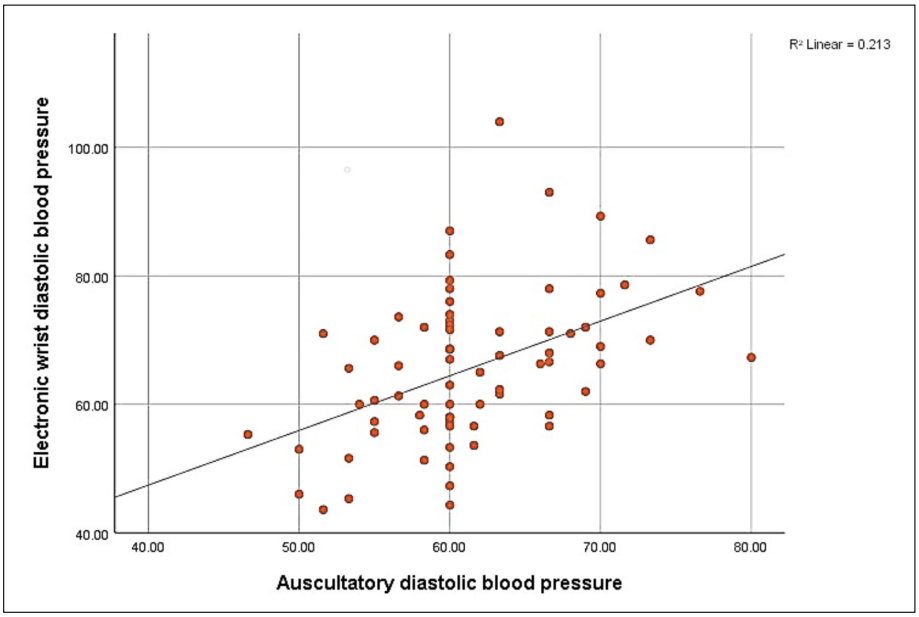

Figure 2. Correlation between electronic wrist diastolic blood pressure and auscultatory diastolic blood pressure (Correlation coefficient r:0.462, $p<0.01$).

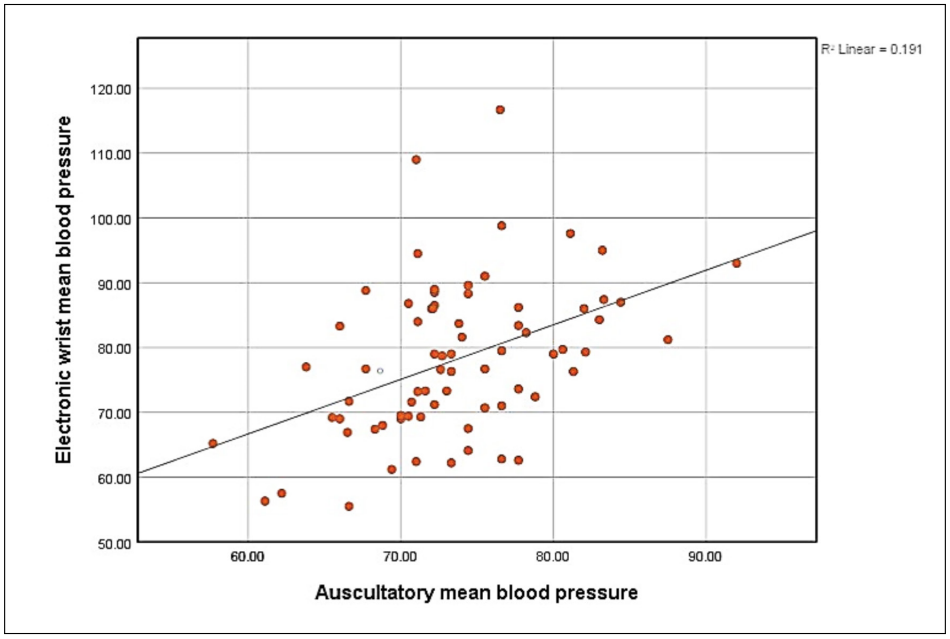

Figure 3. Correlation between electronic wrist mean blood pressure and auscultatory mean blood pressure (Correlation coefficient r: 0.437, $p<0.01$).

scultatory measurement. The difference between EWBP and ABP measurements was significantly higher for systolic blood pressure results [4.7 (10.2)] ($p<0.01$). Diastolic blood pressure values were found to be more than 4 mmHg higher when EWBP measurement was performed compared to ABP measurement. When cuff pressure exceeds venous pressure, it causes an obstruction in venous return[3]. As a result, diastolic escape of blood is impaired, and diastolic pressure increases. Oscillometric methods are not standardized; therefore, differences are observed between devices in ABP measurements[11]. In addition, differences between studies in terms of electronic measurement and auscultatory measurement values may be related to different age ranges, differences in wrist circumferences, and the use of different electronic devices.

When analyzed according to age groups, we found that there was a significant correlation between both systolic and diastolic blood pressures in both measurement methods. When auscultatory and electronic blood pressure measurements were compared, we detected a weak correlation between diastolic blood pressures. Krishna et al[11] detected that non-invasive methods significantly under-estimate systolic blood pressure and over-estimate diastolic pressure. It was observed that the weakness in the correlation in diastolic pressures continued with increasing age.

In studies involving adult patients[12,13], electronic mean blood pressure values were significantly lower than auscultatory measurements, even in routine screenings. In a study[14], the difference between automated blood pressure measurement and auscultatory blood pressure measurement was 8-15 mmHg for systolic blood pressure and 2-8 mmHg for diastolic blood pressure.

A meta-analysis comparing oscillometric and auscultatory measurements in children concluded that the oscillometric method is an important alternative to the auscultatory method in the initial screening[15]. However, it was reported that there were considerable differences between studies, and nearly half of the blood pressure measuring devices were not validated with a standardized protocol[15]. Small arm and wrist circumferences and motion artifacts cause electronic oscillometric blood pressure values to be lower than expected. These problems cause difficulties in measurement and evaluation with the electronic oscillometric method[15,16].

Limitations

The limitations of our study were the small number of patients included and the fact that a single person carried out auscultation measurements. It is important to conduct multicenter studies comparing automated wrist blood

pressure measurement with auscultatory measurement to reach more accurate results. Ease of measurement, less patient agitation, and the potential to reduce white coat hypertension may allow a more practical approach to the use of the automated EWBP method[2,15].

Conclusions

EWBP measurement method is considered a convenient alternative for home blood pressure measurement in pediatric patients. The differences of less than 4 mmHg in systolic and diastolic pressures between the EWBP and auscultatory methods suggest that EWBP measurement may be important in first line of blood pressure screening. However, we think that future studies with strong validations as well as multicenter studies are needed for this method to be established as having a role in the diagnosis of hypertensive pediatric patients.

Conflict of Interest
The Author declares that he has no conflict of interests.

Informed Consent
Informed consent was obtained from the families of the participants.

Availability of Data and Materials
The data supporting this study's findings are available from the corresponding author, [Z.YÖ.], upon reasonable request.

Ethics Approval
Ethical approval was obtained from local Ethical Committee of Niğde Ömer Halisdemir University Training and Research Hospital (Approval number: 2022/78, Date: 11.08.2022).

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