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Comparison of Different Methods of Blood Pressure Measurements from the Arm and the Ankle in Young and Elderly People: A Cross-Sectional Study

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Abstract

Objective: In this study, we aimed to compare different methods of measuring blood pressure devices and to investigate the inter-arm and inter-leg difference (IAD and ILD), the ankle brachial index, and variables that affect them in young and elderly participants.

Methods: This study was conducted in Turkey with 150 students studying at a university and 150 individuals aged over 60, a total of 300 participants. Data regarding the measurements of arm and ankle blood pressures using an automated oscillometric device and an aneroid sphygmomanometer were collected between December 2019 and January 2020 by the researchers.

Results: There was a correlation between the right arm systolic blood pressure and the variable of bodyweight, and measurements made by automatic oscillometry were higher than those made using an aneroid manometer. A large IAD of ≥ 10 mmHg was found in 22.7% of the participants, and large ILD was found in 30%. Mean IAD was associated with bodyweight and body mass index. ILD was greater in men than in women and in older individuals compared with those in younger participants. In addition, low ankle brachial index values of ≤ 0.9 were found in 2.3% of the participants.

Conclusion: The present data show the results of a comparison of blood pressure measurements in young and old individuals made using different devices and parts of the body. We believe that the findings will create awareness in the researchers and health personnel regarding comparison of IAD and ILD and ankle brachial index in these individuals.

Keywords: Automatic oscillometry, aneroid manometer, arm blood pressure, ankle blood pressure, ankle brachial index, blood pressure measurement, inter-leg differences, inter-arm differences

Genç ve Yaşlı Bireylerde Kol ve Ayak Bileğinden Farklı Kan Basıncı Ölçüm Yöntemlerinin Karşılaştırılması: Kesitsel Bir Çalışma

Özet

Amaç: Bu çalışmanın amacı genç ve yaşlı bireylerde dijital ve aneroid kan basıncı ölçüm cihazları kullanılarak ölçülen kol ve ayak bileğinden kan basıncı ölçüm değerlerini karşılaştırmak ve ölçüm sonucunu etkileyen değişkenleri araştırmaktır.

Yöntemler: Bu çalışma Türkiye'de bir üniversitede Yaşlı Bakımı bölümünde eğitim-öğretim gören 18-30 yaş arası 150 öğrenci ve yaşlı evlerine kayıtlı 60 yaş üstü 150 birey olmak üzere toplam 300 katılımcı ile yürütülmüştür. Araştırmanın verileri Aralık

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2019- Ocak 2020 tarihleri arasında araştırmacılar tarafından otomatik osilometrik cihaz ve aneroid tansiyon aleti kullanılarak kol ve ayak bileğinden tansiyon ölçümü yapılarak gerçekleştirildi.

Bulgular: Sağ kol sistolik kan basıncı ile vücut ağırlığı değişkeni arasında korelasyon bulundu ve otomatik osilometri ile yapılan ölçümlerin aneroid manometre kullanılarak yapılan ölçümlerden daha yüksek olduğu görüldü. Katılımcıların %22.7'sinde 10 mmHg'dan büyük kollar arası fark ve %30'unda bacaklar arası ölçümlerde farklılıklar bulundu. Kollar arası ortalama farklılıklar ile vücut ağırlığı ve vücut kitle indeksi arasında ilişki saptandı. Bacaklar arası ortalama farklılıklar erkeklerde kadınlardan ve yaşlılarda gençlerden daha fazlaydı. Ayrıca, katılımcıların %2.3'ünde brakiyal indeksi değerleri ≤0.9 altında bulundu.

Sonuç: Mevcut veriler, genç ve yaşlı bireylerde farklı cihazlar ve vücudun farklı bölümleri kullanılarak yapılan kan basıncı ölçümlerinin karşılaştırmalı sonuçlarını göstermektedir. Elde edilen bulguların, genç ve yaşlılarda kollar arası ve bacaklar arası ölçüm farklılıkları ile ayak bileği brakiyal indeksinin karşılaştırılması konusunda araştırmacılar ve sağlık personeline farkındalık sağlayacağı düşünülmektedir.

