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Comparison Between Mercury Manometer, Digital Device and Aneroid Device in Blood Pressure Measurements

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Abstract

Objective: To compare the readings of automated and aneroid devices to the gold standard apparatus, mercury sphygmomanometer in taking blood pressure measurements. *Design:* Sample data were collected by measuring blood pressure of volunteers. Three systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were taken by 2 observers using the 3 devices as mentioned. *Setting:* This study was conducted at Melaka Manipal Medical College (MMMC), a tertiary institution placed in Melaka and Muar, Malaysia, from December 2017 to February 2018. *Subjects:* The total number of participants was 115, including 46 males and 69 females (age range 18-35). *Analysis:* Statistical analyses including the Epi Info 7, Pearson Correlation Coefficient calculator and Bland- Altman plot in Excel. *Results:* The systolic blood pressure measurements of mercury and digital sphygmomanometer has a significantly high correlation, and significantly moderate correlation for diastolic blood pressure measurements. Upon plotting Bland and Altman plot, 95% of the results are within the ±2 standard deviation for both systolic and diastolic BP, hence it is significant. While the systolic and diastolic blood pressure measurements of mercury and aneroid sphygmomanometer were highly correlated, hence with a significant association. Subsequent to plotting the Bland and Altman plot, 95% of the result falls between ±2 standard deviation for both systolic and diastolic BP, proved it is significant. *Conclusion:* Hence, these proves a good agreement. Therefore, for those who do not acquire the skill of measuring BP using the standard method could utilize the digital device which is more convenient and easier to record the BP readings. While for aneroid sphygmomanometer, it is more environmental friendly compared to mercury sphygmomanometer and it can help in preventing mercury poisoning in hospital setting. However, mercury sphygmomanometer is still the gold standard for BP measurements. This study's findings will be a useful resource for diagnosing hypertension research in Malaysia.

Keywords

Blood Pressure, Sphygmomanometer, Mercury, Medical Students

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1. Introduction

Five years have gone since the last form of the Clinical Practice Guideline on Management of Hypertension was issued on the year 2013, amid which time there have been significant changes in the courses by which blood pressure is estimated in clinical practice and research [1]. Blood pressure measurements keeps on being a standout amongst the most vital estimations in all of clinical pharmaceutical is as yet a standout amongst the most mistakenly performed [2].

The gold standard for clinical blood pressure estimation has been readings taken by a trained health care provider

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utilizing a mercury sphygmomanometer and the Korotkoff sound system. This approach requires broad preparing for wellbeing experts with a specific end goal to institutionalize methods for BP estimation [2]. There is expanding proof that this methodology may prompt the misclassification of vast quantities of people as hypertensive and furthermore to an inability to analyse blood pressure that might be typical in the center setting yet raised at different circumstances in a few people. There are 3 primary purposes behind this: (1) mistakes in the techniques, some of which are avoidable; (2) the inborn fluctuation of blood pressure; and (3) the inclination for pulse to increment within the sight of a doctor (the supposed white coat impact) [3].

It is settled that various mistakes, predispositions and oversights in recording blood pressure exist [4]. This investigation had a solitary organized objective, to analyse readings of the automated device and aneroid device in pulse estimations against the gold standard, mercury sphygmomanometer and to quantify the scattering of each other to the last mentioned [5, 6]. The examination ponder was embraced to record the BP of around 115 volunteer participants from the group of students of Melaka-Manipal Medical College (Muar and Melaka Campus). The BP readings were taken with a mercury sphygmomanometer (Diamond Mercurial Blood Pressure Apparatus - EHL-DIAMOND-BPMR 120), an automated sphygmomanometer (OMRON Automatic Blood Pressure Monitor – HEM-7203) and an aneroid sphygomomanometer (Spirit – CK-110) under similar standardized conditions so as to contrast the BP readings and the among the three diverse started gadgets, to prevent errors [7, 8, 9].

