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Comparative Study of Different Blood Pressure Measuring Instruments in Human

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Abstract

Hypertension is one of the major public health problems affecting the whole world and has been identified as the most common communicable disease in Nigeria. Accurate measurement of blood pressure is of utmost importance for early diagnosis and management. Concerns related to the potential ill effects of mercury on health and environment have led to the call for the removal of mercury sphygmomanometers from clinical investigations, and the widespread use of non-mercury sphygmomanometers. However, the accuracy of these non-mercury measures needs to be ascertained. This study was conducted to compare the accuracy of aneroid and digital sphygmomanometers with reference to a mercury sphygmomanometer. A total of 72 subjects (34 males and 38 females) were used for this study. All the subjects were between the ages of 20-25 years and weighed between 52kg-80kg. Three blood pressure (BP) readings were taken from each arm using each sphygmomanometer type, and the means of these readings were recorded. Paired t-test and independent t-test were used to analyze the data and values of $p < 0.05$ were considered statistically significant. The results showed that the males had significantly higher systolic and diastolic BPs than the females. The males also had higher inter-arm differences than the females, which was significant only with the mercury sphygmomanometer. Absolute systolic inter-arm difference ≥10mmHg and diastolic inter arm difference ≥ 5mmHg were considered the risk factors of future cardiovascular morbidities. Therefore, the inter-arm difference should be considered during blood pressure measurement for the correct management of hypertension. The results also showed significant differences between the mercury and Aneroid measures, and also between the mercury and digital measures. However, these variations were within the threshold set by the Association for the Advancement of Medical Instrumentation guidelines, with the exception of the diastolic pressures measured by the digital instrument, which were lower than the mercury measures. This means that both non-mercury instruments can serve as independent instruments for accurate blood pressure measurement in clinical and research settings.

Keywords

Hypertension, Mercury Sphygmomanometer, Inter-arm Difference, Systolic Blood Pressure, Diastolic Blood Pressure, Digital Sphygmomanometer, Aneroid Sphygmomanometer

1. Introduction

Blood pressure (BP) is one of the vital signs, along with respiratory rate, heart rate, oxygen saturation, and body temperature [1-2]. It is defined as the pressure of circulating blood on the walls of blood vessels and is usually expressed in terms of the systolic pressure over diastolic pressure. It is measured in millimeters of mercury (mmHg) [3-4]. Normal resting blood pressure in an adult is approximately 120 millimetres of mercury (Systolic), and 80 millimetres of mercury (diastolic) [5-6]. Hypertension, defined as a systolic BP $\geq$ 140mmHg and/or a diastolic BP $\geq$ 90mmHg, is one of the most common chronic diseases [7-8]. Raised blood pressure throughout its range is the most significant cause of death and disability in the world [9-10]. It is estimated that hypertension affects about one billion people all over the world, and it is the main risk factor for many other cardiovascular diseases [11-12]. Report of data from studies done in hospitals reveals that hypertension and cardiovascular disease complications are the commonest non-communicable diseases in Nigeria [13-14]. Blood pressure measurement is, therefore, very vital for the prevention and treatment of blood pressure related diseases, and for monitoring cardiovascular homeostasis [15].

Mercury sphygmomanometers first developed over 100 years ago and largely unchanged are used in both hospital and ambulatory settings. They have been considered the ‘gold standard’ blood pressure measuring devices from which treatment guidelines are developed [5]. The indirect blood pressure measurement with mercury sphygmomanometers has been shown to be valuable in several clinical circumstances. Their extensive use has allowed the collection of the necessary evidence to identify arterial hypertension as a major risk factor for cardiovascular diseases [16].

However, mercury which is the major component of the mercury sphygmomanometer has been found to be a potent human neurotoxin [17]. As healthcare facilities contribute to mercury pollution via breaks and spills and the burning of medical waste, the effort has been developed over the last several years to eliminate the most common health care sources of mercury – the thermometer and sphygmomanometer [5]. This has led to the replacement of mercury sphygmomanometers by mercury-free blood pressure devices in many health-care settings. The two commonly used alternatives to mercury sphygmomanometers are the aneroid and oscillometric devices [15]. However, uncertainty surrounding the accuracy of alternative blood pressure devices has led to reluctance on the part of health-care providers to replace mercury sphygmomanometers with alternatives, which are less likely to contribute to environmental mercury pollution [18]. This is because BP which is one of the vital signs can be measured inaccurately due to inefficiency of the blood pressure monitors, resulting in inappropriate treatment with anti-hypertension medications, thereby exposing patients to adverse drug effects, psychological effects of misdiagnosis and unnecessary cost [19-20].