Anahtar sözcükler: Otomatik osilometri, aneroid manometre, kol kan basıncı, ayak bileği kan basıncı, ayak bileği kol indeksi, kan basıncı ölçümü, bacaklar arası farklar, kollar arası farklar

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Blood pressure (BP) measurement is critical for clinical practice.[1] Although many hypertension guidelines have been developed, the American College of Cardiology (ACC)/American Heart Association (AHA) 2017 and European Society of Cardiology (ESC)/European Society of Hypertension 2018 guidelines are two well-established and frequently referenced documents.[1-3] In both guides, emphasis is placed on the accuracy of BP measurements and home BP monitoring.[1-3] Accurate measurement of BP is important for the diagnosis of cardiovascular disease (CVD), better hypertension management, and the detection of disease symptoms.[4]

The standard location for BP measurement is the upper arm. Alternative sites to measure BP include the wrist, finger, and ankle.[4] BP should be measured in both arms at the initial assessment [4,5] because the identification of inter-arm differences (IAD) for BP in the arms allows the treatment of hypertension more accurately.[6] However, in many situations, practical problems make it difficult to measure the BP of both arms.[5] A systolic BP IAD ≥ 10 mm Hg would be considered clinically significant and is associated with a greater incidence of CVD.[4,7,8] In addition, low ankle brachial index (ABI) associated with lower extremity artery disease has a predictive value for cardiovascular events and is indicative of advanced atherosclerosis.

Many studies have compared BP, measured in both arms, mostly using the auscultation technique. [9-13] However, no clear conclusions were reached.[10,11,14] In a meta-analysis by Verberk et al.[15] 14% of the subjects had an IAD of 10 mmHg or more for systolic BP and reported no BP difference between the right and the left arms. In addition, IAD studies were conducted on hypertensive, normotensive, and elderly patients; patients with diabetes, patients with HIV, and pregnant women;[15] and those with chronic kidney disease[16,17] and peripheral arterial disease.[18] It was observed that these studies were conducted in people of middle age and over (a median age of 56, range 31–79 years).[15] Clark et al.[19] reported that IAD in patients with hypertension was higher than that in non-hypertensive East Asian population than that in Western populations. Therefore, this systematic review and meta-analysis suggested that the prevalence of IAD may vary by ethnicity.[19]

An alternative site to measure BP is the ankle.[4,20] Lower extremity blood pressure measured at the ankle is important data that help to diagnose peripheral arterial disease with the ankle-brachial index (ABI).[20] ABI has been shown to be an efficient method for detecting arterial stenosis in the lower extremities, using ABI ≤ 0.9 as a cut-off value.[21] Some studies have suggested that decreased ABI is associated with the risk of CVD[22-24] and recurrent stroke.[25-27] However, other studies showed no association.[28,29] In the studies included in a meta-analysis by Hong et al.[21] with individuals aged ≥45 years, it was observed that the type of device used for the measurement of BP affected the readings.[21] Aneroid/manual sphygmomanometers have become common in clinical settings,[4] and automated oscillometric devices are also frequently used for outpatient BP measurements on the upper arm and wrist.[4,30,31] Roerecke et al.[32] stated in a meta-analysis that automated office BP measurement should be the preferred method in routine clinical practice. Both oscillometric devices and manual sphygmomanometers have been assessed in a few studies in the literature.[11,33]

To the best of our knowledge, this is the first study to compare IAD, inter-leg differences (ILD), and ABI results in young and old individuals using BP measurement instruments such as aneroid and automated oscillometric devices. We believe that the findings will create awareness in researchers and healthcare personnel regarding the comparison among IAD, ILD, and ABI in these individuals. In addition, we predict that the results of this study will help health personnel in planning the necessary procedures for measuring BP.

Materials and Methods

In this study, we aimed to compare different methods and devices for measuring BP and to investigate IAD and ILD, ABI, and the variables that affect them in young and older participants.

Study Design

This was a cross-sectional study.

Participants and Sampling

This study was conducted in Antalya, Turkey, with 150 students studying at the Aged care department of the health services college of a university, and 150 individuals aged over 60 years registered at old people's homes attached to the Municipality Social Assistance Services Directorate, a total of 300 participants. The eligibility criteria for inclusion comprised the ability to provide verbal or written consent to participate in the study and age above 60 years for the old-age group. Participants were excluded if they were diagnosed with hypertension and had undergone extremity amputation. The purposive sampling method was used for all the samples. One hundred and fifty of the 200 students registered and currently studying in the Aged Care Program of the University Health Services Vocational College in the academic year 2019–2020 agreed to participate in the study.