Even if BP is measured by using multiple measurements, there is no general agreement regarding the use of ADs for single measurements [10, 11] and nowadays use of automated blood pressure measurement devices (AD) to detect blood pressure changes are becoming increasingly widespread in healthcare settings. Their comparability with manual Mercury Sphygmomanometer (MM) readings is unequivocal. Moreover, a recent study on comparison between an AD and MM suggests that the AD devices are easy to use and underestimate the prevalence of hypertension [12].

The ultimate question underlying this study is to identify any presence of dispersion between the gold standard apparatus for blood pressure measurement with the other blood pressure measuring apparatus. The overall objective of this study was to compare mercury sphygmomanometer to readings of the automated and aneroid manometers. The initial expectation is that no large dispersion would be present between the three devices.

2. Methodology

It is a cross sectional study conducted to compare mercury, digital and aneroid sphygmomanometer in blood pressure measurements, while using the mercury sphygmomanometer as the gold standard method.

2.1. Study Setting, Sample Size and Subject Selection

The study was conducted in Melaka Manipal Medical College (MMMC), Malaysia. This study was held from December 2017 to February 2018. We used purposive sampling method and included the students who were willing to provide informed consent. We excluded the students who withdrawal during data collection and were having any illnesses. Hence, 15 participants were excluded from this study. Total of 115 students participated and the response rate was 88.46%.

2.2. Devices

The study was conducted to compare the measurements between digital sphygmomanometer and mercury sphygmomanometer, aneroid sphygmomanometer and mercury sphygmomanometer, while using the mercury sphygmomanometer as the gold standard.

The equipment used for this study were the mercury sphygmomanometer, aneroid sphygmomanometer, digital sphygmomanometer and stethoscope.

2.2.1. Mercury Sphygmomanometer Diamond®

The mercury sphygmomanometer of the brand Diamond® was manufactured in India on the 10^{th} of August 2017. It has a measurement range of 0-300 of mm Hg scale with elegant finish, fine numbering and durable background contrast paint for clear visibility.

2.2.2. Digital Sphygmomanometer Omron® HEM-7203

The digital sphygmomanometer of the brand Omron® with the model HEM-7203 was manufactured in Vietnam. It has a measurement range of 0 mm Hg-299 mm Hg with an easy one touch operation which displays average of last three readings and a blood pressure indicator.

2.2.3. Aneroid Sphygmomanometer Spirit® CK-110

The aneroid sphygmomanometer of the brand Spirit® with the model CK-110 aneroid portable sphygmomanometer was manufactured in Taiwan. It has a measurement range of 0 mm Hg- 300 mm Hg which comes with an inflation system, including a portable pouch and features a no pin stop with an accurately calibrated gauge of 300 mm Hg.

2.2.4. Stethoscope 3M Littmann® Classic III

The stethoscope used to measure the blood pressure for mercury sphygmomanometer was 3M Littmann® Classic III Stethoscope, which has two-sided chest piece with tunable diaphragms on both sides.

2.2.5. Stethoscope MDF® MD One® Stainless Steel Dual Head (MDF777)

The stethoscope used for aneroid sphygmomanometer was MDF® MD One® Stainless Steel Dual Head Stethoscope (MDF777) which has ultrasensitive diaphragm sealed with a non-chill retaining ring to provide a secure acoustic transmission.

2.3. Procedure

The method of data collection employed was firstly with the participants written informed consent. Then a self-administered questionnaire was employed for the collection of socio-demographic details. Participants' were requested to write down their height and weight.

A quiet environment and room temperature was maintained. The participants were given 5 minutes of resting time before the measurement was taken. The blood pressure was taken as the participants were seated on a chair with their back supported, both feet resting comfortably on the floor, and the left forearm supported on the table at the level of the heart. The participants were told to take several deep breaths and relax. Following which the blood pressure was taken using a standard cuff size of (22-32cm) of adult upper arm circumference in all three devices. The cuff was placed around the upper arm with a distance of around 2-finger width from the arm to elbow.