In a large study which examined the comparability of measurement accuracy of all three categories of sphygmomanometers, it was found that digital instruments were almost as accurate as Mercury instruments, while higher failure rate existed with the Aneroid ones [18-21]. In another research by Shahbabu *et al* in 2016, they found out that the mean difference and standard deviation of the Aneroid device was within the accepted threshold (±5mmHg or less; with a standard deviation of 8mmHg or less) [15] recommended by the Association for the Advancement of Medical Instrumentation guidelines [22], but the digital device failed to achieve that. This suggested the superiority of aneroid devices with respect to digital instruments in accurately measuring BP in a primary care setting.

Mercury Sphygmomanometers are being phased out because of the toxicity of mercury, and they have been replaced with the Aneroid and Digital Sphygmomanometers but the accuracy of these non-mercury devices is still in question. Inaccurate measurement of BP has been identified as a risk for cardiovascular morbidity. Therefore, a wrong measurement of BP above the true value may result in inappropriate treatment with anti-hypertension medications [19]. Patients would, therefore, be exposed to adverse drug effects, psychological effects of misdiagnosis, and unnecessary cost [19]. This study was therefore designed to determine the accuracy of blood pressure readings of the Aneroid and Digital Sphygmomanometers with reference to the Mercury Sphygmomanometer in normotensive subjects in a bid to educate people on if the non-mercury sphygmomanometers are accurate enough to replace the mercury sphygmomanometer. Inter-arm blood pressure difference [23], an early detector of risk for hypertension was also evaluated.

2. Materials and Methods

2.1. Materials

These include: Height and weight scale (Stadiometer) (402KL-Washington, USA), Mercury Sphygmomanometer (Accoson-Dekamet MK.3, England), Aneroid Sphygmomanometer (Kris Aloy-115; China), Digital Sphygmomanometer (Omron M2 Basic; Hem-7120-E; Vietnam), Stethoscope (Kris Aloy-115; China) and Recording files.

2.2. Study Population

The subjects used were male and female students of College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria. They were 72 in number, consisting of 34 males and 38 females, and within the age range of 20-25 years.

2.3. Methods

2.3.1. Ethical Approval

The study was approved by the Ethical Approval

Committee, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

2.3.2. Informed Consent

The procedure of the experiment was explained to the subjects, and their informed consent obtained.

2.3.3. Inclusion and Exclusion Criteria

The following were excluded from the study; Obese people, Menstruating people, Pregnant ladies and Smokers.

2.3.4. Anthropometric Measurements

The subjects were asked to stand on a height and weight scale on bare feet. The weight was measured in Kilograms, and height was measured in meters. Body Mass Indices of the subjects were calculated using the formula; BMI=Weight (Kg)/Height (m^2).

2.3.5. Blood Pressure (BP) Measurement

The subjects were asked to sit down with both feet on the floor after resting quietly for about 5 minutes. The arm was supported on a table at the heart level. All cuffs used were of appropriate sizes based on the circumference of the upper arm. The BP was first measured in the left arm using a mercury sphygmomanometer. The cuff was wrapped snugly around the arm, just a couple of centimeters above the elbow crease. The diaphragm of the stethoscope was placed at the antecubital fossa, over the brachial artery. The BP cuff was then inflated. Thereafter, the cuff was deflated by turning the air release valve counterclockwise. The first rhythmic sound heard as blood began to flow through the artery was recorded as the subject's systolic pressure. The sound faded as the BP cuff pressure dropped, and the pressure at which the sound stopped was recorded as the diastolic pressure. This was repeated twice, and the average of the three readings was taken. The same procedure was repeated using the aneroid sphygmomanometer. BP was also measured thrice using the digital sphygmomanometer, and the average of the three readings was taken. The same procedures were repeated in the right arm.

2.4. Data Analysis

The data were analyzed using Statistical Package for the Social Sciences (SPSS) version 20.0 and Microsoft Office Excel 2016. The demographic characteristics and gender blood pressures were analyzed using independent t-test. Inter-arm blood pressure differences and comparisons of BP readings of the three instruments were analyzed using a paired t-test. The results were presented as mean ± standard deviations and were considered statistically significant at $p<0.05$.