Data Collection

Collection of research data was conducted by means of a personal information form created by the researchers and through measurements. The personal information form consisted of questions on sex, age, body weight, and body mass index. Blood pressure measurements were made manually and digitally from the arm and leg between 10 am and 5 pm. The comparison analysis was divided into four categories: digital versus manual manometer, young versus older participants, arm versus ankle measurement, and right BP versus left BP. Arm blood pressure was measured in a seated position simultaneously for both arms using an automated oscillometric device equipped with two cuffs. The measurements were made by researchers who were experienced in the fields of medical anatomy and internal medicine nursing. The researchers made the measurements according to the steps for measuring BP and recorded the results on a questionnaire. First, the participants' BP was manually and then digitally measured. It was ensured that different researchers made the manual and digital measurements, and no information regarding the measurements was given to the patients until all measurements were completed. Therefore, the researcher making the manual measurements was prevented from affecting the other results. Before performing systolic BP (SBP) and diastolic BP (DBP) measurements, the participants were given five minutes of rest in a sitting position, after which the BP measurements began. Key steps essential for proper BP measurement are as follows: the proper preparation of the patient in a quiet area, and the patient should be seated in a chair, with the back firmly supported and feet flat on the ground, the arm supported, and with the appropriate size cuff.[1,4] Thus, careful attention was paid in the preparation of the participant and the environment before measurement. Moreover, white coats were not used by the researchers with the aim of preventing the white coat effect. BP measurement steps were followed in accordance with the ESC and AHA guidelines.[2,3]

Measurements were made after the participants were given information about the content of the study. The participants were informed by the researchers that the study included BP measurements and a few questions on BP measurement. BP measurement data made in the University Health Services were collected in the laboratory of the school. BP measurement of the older participants was performed in an area in the lobby of the old people's home where they came to spend time during the day where they could lie on their backs. Eating status, smoking status, climbing stairs and emptying their bladders were evaluated before blood pressure measurement of the participants. Their clothing was then loosened on all four limbs, and they were allowed to rest for five minutes. Simultaneous BP measurements were made from the four extremities while supine, first manually and then with the automatic measurement devices, once each at intervals. The lower extremity measurements were made supine. The data collection period lasted approximately 20–30 minutes for each participant.

Characteristics of the Measurement Devices

The digital and manual BP measurement devices used in the study were those recommended by the guidelines.[1-3] The German licensed ERKA and Swiss licensed Microlife digital and manual blood pressure equipment were calibrated and adjusted for use to be used in the study. For arm and leg BP measurements, we used an oscillometric BP device first device. This had a cuff circumference of 22–42 cm (size M and L) and weighed 354 g (including batteries). It had a measurement range of 20–280 mmHg BP and 40–200 beats per minute pulse, a cuff pressure display range of 0–299 mmHg, and a pulse accuracy of 5%. The second device was an aneroid manometer for measuring BP. A single researcher performed the measurements. The aneroid manometer was calibrated accurately and had a cuff circumference of 22–32 cm and weighed 450 g; it had a measurement range of 0–300 mmHg BP and a pressure reduction rate of 2–3 mmHg/s. A digital scale with 100 g sensitivity was used to measure bodyweight, and a rigid measure was used to measure height.

Ethical Considerations

Institutional permission to conduct the study was first obtained from the Health Services Vocational College of the university and from the municipality. Permission for the study was obtained from the Akdeniz University Faculty of Medicine clinical research ethics committee (05.07.2019/No. 300) of the university. Verbal and written approval was obtained from the participants who agreed to participate in the research after being informed that their participation was voluntary and that a decision not to participate would not affect their status. When a significant difference was seen in BP values, the individual was directed to go to a health institution for a cardiovascular assessment. This study was conducted in accordance with the principles of the Helsinki Declaration.

Data analyses

The Statistical Package for Social Sciences version 23.0 (IBM SPSS Corp., Armonk, NY, USA) was used for statistical analysis. Descriptive statistics were used for categorical variables, and these were expressed as numbers, percentages, means, and mean differences. Before comparisons were made, the data were examined for normal distribution. For normal distribution, skewness and kurtosis values were used and were established as having normal distribution in the range +1.5 to −1.5.[34] We used the t test to test group differences in mean systolic and diastolic BP. Inter-arm BP difference was evaluated using the paired t-test. Comparisons of BP data were performed using paired *t*-tests and independent *t*-tests. Multilinear and logistic regression analyses and odds ratio were also used. Statistical significance was defined as a 2-sided p value of <0.05.