For mercury and aneroid sphygmomanometer, auscultatory method was used. The chest piece of the stethoscope was placed in the left antecubital space below the cuff, distal to the brachium, on the left brachial artery. Initially, three systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements were taken by 2 observers using the first allocated device, and the procedure was then repeated with the other 2 allocated devices. The mercury, digital and aneroid sphygmomanometer individual determination was repeated at 30 second intervals. The participant proceeded from one device to another device at 1 minute interval. The observers were blinded to each other's readings. Confidentiality of the participants' data was maintained. This research study was approved by ethics committee of Melaka Manipal Medical College.

2.4. Data Analysis

The data was analysed using various methods, which includes Epi Info 7, Pearson Correlation Coefficient calculator and Bland- Altman plot in Excel. The mean and standard deviation value for age, and systolic and diastolic blood pressure for all three devices were calculated, followed by the frequency and percentage for gender, ethnicity and body mass index (BMI) via Epi Info 7. The formula used for BMI calculation was BMI = Weight (kg)/Height^2 (m)^2. The classification of weight by BMI used was according to CPG- Obesity by Academic of Medicine of Malaysia [13]. The inter-observer and intra-observer variation were calculated by Pearson Correlation Coefficient calculator, while the *P*-value was calculated by Pearson (R) calculator. While the Bland- Altman plot was plotted with an x-axis of the average of digital with mercury readings and the average of aneroid with mercury readings for both systolic and diastolic blood pressure against the y- axis of the difference between digital with mercury readings and difference of aneroid with mercury readings for both systolic and diastolic blood pressure. The level of significance was set at 95% (P value < 0.05).

3. Results

A total of 115 participants were subjected to blood pressure measurement by three devices. The mean age of the participants was 20.8(2.2). The subjects in this study comprised of 46 males and 69 females. Majority of the subjects were Chinese (47.0%) and Indian (41.7%), followed by Malay (7.8%), Sinhalese (2.6%) and Punjabi (0.9%). 42.6% of the participants belong to normal BMI, 21.7% of them were underweight, 22.6% of the participants were overweight, 3.5% belongs to pre-obese category and 9.6% belongs to obese category. The mean of SBP using the MM, DD and AD were 120.9(10.5), 115.3(12.5) and 116.5(11.0) respectively and mean of DBP were 79.7(8.2), 71.0(7.5) and 70.7(7.2) respectively. (Table 1)

Table 1. Socio-demographic characteristics of participants (n=115).

Variables	N (%)
Age [a]	20.8(2.2)
Gender	
Male	46(40.0)
Female	69(60.0)
Ethnicity	
Chinese	54(47.0)
Indian	48(41.7)
Malay	9(7.8)
Punjabi	1(0.9)
Sinhalese	3(2.6)
Body Mass Index (BMI)	
Underweight (<18.5)	25(21.7)
Normal (18.5-22.9)	49(42.6)
Overweight (>23.0)	26(22.6)
Pre-Obese (23.1-27.4)	4(3.5)
Obese (>27.5)	11(9.6)
Body Mass Index (BMI) [a]	22.1(4.2)
Mercury Manometer (MM)	
SBP [a]	120.9(10.5)

Variables	N (%)
DBP [a]	79.7(8.2)
Digital Device (DD)	
SBP [a]	115.3(12.5)
DBP [a]	71.0(7.5)
Aneroid Device (AD)	
SBP [a]	116.5(11.0)
DBP [a]	70.7(7.2)

[a] Mean (Standard deviation)

The correlation coefficient for systolic blood pressure (SBP) and diastolic blood pressure (DBP) of Observer A and B using mercury manometer was 0.945 and 0.913, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) and diastolic blood pressure (DBP) of Observer C and D using digital device was 0.924 and 0.823, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) and diastolic blood pressure (DBP) of Observer C and D using aneroid device was 0.855 and 0.714, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. (Table 2)

Table 2. Inter-observer variation regards to systolic and diastolic readings.