3. Results

Demographic Characteristics of Male and Female Subjects

Table 1 shows the comparison of the demographic characteristics of the male and female subjects. 38 females with a mean age of 22.39±1.50 and 34 males with a mean age of 22.94±1.59 participated in the study. The results revealed that the mean ± SD of body mass index (BMI) of the male subjects (21.77±1.96), and that of the females (21.83±1.97) showed no significant difference ($p>0.05$). The mean weight and mean height of the males were significantly higher than that of the females ($p<0.05$).

Table 1. *Demographic Characteristics of Male and Female Subjects.*

PARAMETERS	MALE (N=34)	FEMALE (N=38)	p-VALUE
	MEAN±SD	MEAN±SD	
AGE (20-25)	22.94±1.59	22.39±1.50	0.140
WEIGHT (Kg)	66.78±6.74	59.34±5.65	0.000*
HEIGHT (m)	1.75±0.07	1.65±0.04	0.000*
BMI (Kg/m^2)	21.77±1.96	21.83±1.97	0.882

Significant at $p<0.05$

Comparison of Male and Female Blood Pressures, Measured with the Three Sphygmomanometers, in Both Arms

Using the Mercury Sphygmomanometer, the left mean systolic pressure of the males (114.51±9.83) was significantly higher ($p<0.05$) than that of the females (107.87±7.78); the left mean diastolic pressure of the males (76.44±7.98) was also significantly higher ($p<0.05$) than that of the females (70.08±7.33). In the right arm, the mean systolic pressure of the males (116.45±12.52) was insignificantly higher ($p>0.05$) than that of the females (109.39±6.92); the mean diastolic pressure of the males (76.18±10.10) was also significantly higher ($p<0.05$) than that of the females (71.33±7.67) (Table 2). Using the Aneroid Sphygmomanometer, the left mean Systolic pressure of the males (111.98±9.70) was significantly higher ($p<0.05$) than that of the females (106.16±8.64) and the left mean Diastolic pressure of the males (72.45±7.97) was significantly higher ($p<0.05$) than that of females (68.59±8.50). In the right arm, the mean systolic pressure of the males (113.02±11.56) was significantly higher ($p<0.05$) than that of the females (107.85±9.18), but the mean diastolic pressures of males and females (69.91±10.36 and 67.08±9.27) had no significant difference ($p>0.05$) (Table 2). Using the Digital Sphygmomanometer, the left mean Systolic pressure of the males (110.13±9.61) was significantly higher ($p<0.05$) than that of the females (100.40±9.09), but there was no significant difference ($p>0.05$) between the diastolic blood pressures of the males and females (58.91±7.04 and 58.30±8.08 respectively). Also, in the right arm, the mean Systolic pressure of the males (112.27±11.29) was significantly higher ($p<0.05$) than that of the females (101.11±7.12), but the diastolic pressure of the females

(57.52±8.66) was higher than that of the males (56.91±8.39), though not statistically significant (Table 2).

Table 2. *Comparison of Male and Female Blood Pressures, Measured with the Three Sphygmomanometers, in Both Arms.*

ARM	INSTRUMENT	BP PHASE	SEX MALE (N=34) AND FEMALE (N=38)	BP (mmHg) MEAN±SD	p-VALUE	t-VALUE
LEFT	MERCURY	SYSTOLE	MALE FEMALE	114.51±9.83 107.87±7.78	0.002*	3.152
		DIASTOLE	MALE FEMALE	76.44±7.98 70.08±7.33	0.001*	3.507
	ANEROID	SYSTOLE	MALE FEMALE	111.98±9.70 106.16±8.64	0.009*	2.677
		DIASTOLE	MALE FEMALE	72.45±7.97 68.59±8.50	0.051	1.990
	DIGITAL	SYSTOLE	MALE FEMALE	110.13±9.61 100.40±9.09	0.000*	4.396
		DIASTOLE	MALE FEMALE	58.91±7.04 58.30±8.08	0.732	0.344
RIGHT	MERCURY	SYSTOLE	MALE FEMALE	116.45±12.52 109.39±6.92	0.005*	2.915
		DIASTOLE	MALE FEMALE	76.18±10.10 71.33±7.67	0.027*	2.271
	ANEROID	SYSTOLE	MALE FEMALE	113.02±11.56 107.85±9.18	0.041*	2.084
		DIASTOLE	MALE FEMALE	69.91±10.36 67.08±9.27	0.228	1.217
	DIGITAL	SYSTOLE	MALE FEMALE	112.27±11.29 101.11±7.12	0.000*	4.950
		DIASTOLE	MALE FEMALE	56.91±8.39 57.52±8.66	0.764	-0.301