Table 1. General characteristics of the study participants

Participant characteristics	Young n=150	Elderly n=150	Total
Gender			
Female	105 (70%)	79 (52.7%)	184 (61.3%)
Male	45 (30%)	71 (47.3%)	116 (38.7%)
Age (years) $\bar{X}$±SD	19.85±1.32	67.45±6.93	43.59±24.43
Weight $\bar{X}$±SD (kg)	60.24±9.48	71.98±9.67	66.11±11.2
BMI (kg/m^2)	21.42±2.90	26.91±3.85	24.16±4.37
Smoking			
Smoker	40 (26.7%)	3 (2%)	43 (14.3%)
Non-smoker	110 (73.3%)	147(98%)	257 (85.7%)
Exercise			
Exercises	20 (13.3%)	77 (51.3%)	97 (32.3%)
No exercise	130 (86.7%)	73 (48.7%)	203 (67.7%)

BMI: body mass index; SD: standard deviation

Results

Characteristics of the Study Participants

A total of 300 participants aged 43.59±24.43 years (mean±SD; range 18–95 years) were recruited. The general characteristics of the study participants are presented in Table 1.

Results of Arm Blood Pressure Measurements

We performed arm BP measurements with an aneroid manometer and by automatic oscillometry in young and older participants. The comparison analysis was divided into three categories: aneroid manometer versus automatic oscillometry, young versus older participants, and right versus left arm BP measurement.

Factors Associated with Arm Blood Pressure

Table 2 presents the factors associated with arm BP of the study participants.

Comparisons of Arm Blood Pressure with Different Types of Device and Different Participants

Table 3 presents comparisons of arm BP measurement with different types of devices and different participants.

Large Inter-Arm Difference in Blood Pressure

Table 4 presents the factors associated with large IAD in BP.

Table 2. Factors associated with arm blood pressure

	Left arm SBP			Left arm DBP			Right arm SBP			Right arm DBP		
	Beta	*t*	p	Beta	*t*	p	Beta	*t*	p	Beta	*t*	p
Sex	0.076	1.30	0.194	0.093	1.33	0.184	0.055	0.99	0.318	0.026	0.38	0.701
Group (old/young)	0.434	6.12	**0.000***	0.196	2.30	**0.022**	0.505	7.51	**0.000**	0213	2.55	**0011**
BMI	0.036	0.307	0.759	0.125	0.90	0.368	-0.029	-0.26	0.794	0.151	1.10	0.269
Weight	0.180	1.66	0.097	-0.014	-0.11	0.912	0.238	2.33	**0.020**	0.023	0.181	0.856
Exercise	-0.004	-0.06	0.945	0.082	1.31	0.190	0.050	1.00	0.316	0.081	1.31	0.190
Smoking	-0.010	-0.19	0.844	0.003	0.05	0.190	0.041	0.85	0.395	0.017	0.27	0.782

SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index

Table 3. Comparisons of arm blood pressure measurements with different types of device and different participants