	Correlation coefficient (r)	*P* value
Mercury		
Systolic	0.945	<0.001
Diastolic	0.913	<0.001
Digital		
Systolic	0.924	<0.001
Diastolic	0.823	<0.001
Aneroid		
Systolic	0.855	<0.001
Diastolic	0.714	<0.001

The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer A using mercury manometer was 0.969, 0.958 and 0.973, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.939, 0.922 and 0.962, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer B using mercury manometer was 0.956, 0.961 and 0.972, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.938, 0.919 and 0.939, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer C using digital device was 0.884, 0.883 and 0.938, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.833, 0.745 and 0.874, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer D using digital device was 0.899, 0.906 and 0.963, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.810, 0.778 and 0.742, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer E using aneroid device was 0.939, 0.939 and 0.973, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.822, 0.812 and 0.921, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. The correlation coefficient for systolic blood pressure (SBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd of Observer D using aneroid device was 0.969, 0.967 and 0.984, respectively (*P* value <0.001). The correlation coefficient for diastolic blood pressure (DBP) of 1st and 2nd, 1st and 3rd and 2nd and 3rd was 0.927, 0.930 and 0.934, respectively (*P* value <0.001). The correlation coefficient for both SBP and DBP was high. (Table 3)

Table 3. Intra-observer variation.

		SBP_{MM}		DBP_{MM}	
		Correlation coefficient (r)	*P* value	Correlation coefficient (r)	*P* value
Observer A	1st & 2nd	0.969	< 0.001	0.939	< 0.001
	1st & 3rd	0.958	< 0.001	0.922	< 0.001
	2nd & 3rd	0.973	< 0.001	0.962	< 0.001
Observer B	1st & 2nd	0.956	< 0.001	0.938	< 0.001
	1st & 3rd	0.961	< 0.001	0.919	< 0.001
	2nd & 3rd	0.972	< 0.001	0.939	< 0.001

		SBP_{DD}		DBP_{DD}	
		Correlation coefficient (r)	*P* value	Correlation coefficient (r)	*P* value
Observer C	1st & 2nd	0.884	< 0.001	0.833	< 0.001
	1st & 3rd	0.883	< 0.001	0.745	< 0.001
	2nd & 3rd	0.938	< 0.001	0.874	< 0.001
Observer D	1st & 2nd	0.899	< 0.001	0.810	< 0.001
	1st & 3rd	0.906	< 0.001	0.778	< 0.001
	2nd & 3rd	0.906	< 0.001	0.742	< 0.001

		SBP_{AD}		DBP_{AD}	
		Correlation coefficient (r)	***P* value**	**Correlation coefficient (r)**	***P* value**
Observer E	1st & 2nd	0.939	< 0.001	0.822	< 0.001
	1st & 3rd	0.939	< 0.001	0.812	< 0.001
	2nd & 3rd	0.963	< 0.001	0.921	< 0.001
Observer D	1st & 2nd	0.969	< 0.001	0.927	< 0.001
	1st & 3rd	0.967	< 0.001	0.930	< 0.001
	2nd & 3rd	0.984	< 0.001	0.934	< 0.001