Significant at $p<0.05$

Inter-Arm Blood Pressure Differences in The Subjects

Table 3 compares the Blood Pressures of the left arm against those of the right arm. Using the Mercury Sphygmomanometer, there was no statistically significant inter-arm blood pressure difference in both Systolic and Diastolic BPs in the males ($p>0.05$). In the females, the right arm had a significantly higher ($p<0.05$) systolic BP (109.39±6.92) than the left arm (107.87±7.78), but there was no significant difference in the diastolic pressures of the right and left arms ($p>0.05$). Using the Aneroid Sphygmomanometer, there was no significant inter-arm difference between the systolic BP in the males ($p>0.05$), but the Left arm had a significantly higher ($p<0.05$) diastolic BP (72.45±7.97) than the right arm (69.91±10.36). In the females, there was no significant inter-arm difference in both systolic and diastolic phases ($p>0.05$). Using the Digital Sphygmomanometer, there was no significant inter-arm difference between the systolic BP in the males ($p>0.05$), but the Left arm had a significantly higher ($p<0.05$) diastolic BP (58.91±7.04) than the right arm (56.91±8.39). In the females, there was no significant inter-arm difference ($p>0.05$) in both systolic and diastolic phases.

Table 3. *Inter-Arm Blood Pressure Differences in The Subjects.*

INSTRUMENT	BP PHASE	ARM	MALE (N=34)			FEMALE (N=38)		
			BP (mmHg) MEAN±SD	p-VALUE	t-VALUE	BP (mmHg) MEAN±SD	p-VALUE	t-VALUE
MERCURY	SYSTOLE	LEFT RIGHT	114.51±9.83 116.45±12.42	0.157	-1.448	107.87±7.78 109.39±6.92	0.045*	-2.077
	DIASTOLE	LEFT RIGHT	76.44±7.98 76.18±10.10	0.800	0.255	70.08±7.34 71.33±7.67	0.134	-1.533
ANEROID	SYSTOLE	LEFT RIGHT	111.98±9.7 113.02±11.56	0.337	-0.975	106.16±8.64 107.85±9.18	0.081	-1.795
	DIASTOLE	LEFT RIGHT	72.45±7.97 69.91±10.36	0.012*	2.665	68.59±8.50 67.08±9.27	0.148	1.477
DIGITAL	SYSTOLE	LEFT RIGHT	110.13±9.61 112.27±11.29	0.091	-1.741	100.40±9.09 101.11±7.12	0.452	-0.760
	DIASTOLE	LEFT RIGHT	58.91±7.04 56.91±8.39	0.038*	2.165	58.30±8.08 57.52±8.66	0.322	1.004

Significant at $p<0.05$

Comparison of Absolute Inter-Arm Differences (AIADs) of Systolic and Diastolic Blood Pressures Between Males and Females, Using the Three Instruments

Absolute inter-arm blood pressure difference is represented as the pressure of right arm minus pressure of the left arm (Table 4). Using the Mercury Sphygmomanometer, the systolic AIAD was significantly higher (p<0.05) in the males (6.22±5.02) than in the females (3.66±2.98), but there was no significant difference (p>0.05) between the diastolic AIAD of the males and females (4.60±3.87 and 4.20±2.99 respectively) (Table 4). Using the Aneroid and Digital Sphygmomanometers, there was no significant difference (p>0.05) between the AIAD of the males and females in both systolic and diastolic phases (Table 4).