Automatic oscillometry LA	SBP X̄±SD	DBP X̄±SD	Automatic oscillometry RA	SBP X̄±SD	DBP X̄±SD
Young	113.76±13.93	69.95±9.37	Young	110.85±10.97	68.81±8.58
Old	133.82±15.60	74.39±7.70	Old	131.77±15.48	73.91±7.80
p/F	0.000/ 1.493	0.000/5.921	p/F	0.000/6.854	0.000/2.612
Mean diff (Lower/Upper)	−20.06 (−23.42/−16.69)	−4.43 (−6.38/−2.48)	Mean diff (Lower/Upper)	−20.91 (−23.96/17.86)	−5.10 (−6.96/−3.23)
Aneroid Manometer LA	**SBP X̄±SD**	**DBP X̄±SD**	**Aneroid manometer RA**	**SBP X̄±SD**	**DBP X̄±SD**
Young	112.08±9.54	70.27±8.43	Young	110.81±9.79	69.75±8.24
Old	126.79±14.48	70.07±8.67	Old	125.75±12.91	70.12±9.38
p/F	0.000/25.29	0.834/0.140	p/F	0.000/11.044	0.720/2.222
Mean diff (Lower/Upper)	−14.71 (−17.50/−11.92)	0.207 (−1.73/2.151)	Mean diff (Lower/Upper)	−14.94 −17.54−12.33)	−0.36 (−2.37/1.64)
LA	**SBP X̄±SD**	**DBP X̄±SD**	**RA**	**SBP X̄±SD**	**DBP X̄±SD**
Aneroid manometer	119.44±14.29	70.17±8.54	Aneroid manometer	118.28±13.67	69.94±8.82
Automatic oscillometry	123.79±17.86	72.17±8.84	Automatic oscillometry	121.31±17.00	71.36±8.57
p/t	0.000/4.889	0.001/3.30	p/t	0.000/4.06	0.013/2.49
Mean (Lower/Upper)	4.35 (2.60/6.10)	2.00 (0.81/3.19)	Mean (Lower/Upper)	3.02 (1.56/4.49)	1.42 (0.29/2.55)
Automatic oscillometry	**SBP X̄±SD**	**DBP X̄±SD**	**Aneroid manometer**	**SBP X̄±SD**	**DBP X̄±SD**
LA	123.79±17.86	72.17±8.84	LA	119.44±14.29	70.17±8.54
RA	121.31±17.00	71.36±8.57	RA	118.28±13.67	69.94±8.82
p/t	0.000/3.76	0.048/1.98	p/t	0.013/2.49	0.594/0.534
Mean (Lower/Upper)	2.48 (1.18/3.77)	0.807 (0.009/1.605)	Mean (Lower/Upper)	1.15 (0.24/2.06)	0.233 (−0.62/1.09)

SBP: systolic blood pressure; DBP: diastolic blood pressure; RA: Right arm; LA: Left arm; Lower- upper: 95% CI; diff: difference; SD: standard deviation

Table 4. Factors associated with large IAD in BP

Variables	p	SBP (right-left) ≥10 Odds ratio* (95% CI)	p	DBP (right-left) ≥10 Odds ratio* (95% CI)
Group (young/old)	0.535	1.357 (0.518-3.557)	0.695	0.770 (0.209-2.835)
Sex	0.224	0.628 (0.297-1.328)	0.094	0.407 (0.142-1.167)
Weight	0.001*	1.110(1.041-1.183)	0.030*	1.096 (1.009-1.191)
BMI	0.017*	0.802 (0.669-0.962)	0.133	0.835 (0.660-1.056)
LA systolic	0.000*	1.065(1.033-1.098)	0.014*	0.993(0.954-1.034)
LA diastolic	0.014*	0.942(0.898-0.988)	0.580	0.984 (0.928-1.043)
RA systolic	0.009*	0.957(0.926-0.989)	0.746	1.045 (1.009-1.082)
RA diastolic			0.197	0.984 (0.928-1.043)

BMI: body mass index; RA: Right arm; LA: Left arm; IAD: inter-arm difference; BP: blood pressure

Results of Leg Blood Pressure Measurements

We performed leg BP measurements with the aneroid manometer and by automatic oscillometry in young and older participants. The comparison analysis was divided into three categories: automatic oscillometry versus aneroid manometer, young versus older participants, and right versus left leg BP.

Factors Associated with Leg Blood Pressure

Table 5 presents the factors associated with leg BP and the ILD of the study participants.

Comparisons of Ankle Blood Pressure with Different Types of Devices and Different Participants

Table 6 presents comparisons of ankle BP measurement with different types of devices and different participants.

Table 5. Factors associated with leg BP and ILD

	ILD			Right ankle SBP			Right ankle DBP		
Variables	**Beta**	***t***	**p**	**Beta**	***t***	**p**	**Beta**	***t***	**p**
Sex	–0.159	–2.24	**0.026***	0.144	2.08	**0.038***	–0.021	–0.297	0.766
Group (old/young)	0.156	1.81	0.071	0.086	1.05	0.292	–0.260	–3.09	**0.002***
BMI	–0.321	–2.26	**0.024**	–0.127	–0.925	0.355	–0.043	–0.312	0.755
Weight	0.291	2.21	0.27	0.289	2.26	0.024*	0.394	3.08	**0.002**
Exercise	–0.009	–0.14	0.886	0.084	1.34	0.180	–0.006	–0.099	0.921
Smoking	0.116	1.87	0.061	–0.022	–0.362	0.718	0.000	0.002	0.999

SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; ILD: inter-leg difference; BP: blood pressure

Table 6. Comparisons leg BP measurement with different types of devices and different participants

Automatic oscillometry Left ankle	**SBP X̄±SD**	**DBP X̄±SD**	**Automatic oscillometry Right ankle**	**SBP X̄±SD**	**DBP X̄±SD**
Young	147.91±15.01	83.87±10.83	Young	147.96±18.65	83.63±9.33
Old	156.29±24.10	82.25±13.64	Old	154.15±23.60	81.67±14.29
p/F	0.000/17.42	0.256/3.17	p/F	0.012/6.95	0.159/19.59
Mean diff (Lower/Upper)	–8.38 (–12.94/–3.81)	1.62 (–1.17/4.41)	Mean diff (Lower/Upper)	–6.18 (–11.02/–1.35)	1.96 (–0.776/4.71)
Aneroid Manometer Left ankle	**SBP X̄±SD**	**DBP X̄±SD**	**Aneroid manometer Right ankle**	**SBP X̄±SD**	**DBP X̄±SD**
Young	152.33±16.55	84.63±9.08	Young	151.73±14.57	84.40±9.02
Old	147.43±19.24	78.91±12.69	Old	149.68±20.08	78.77±11.75
p/F	0.019/0.889	0.000/15.81	p/F	0.312/3.60	0.000/8.25
Mean diff (Lower/Upper)	4.90 (0.82/8.98)	5.72 (3.21/8.23)	Mean diff (Lower/Upper)	2.053 (–1.93/6.04)	5.63 (3.25/8.01)
Left Ankle	**Systolic X̄±SD**	**DBP X̄±SD**	**Right Ankle**	**SBP X̄±SD**	**DBP X̄±SD**
Aneroid manometer	149.88±18.08	81.77±11.38	Aneroid manometer	150.71±17.54	81.58±10.83
Automatic oscillometry	152.10±20.48	83.06.±12.32	Automatic oscillometry	151.05±21.46	82.65±12.09
p/t	0.041/–2.05	0.085/1.72	p/t	0.681/0.412	0.055/1.92
Mean (Lower/Upper)	–2.21 (–4.34/–0.091)	1.28 (–0.181/2.75)	Mean (Lower/Upper)	0.347 (–1.31/2.00)	1.06 (–0.023/2.156)
Automatic Oscillometry	**SBP X̄±SD**	**DBP X̄±SD**	**Aneroid manometer**	**SBP X̄±SD**	**DBP X̄±SD**
Left Ankle	152.10±20.48	83.06±12.32	Left Ankle	149.88±18.08	70.17±8.54
Right Ankle	151.05±21.46	82.65±12.09	Right Ankle	150.71±17.54	69.94±8.82
p/t	0.210 (1.25)	0.526 (0.63)	p/t	0.081/–1.75	0.594/–0.53
Mean (Lower/Upper)	1.04 (–0.59/2.67)	0.407 (–0.85/1.66)	Mean (Lower/Upper)	–0.827 (–1.75/0.103)	–0.23 (–1.09/0.627)

SBP: systolic blood pressure; DBP: diastolic blood pressure; Lower- upper: 95% CI; SD: standard deviation; diff: difference; BP: blood pressure

Comparisons of Arm and Leg Blood Pressure Measurements

Comparisons of arm, wrist, and leg BP measurements with different types of devices and different participants are shown in Table 7.

Comparisons of Ankle brachial index Blood Pressure Measurements

Comparisons of ankle brachial index BP measurements with different types of devices and different participants are shown in Table 8.

Discussion

To the best of our knowledge, this is the first study to compare mean BP differences in young and older individuals using 2 measurement devices and to examine factors related to BP in the general Turkish population. The majority of studies in the literature based on BP differences are con-

Table 7. Comparisons of arm and leg blood pressure measurement with different types of devices and different participants