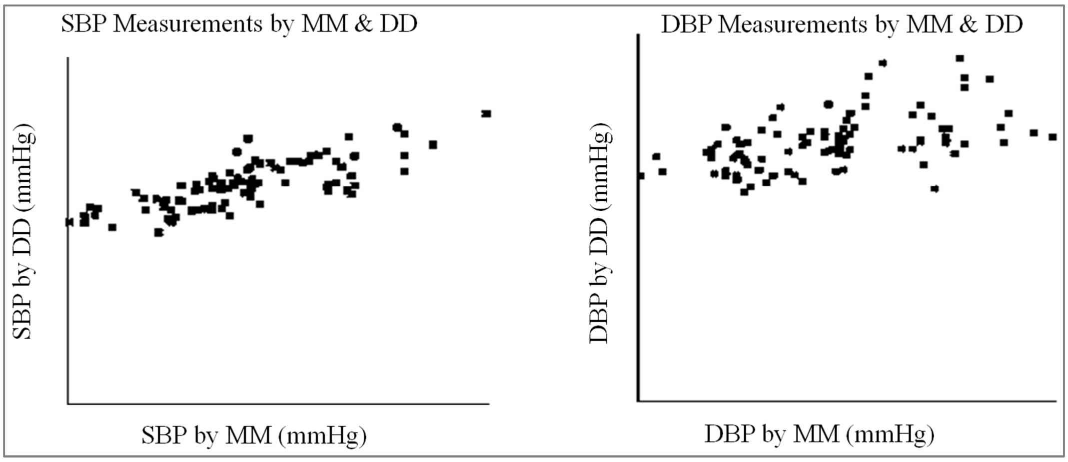

Figure 1. Correlation between systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements recorded with a mercury sphygmomanometer vs. a digital device. Pearson correlation coefficients is high for systolic blood pressure and low for diastolic blood pressure ($P < 0.001$). Abbreviations: MM, mercury manometer; DD, digital device.

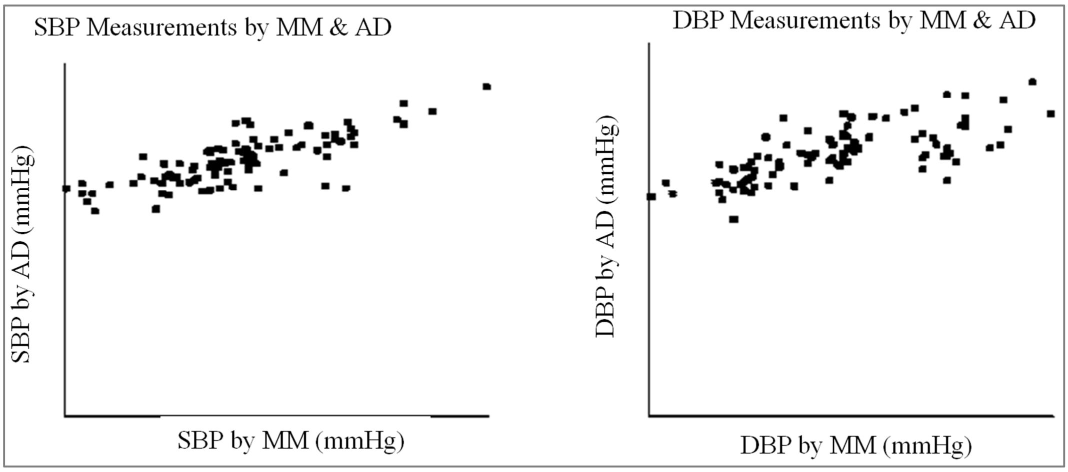

Figure 2. Correlation between systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements recorded with a mercury sphygmomanometer vs. an aneroid device. Pearson correlation coefficients is high for both systolic and diastolic blood pressure ($P < 0.001$). Abbreviations: MM, mercury manometer; AD, aneroid device.

The correlation coefficient for systolic blood pressure (SBP) and diastolic blood pressure (DBP) for mercury manometer and digital device was 0.775 and 0.498, respectively (*P* value <0.001). The correlation coefficients was high for SBP and low for DBP measurements recorded with mercury sphygmomanometer and digital device. The correlation coefficient for systolic blood pressure (SBP) and diastolic blood pressure (DBP) for mercury manometer and aneroid device was 0.787 and 0.701, respectively (*P* value <0.001). The correlation coefficients was high for both SBP and DBP measurements recorded with mercury sphygmomanometer and aneroid device. (Table 4)

Table 4. Comparison between Mercury, Digital and Aneroid devices.