Table 4. *Comparison of Absolute Inter-arm differences (AIAD) of Systolic and Diastolic Blood Pressures Between Males and Females, Using the Three Instruments.*

INSTRUMENT	BP PHASE	SEX	AIAD (RIGHT-LEFT) MEAN±SD	p-VALUE	t-VALUE
MERCURY	SYSTOLE	MALE	6.22±5.02	0.012*	2.591
		FEMALE	3.66±2.98		
	DIASTOLE	MALE	4.60±3.87	0.632	0.482
		FEMALE	4.20±2.99		
ANEROID	SYSTOLE	MALE	4.89±3.83	0.908	-0.116
		FEMALE	4.99±3.34		
	DIASTOLE	MALE	4.17±4.43	0.723	-0.356
		FEMALE	4.54±4.56		
DIGITAL	SYSTOLE	MALE	5.49±5.01	0.361	0.921
		FEMALE	4.54±3.59		
	DIASTOLE	MALE	4.53±3.50	0.312	1.091
		FEMALE	3.73±3.10		

Significant at p<0.05

Prevalence of Systolic and Diastolic Inter-Arm Differences in Male and Female Subjects

Male Subjects

Using the Mercury Sphygmomanometer, the prevalence of SIAD≥10mmHg was 23.53%, while the prevalence of DIAD≥5mmHg was 41.18% (Table 5). Using the Aneroid Sphygmomanometer, the prevalence of SIAD≥10mmHg was 11.76%, while the prevalence of DIAD≥5mmHg was 32.35% (Table 5). Using the digital sphygmomanometer, the prevalence of SIAD≥10mmHg was 17.65%, while that of DIAD≥5mmHg was 35.29% (Table 5).

Female Subjects

Using the Mercury sphygmomanometer, the prevalence of SIAD≥10mmHg was 5.26%, while the prevalence of DIAD≥5mmHg was 41.18% (Table 5). Using the Aneroid sphygmomanometer, the prevalence of SIAD≥10mmHg was 10.53%, while DIAD≥5mmHg was 31.58% (Table 5). Using the Digital Sphygmomanometer, the prevalence of SIAD≥10mmHg was 7.89%, while DIAD≥5mmHg was 21.05mmHg (Table 5).

Table 5. *Prevalence of Systolic and Diastolic Inter-Arm Differences in Male and Female Subjects.*

	INSTRUMENT	SYSTOLE		DIASTOLE	
		SIAD<10 mmHg (%)	SIAD≥10mmHg (%)	DIAD<5mmHg (%)	DIAD≥5mmHg (%)
MALE N=34	MERCURY	76.47	23.53	58.82	41.18
	ANEROID	88.24	11.76	67.65	32.35
	DIGITAL	82.35	17.65	64.71	35.29
FEMALE N=38	MERCURY	94.74	5.26	60.53	39.47
	ANEROID	89.47	10.53	68.42	31.58
	DIGITAL	92.11	7.89	78.95	21.05

Prevalence of Systolic and Diastolic Inter-Arm Differences in The Entire Population

Using the Mercury sphygmomanometer, the prevalence of SIAD≥10mmHg is 12.5%, while that of DIAD ≥ 5mmHg was 38.89% (Table 6). Using the Aneroid sphygmomanometer, the prevalence of SIAD≥10mmHg is 8.33%, while that of DIAD≥5mmHg is 30.56% (Table 6). Using the Digital sphygmomanometer, the prevalence of SIAD≥10mmHg was 12.5%, while that of DIAD≥5mmHg was 25% (Table 6).

Table 6. *Prevalence of Systolic and Diastolic Inter-Arm Differences in The Entire Population.*

SEX	INSTRUMENT	SYSTOLE		DIASTOLE	
		SIAD<10mmHg (%)	SIAD≥10mmHg (%)	DIAD<5mmHg (%)	DIAD≥5mmHg (%)
MALE	MERCURY	87.5	12.5	61.61	38.89
	ANEROID	91.67	8.33	69.44	30.56
	DIGITAL	87.5	12.5	75	25

SIAD- SYSTOLIC INTER-ARM DIFFERENCE

DIAD- DIASTOLIC INTER-ARM DIFFERENCE

SIAD≥10mmHg and DIAD≥5mmHg are considered abnormal.