Automatic oscillometry	SBP X̄±SD	DBP X̄±SD	Automatic oscillometry	SBP X̄±SD	DBP X̄±SD
Left Brachial	123.79±17.86	72.17±8.84	Right Brachial	121.31±17.00	71.36±8.57
Left Ankle	152.10±20.48	83.06±12.32	Right Ankle	151.05±21.46	82.65±12.09
p/t	0.000/–21.422	0.000/–12.02	p/t	0.000/–22.36	0.000/–13.31
Mean (Lower/Upper)	–28.30 (–30.90/–25.70)	–10.88 (–12.66/–9.10)	Mean (Lower/Upper)	–29.74 (–32.36/–27.12)	–11.28 (–12.95/–9.61)
Aneroid manometer	**SBP X̄±SD**	**DBP X̄±SD**	**Aneroid manometer**	**SBP X̄±SD**	**DBP X̄±SD**
Left Brachial	119.44±14.29	70.17±8.54	Right Brachial	118.28±13.67	69.94±8.82
Left Ankle	149.88±18.08	81.77±11.38	Right Ankle	150.71±17.54	81.58±10.83
p/t	0.000/–24.29	0.000/–15.41	p/t	0.000/–26.45	0.000/–15.64
Mean (Lower/Upper)	–30.44 (–32.90±27.97)	–11.60 (–13.08/–10.11)	Mean (Lower/Upper)	–32.42 (–34.83/–30.011)	–11.64 (–13.11/–10.18)

SBP: systolic blood pressure; DBP: diastolic blood pressure; Lower-upper: 95% confidence interval

Table 8. Ankle brachial index

ABI	SBP X̄±SD	ABI	SBP X̄±SD
Young	1.31±0.20	Female	1.24±0.21
Old	1.17±0.19	Male	1.25±0.19
p/F	0.000/0.178	p/F	0.585/1.86
Mean diff (Lower/Upper)	0.14 (0.09/0.18)	Mean diff (Lower/Upper)	–0.013 (–0.06/0.035)

ABI: ankle brachial index; SBP: systolic blood pressure; Lower- upper: 95% confidence interval; diff: difference

ducted with middle-aged and older individuals, and those with various chronic illnesses have been included in these studies.[19,21,35] However, it was observed that there were relatively fewer studies comparing BP differences in young and older people.[15,36] We believe that this study will raise awareness in researchers and healthcare personnel regarding the differences in BP in people according to age and the part of the body where the measurement is made.

In this study, the SBP and DBP measurements of older individuals were higher than those in younger individuals. It was seen that mean SBP in older subjects was 130 mmHg; whereas in younger subjects, it was 110 mmHg. When comparing the 2 guideline definitions of hypertension, ESC/ESH defines hypertension as >140/90 mmHg BP, whereas the ACC/AHA guidelines define it as ≥130/80 mmHg BP.[1-3] Thus, BP measurement results in older individuals show marginal hypertension. Mean differences in SBP and DBP in the young and older individuals were –20 mmHg and –4/–5 mmHg, respectively. Similar to the results of our study, Kawabe and Saito[37] indicated that older (≥40 years) subjects showed higher hypertension than those under 40 years of age. Older patients are more likely to have hypertension[31] because with aging, large arteries undergo significant changes and increase in arterial stiffness.[38] In addition, older patients are more likely to have comorbidities such as renal impairment and atherosclerotic vascular disease.[3] Guidelines state that the prevalence of hypertension increases with age, with a prevalence of 60% in those over the age of 60 years and 75% in those over the age of 75 years.[3]

It was found in this study that mean left arm SBP and DBP were higher than those in the right arm. Multiple guidelines state that in BP measurement, there may be differences between the arms and that both should be measured at the first examination.[31] If there is a difference in BP, the arm with higher values should be used for BP measurements.[39] The results of many studies were examined; however, no clear conclusions were reached regarding which arm gives higher values than the other.[9-13] In contrast to our study, Cassidy and Jones[9] reported that the right arm BP tends to be higher than the left arm BP. Cassidy and Jones[9] also stated that if one arm is to be preferred for clinical BP measurement purposes, then it should be the right arm. Tak et al.[39] stated that right arm BP was significantly higher than the left. In a meta-analysis by Verberk et al.[15] it was reported that there was no BP difference between the right and left arms.