	Correlation coefficient (r)	***P* value**
Mercury vs. Digital		
Systolic	0.775	<0.001
Diastolic	0.498	<0.001
Mercury vs. Aneroid		
Systolic	0.787	<0.001
Diastolic	0.701	<0.001

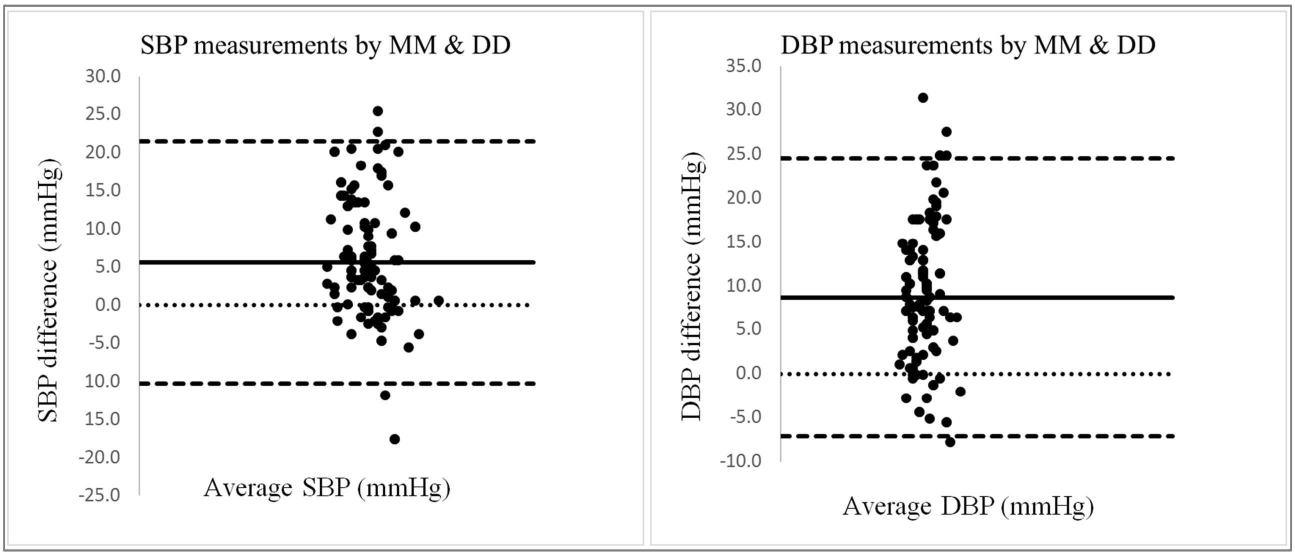

Figure 3. Bland–Altman plots comparing the difference in systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements obtained with a mercury sphygmomanometer, vs. a digital device. Abbreviations: MM, mercury manometer; DD, digital device.