Comparison of Blood Pressure Readings of Mercury, Aneroid and Digital Sphygmomanometers in Male Subjects

In the left arm, the Mercury Sphygmomanometer had a significantly higher (p<0.05) mean systolic pressure (114.51±9.83) than that of the Aneroid (111.98±9.70) and Digital (111.13±9.61) sphygmomanometers. Also, the mean diastolic pressure measured using the Mercury Sphygmomanometer (76.44±7.98), was significantly higher (p<0.05) than that of the Aneroid (72.45±7.97) and Digital (58.91±7.04) Sphygmomanometers (Table 7). In the right arm, the Mercury Sphygmomanometer had a significantly higher (p<0.05) mean Systolic pressure (116.45±12.52) than that of the Aneroid (113.02±11.56) and Digital (112.27±11.29) Sphygmomanometers. Also, the mean diastolic pressure measured with the Mercury Sphygmomanometer (76.18±10.10), was significantly higher (p<0.05) than that measured with Aneroid (69.91±10.36) and Digital (56.91±8.39) sphygmomanometers (Table 7).

Table 7. *Comparison of Blood Pressure Readings of Mercury, Aneroid and Digital Sphygmomanometers in Male Subjects.*

ARM	BP PHASE	SPHYGMOMANOMETER	MALE N=34		
			MEAN±SD	p-VALUE	t-VALUE
LEFT	SYSTOLE	MERCURY	114.51±9.83	0.015*	2.558
		ANEROID	111.98±9.70		
		MERCURY	114.51±9.83	0.001*	3.672
		DIGITAL	110.13±9.61		
		ANEROID	111.98±9.70	0.149	1.476
		DIGITAL	110.13±9.61		
	DIASTOLE	MERCURY	76.44±7.98	0.002*	3.407
		ANEROID	72.45±7.97		
		MERCURY	76.44±7.98	0.000*	14.670
		DIGITAL	58.91±7.04		
		ANEROID	72.45±7.97	0.000*	11.514
		DIGITAL	58.91±7.04		
RIGHT	SYSTOLE	MERCURY	116.45±12.52	0.003*	3.255
		ANEROID	113.02±11.56		
		MERCURY	114.45±12.52	0.001*	3.807
		DIGITAL	112.27±11.29		
		ANEROID	113.02±11.56	0.499	0.684
		DIGITAL	112.27±11.29		
	DIASTOLE	MERCURY	76.18±10.10	0.000*	5.657
		ANEROID	69.91±10.36		
		MERCURY	76.18±10.10	0.000*	16.565
		DIGITAL	56.91±8.39		
		ANEROID	69.91±10.36	0.000*	10.535
		DIGITAL	56.91±8.39		

Significant at p<0.05

Comparison of Blood Pressure Readings of Mercury, Aneroid and Digital Sphygmomanometers in Female Subjects

For the left arm, the results showed no significant difference (p>0.05) between the mean Systolic pressure measured using the Mercury sphygmomanometer (107.87±7.78) and that measured using the Aneroid sphygmomanometer (106.16±8.64), but the mean Systolic pressure measured using the Mercury Sphygmomanometer was significantly higher (p<0.05) than that measured with the Digital Sphygmomanometer (100.40±9.09). Also, there was no significant difference (p>0.05) between the mean Diastolic pressure measured with Mercury Sphygmomanometer (70.08±7.34) and that measured with Aneroid Sphygmomanometer (68.59±8.50), but there was a significant difference (p<0.05) between the mean diastolic pressure measured with Mercury sphygmomanometer and that measured with Digital Sphygmomanometer (58.30±8.08) (Table 8).

For the right arm, there was no significant difference (p<0.05) between the mean Systolic pressure measured using the Mercury sphygmomanometer (109.39±6.92) and that measured using the Aneroid sphygmomanometer (107.85±9.18), but the mean Systolic pressure measured using the Mercury Sphygmomanometer was significantly higher (p<0.05) than that measured with the Digital Sphygmomanometer (101.11±7.12). The mean diastolic pressure measured with the Mercury Sphygmomanometer (71.33±7.67), was significantly higher (p<0.05) than that measured with Aneroid (67.08±9.27) and Digital (57.52±8.66) sphygmomanometers (Table 8).