The mean IAD in our study was 7.90+8.58 mmHg for SBP and 4.96+5.03 for DBP. Large IAD was found in SBP in 22.7% of participants and in DBP in 10.3%. In a meta-analysis study by Verberk et al.[15] SBP and DBP showed a mean absolute IAD of 5.4 and 3.6 mmHg, respectively. Arnett et al.[40] found that 1.6% of subjects for DBP and 9.2% of subjects for SBP had an inter-arm DBP difference of 10 mmHg or more. Tak et al.[39] indicated that in 20.9% (SBP) and 7.2% (DBP) of the patients, the IAD of BP was more than 10 mmHg; however, differences of 1.4% to 39% are widely reported.[11,14,41] In a meta-analysis by Verberk et al.[15] 14% of the subjects had an IAD of 10 mmHg or more for systolic BP.

In our study, a correlation was found between right arm SBP and the variable of weight; as weight increased, SBP also increased. The odds ratio showed that a large IAD in SBP was associated with weight, body mass index, and systolic BP. However, it was seen that mean IAD did not vary according to age or sex. Similar to our study, Brown et al.[42] found strong associations of BMI with hypertension. Dua et al.[43] observed that there was a positive correlation between BMI, fat percentage, and BP. Rosenberger et al.[44] stated that the factors most likely to be associated with IAD in BP were non-married status and hypertension, followed by older age. Large IAD in BP was associated with obesity and higher systolic BP,[40] BMI, and mean SBP,[5] but were not associated with age.[39] In addition, it was found that the number of measurements made affected the IAD in SBP. In the meta-analysis by Verberk et al.[15], when BP was measured successively rather than at the same moment, and when only a single BP measurement was made rather than multiple measurements, it was shown that there was a greater relative risk of obtaining an IAD of ≥10 mmHg.[15] Therefore, in calculating mean IAD in this study, analysis was made using the second measurement results, that is, the BP measurement results taken with the oscillometric device.

The SBP and DBP measurements made by automatic oscillometry in this study were 3–4 mmHg and 1–2 mmHg higher than those made with the aneroid manometer. In a study by Graves and Grossardt[45] it was shown that BP results obtained by oscillometric methods were higher than auscultatory results performed by a nurse. In another study, aneroid and digital sphygmomanometers were compared, and the digital BP result was found to be higher than that made using the aneroid.[46] It was seen that studies using both measurement instruments together were few in number and that automated oscillometric devices were preferred in the studies.[15] In a comparative study by Shahbabu et al.[46] it was stated that an aneroid device had better accuracy than a digital device when compared with a mercury sphygmomanometer.

In our study, results show ankle SBP to be higher than arm SBP. Ankle SBP and DBP measurements were higher in older subjects than those in the younger subjects. In a systematic review and meta-analysis by Sheppard et al.[36], it was stated that ankle SBP was 17.0 mmHg higher than arm SBP. In our study also, large IAD in BP was seen in 30% of the participants, and BP was higher in men and older individuals than in women and younger individuals, respectively. In healthy individuals, ankle SBP is slightly higher than arm SBP.[47] Low ankle BP could be indicative of atheroma or atherosclerosis, and high ankle pressures might reflect arterial stiffness or arteriosclerosis of the vessel wall.[47] In our study, ABI was seen to be lower in the older individuals than in younger subjects. However, ABI did not vary according to sex. A low ABI (i.e., <0.9) indicates lower extremity artery disease[3] and also an increase in CVD risk.[48] Our study results show that low ABI values of ≤0.9 were found in 2.3% of the participants.[47]

Study Limitations

Our study had several limitations, including relatively small sample size. Second, the BP measurements were made on a single day in an office setting at only 2 centers. Third, we could not exclude individuals with subclavian stenosis because data for angiography or imaging studies were unavailable. Finally, we measured BP only twice with 2 devices.

Conclusion

The present data show the results of a comparison of BP measurements made with different measuring instruments and on different parts of the body in young and older individuals. It was shown that BP measurements were higher in older individuals, left arm BP was higher than right arm BP, ankle SBP was higher than arm SBP, and that ABI was low in older individual. The results of this study also showed that BP measurements made by oscillometry were higher than those made with an aneroid manometer and that SBP correlated with body weight and large IAD with BMI. We believe that this study will create awareness in researchers and healthcare personnel regarding the comparison of BP differences according to the measurement devices, different anatomical sites, and age. We also believe that implementing a comparison of upper and lower extremities at the stage of evaluating routine vital findings in the nursing course curriculum will enable students to recognize the differences.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Akdeniz University Faculty of Medicine (Date: 05.07.2019, No. 300).

Informed Consent: Verbal and Written informed consent was obtained from participants who participated in this study.

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