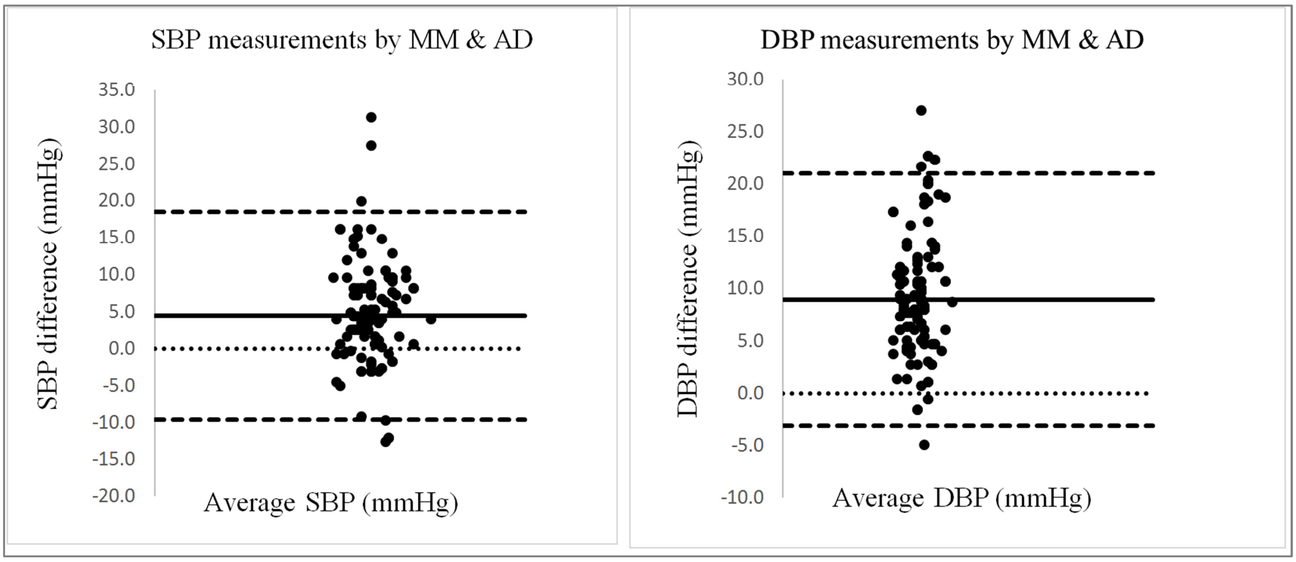

Figure 4. Bland–Altman plots comparing the difference in systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements obtained with a mercury sphygmomanometer, vs. an aneroid device. Abbreviations: MM, mercury manometer; AD, aneroid device.

Figure 3 shows the percentage within ±2 standard deviation of systolic BP and diastolic using mercury manometer and digital device which was 96.5% and 97.4%, respectively. For systolic BP of mercury manometer and digital device, the mean difference (SD) was 5.6(8.0) with lower limit of agree (LOA) of -10.3 and upper LOA of 21.6. For diastolic BP of mercury manometer and digital device, the mean difference (SD) was 8.7(7.9) with lower LOA of -7.1 and upper LOA of 24.5.

Figure 4 shows the percentage for ±2 standard deviation of systolic BP and diastolic using mercury manometer and aneroid device which was 95.7% and 95.7%, respectively. For systolic BP of mercury manometer and aneroid device, the mean (SD) was 4.6(7.2) with lower LOA of -9.8 and upper LOA of 19.0. For diastolic BP of mercury manometer and aneroid device, the mean (SD) was 8.9(6.0) with lower LOA of -3.1 and upper LOA of 21.0.

4. Discussion

Our objective was to compare the accuracy of mercury, digital and aneroid sphygmomanometer in blood pressure measurements, using mercury as the gold standard method.

The systolic blood pressure measurements of mercury and digital sphygmomanometer has a significantly high correlation, and significantly moderate correlation for diastolic blood pressure measurements. In addition, our study shows that the mean difference (SD) of systolic BP of mercury manometer and digital device was 5.6(8.0) and the mean difference (SD) of diastolic BP of mercury manometer and digital device was 8.7(7.9). A comparison study of Automatic Oscillometric and Mercury Sphygmomanometer done by Yechiam Ostchega showed that the mean difference (SD) of systolic BP of the two instruments was 1.6(6.1) and 1.6(6.6) for diastolic BP [14]. Another validation study comparing the three oscillometric blood pressure devices (Welch-Allyn Vital Sign Monitor, Dinamap Procare-120 and Datascope Accutorr Plus) against auscultatory mercury sphygmomanometer done by Wong showing only the Datascope device has a significant value, mean difference (SD) was 0.9(4.3) for systolic blood pressure and 1.2(6.5) for diastolic blood pressure [15]. The first-reading effect seen with a digital device model have different measurement algorithms and thus measure with different quantities [16]. Although the r value for diastolic BP shows moderate positive correlation, subsequent to plotting the Bland and Altman plot, the percentage within the ±2 standard deviation of systolic BP was 96.5% while for diastolic BP was 97.4%. Since 95% of the results are within the ±2 standard deviation for both systolic and diastolic BP, hence it is significant. A validation study for digital device compared to mercury sphygmomanometer done by El Assaad MA, Ombani S and White WB consistently showed lower readings for both systolic and diastolic BP in digital device [17-19]. The digital device using oscillometric method can be used for office measurement, but only devices independently validated according to standard protocols should be used, and individual calibration is recommended. They have the advantage of being able to take multiple measurements, useful for those with hearing-impaired difficulties, for emergency situations when healthcare workers are limited [20] and there was no observer bias for digital device as automated whole number will be given in digital device.