Table 8. *Comparison of Blood Pressure Readings of Mercury, Aneroid and Digital Sphygmomanometers in Female Subjects.*

ARM	BP PHASE	SPHYGMOMANOMETER	FEMALE N=38		
			MEAN ±SD	p-VALUE	t-VALUE
LEFT	SYSTOLE	MERCURY ANEROID	107.87±7.78 106.16±8.64	0.077	1.816
		MERCURY DIGITAL	107.87±7.78 100.40±9.09	0.000*	7.184
		ANEROID DIGITAL	106.16±8.64 100.40±9.09	0.000*	4.810
	DIASTOLE	MERCURY ANEROID	70.08±7.34 68.59±8.50	0.183	1.356
		MERCURY DIGITAL	70.08±7.34 58.30±8.08	0.000*	9.127
		ANEROID DIGITAL	68.59±8.50 58.30±8.08	0.000*	6.915
RIGHT	SYSTOLE	MERCURY ANEROID	109.39±6.92 107.85±9.18	0.070	1.869
		MERCURY DIGITAL	109.39±6.92 101.11±7.12	0.000*	11.064
		ANEROID DIGITAL	107.85±9.18 101.11±7.12	0.000*	6.642
	DIASTOLE	MERCURY ANEROID	71.33±7.67 67.08±9.27	0.001*	3.621
		MERCURY DIGITAL	71.33±7.67 57.52±8.66	0.000*	9.063
		ANEROID DIGITAL	67.08±9.27 57.52±8.66	0.000*	5.772

Significant at $p<0.05$

4. Discussion

This study was conducted to determine the accuracy of non-mercury instruments. An aneroid sphygmomanometer and a digital sphygmomanometer were selected for the purpose and were judged with respect to a properly calibrated mercury sphygmomanometer (Gold Standard). The average body mass indices (BMI) of the male and female subjects were 21.77Kg/m^2 and 21.83Kg/m^2 respectively, indicating that both groups were within the normal BMI range. There was no significant difference between the mean BMI of the male and female subjects, showing that the two groups were comparable [24]. From the study, it can be said that males within 20-25yrs of age have higher blood pressure than age-matched females. This is in accordance with the report of [25]. The exact reason for this variation between genders is not known, but it has been suggested that estrogen receptor stimulates nitric oxide production in the endothelium, and the nitric oxide causes vasodilatation, thereby decreasing BP [26]. Also, it was suggested that estrogen receptor which is present in the kidney increases the release of Na and H_2O, thus, reducing BP in the long term.

This study examined the inter-arm blood pressure difference in young healthy males and females and it confirmed the presence of the inter-arm BP difference. The males had higher inter-arm differences than the females, but just a few people had abnormal inter-arm differences. The normal inter-arm difference is noted as <10mmHg systolic and <5mmHg diastolic, and studies have shown that people with large inter-arm differences are more prone to develop cardiovascular morbidities in future [27-28]. 12.5% of the entire cohort had a SIAD≥10mmHg, while 25% had a DIAD≥5mmHg. Seethalakshmi and Biju (2015) reported a higher prevalence of abnormal IAD of 46% and 35% respectively [29]. This variation could be because most of the subjects used by Seethalakshmi and Biju had a positive family history of hypertension indicating that the subjects are more prone to develop cardiovascular morbidities in future [29]. Hence, inter-arm difference helps in early detection of risk for hypertension and timely modification of lifestyle can be done [30-31].

In the males, the BP readings of the mercury sphygmomanometer were significantly higher than those of the aneroid and digital sphygmomanometers. However, the mean difference and standard deviation were within the accepted threshold (±5 mm Hg or less, with a standard deviation of 8 mm Hg or less) recommended by the Association for the Advancement of Medical Instrumentation guidelines [22], although the digital device recorded lower diastolic pressures. This is in agreement with the work done by Shahbabu *et al* (2016) [15] but is in contrast to the work done by Arash *et al* [32], which showed that the mercury sphygmomanometer recorded lower systolic and diastolic pressures than the Digital sphygmomanometer. This variation may be as a result of a difference in the population used. In the females, though the BP readings of the mercury sphygmomanometer were higher than those of the digital sphygmomanometer, the differences were not significant. The mean difference and standard deviation got in the comparison of the Mercury and digital systolic readings were within the set threshold, but the digital sphygmomanometer recorded low diastolic pressures.

5. Conclusion

These two non-mercury instruments can be used independently in both clinical and research settings for accurate BP measurement but should be used with care. Also, the frequency of significant inter-arm systolic and diastolic inter-arm BP difference suggests that BP should be taken in both arms at the initial consultation. At subsequent visits, the arm with the higher reading should be used for subsequent measurement.

Conflict of Interests

The authors have not declared any conflict of interests.

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