The systolic and diastolic blood pressure measurements of mercury and aneroid sphygmomanometer were highly correlated, hence with a significant association. Moreover, the results of our study shows that the mean difference (SD) of systolic BP of mercury manometer and aneroid device was 4.6(7.2) and the mean difference (SD) of diastolic BP of mercury manometer and aneroid device was 8.9(6.0). A validation study of the A&D TM-2430 device for ambulatory blood pressure monitoring done by Palatini P showed that the differences between mean blood pressures as measured by automated device and mercury sphygmomanometer were 2.2(3.9) for systolic blood pressure and 0.7(4.4) for diastolic blood pressure [9]. Subsequent to plotting the Bland and Altman plot, the percentage within ±2 standard deviation of systolic BP was 95.7% while for diastolic BP was 95.7%. Since 95% of the results are within the ±2 standard deviation for both systolic and diastolic BP, hence it is significant. Observer error and bias are important sources of error when mercury and aneroid sphygmomanometers are used. The differences of auditory acuity for Korotkoff sound between observers may lead to consistent errors and the extent to which inter-observer differences in blood pressure readings are due to different techniques in blood pressure measurement [21]. Digit preference is very common, with most observers recording a disproportionate number of readings ending in 5 or 0 [22]. The average values of blood pressure recorded by trained individual observers have been found to vary by as much as 5 to 10 mmHg [22]. Hence, these are the major causes of discrepancy between mercury and aneroid sphygmomanometers with the true blood pressure. The technical sources of error with auscultatory method, although are fewer when mercury sphygmomanometer is used compared to an aneroid device. The sphygmomanometer should read zero when no pressure applied and it should fall freely when pressure is reduced. Surveys of aneroid device used in clinical practice frequently have shown them to be inaccurate [23].

The study had a number of limitations, one of which was that many previous studies did not include a comparison of all three devices, therefore we have insufficient data to compare with the results obtained from our study. We could not determine the sensitivity and specificity of all the three devices for the diagnosis of hypertension as the population of our study is mainly medical students of the similar age group.

The digital and aneroid device was easy to use and measurements recorded show no significant difference compared to the mercury sphygmomanometer. In principle, there is less to go wrong with mercury sphygmomanometers than other devices, but this should not be any cause for complacency [24]. The setting of the study provided a true measure of the device performance in a survey environment and also shows that an accurate, well-calibrated aneroid device or digital could replace a mercury sphygmomanometer in the quest to remove mercury products from the environment [24-26].

5. Conclusion

In conclusion, the systolic blood pressure measurements of mercury and digital sphygmomanometer has a significantly high correlation, and significantly moderate correlation for diastolic blood pressure measurements. Besides, the systolic and diastolic blood pressure measurements of mercury and aneroid sphygmomanometer were highly correlated. Hence, these proves a good agreement. Therefore, for those who do not acquire the skill of measuring BP using the standard method could utilize the digital device which is more convenient and easier to record the BP readings. While for aneroid sphygmomanometer, it is more environmental friendly compared to mercury sphygmomanometer and it can help in preventing mercury poisoning in hospital setting. However, mercury sphygmomanometer is still the gold standard for BP measurements.

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