THE ACCURACY OF BLOOD PRESSURE MEASUREMENT BETWEEN ANEROID AND DIGITAL SPHYGMOMANOMETER IN REFERENCE TO MERCURY SPHYGMOMANOMETER

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ABSTRACT

Accurate measurement is the utmost important thing in an early stage to diagnose a certain disease. Inaccurate measurement can lead to many major health problem such as hypertension. In order to get the most accurate reading, it is important to choose the right devices or monitor to measure the blood pressure of the human. In this research studies, two measuring devices which are the non-mercury equipment were used to compare the reading of the mercury devices where it is claimed to be the most accurate devices in measuring blood pressure. Even though it is the most accurate, this mercury device has the potential of ill effects on health and environment. Thus, this device will be no longer good to use in the future, hence, it has lead to the widespread of the non-mercury sphygmomanometer in the market. The total of 15 subject were tested by using all the three types of the sphygmomanometer and the result were compared to find which has the accurate reading between the two non-mercury used devices in referral to the mercury sphygmomanometer. Based on the research, the findings show the mean difference between mercury sphygmomanometer vs aneroid sphygmomanometer is lesser compared to mercury sphygmomanometer vs digital blood pressure monitor. From one of test result, percentage mean difference for digital devices compared to mercury devices reach 0.1% while for aneroid devices, the results shows lesser than 0.1%. To conclude the findings, based on all three test on aneroid and digital devices, the mean difference from aneroid vs mercury sphygmomanometer shows lesser difference as compared to digital devices which mean the aneroid is the best accurate devices in referral to mercury sphygmomanometer.

ABSTRAK

Untuk mengenalpasti sesuatu penyakit pada peringkat permulaan, pengukuran yang tepat adalah perkara yang paling penting. Terdapat banyak masalah kesihatan utama seperti tekanan darah tinggi adalah disebabkan pengukuran yang tidak tepat. Untuk mendapatkan bacaan yang paling tepat, pemilihan alat yang betul adalah penting untuk mengukur tekanan darah manusia. Dalam penyelidikan ini, dua alat pengukur yang merupakan peralatan bukan merkuri digunakan untuk membandingkan bacaan alat merkuri di mana ia dikatakan sebagai alat yang paling tepat dalam mengukur tekanan darah. Walaupun ia adalah yang paling tepat, peralatan yang terdapat merkuri ini mempunyai potensi kesan buruk terhadap kesihatan dan juga alam sekitar. Oleh itu, alat ini tidak selamat untuk digunakan pada masa akan datang, justeru, ia telah membawa kepada banyak jenis alatan untuk mengukur tekanan darah bukan merkuri di pasaran. Sebanyak 15 subjek diuji dengan menggunakan ketiga-tiga jenis pengukur tekanan darah dan hasilnya akan dibandingkan dengan mencari alat yang mempunyai bacaan yang paling tepat antara kedua-dua alat bukan merkuri yang digunakan merujuk kepada bacaan alat merkuri. Berdasarkan kajian yang dilakukan, hasilnya menunjukkan perbezaan purata antara alat merkuri dengan alat anaeroid lebih kecil berbanding alat merkuri dengan alat tekanan darah digital. Berdasarkan satu daripada keputusan ujian, purata peratusan perbezaan bagi alat digital dibandingkan dengan alat merkuri mencapai 0.1% manakala bagi alat anaeroid, keputusan menunjukkan kurang daripada 0.1% . Bagi menyimpulkan hasil dapatan, berdasarkan ketiga-tiga ujian pada alat anaeroid dan alat digital, purata perbezaan pada alat aneroid dengan alat merkuri mempunyai perbezaan yang lebih

sedikit berbanding alat digital, yang bermakna alat anaeroid merupakan alat yang paling tepat merujuk kepada alat merkuri.

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LIST OF ABBREVIATIONS AND SYMBOLS

MMHG	MilimeterHg
MAP	Mean Arterial Pressure
NIBP	Non-invasive blood pressure
CFA	Confirmatory Factor Analysis
M	Male
F	Female
BMI	Body mass index
NA	Not applicable
SBP	Systolic blood pressure
DBP	Diastolic blood pressure

CHAPTER 1: INTRODUCTION

1.1 Overview

Sphygmomanometer is best explained as a blood pressure monitor, a blood pressure gauge or a blood pressure meter. This device is meant to measure the human blood pressure. In market, sphygmomanometer consists of several types including digital type, aneroid type, mercury type and the manual type. This devices comes with accessories that help to measure the systolic and diastolic reading and it is consists of an inflatable cuff and a manual operated bulb and valve or a pump operated electrically as a mechanism for inflation (Booth, J , 1977) .

For manual type, a stethoscope is generally required for auscultation which is listening to the internal sounds of the body, usually using a stethoscope. Auscultation is performed for the purposes of examining the circulatory and respiratory systems which is heart and breath sounds, as well as the gastrointestinal system which is bowel sounds as in figure 1.1 below. Manual meters are used by trained practitioners and it is possible to obtain a basic reading through palpation alone, this only yields the systolic pressure.

Figure 1.1: A doctor auscultating a patient’s abdomen –reproduce from Wikipedia (Mc Loughlin S, 2012)

Palpation is the process of using one's hands to check the body, especially while perceiving or diagnosing a disease or illness. Usually this is performed by a health care practitioner, it is the process of feeling an object in or on the body to determine its size, shape, firmness, or location. This procedure is part of the physical examination that was performed by medical practitioners as shown in figure 1.2 below.

Figure 1.2: Palpation of child abdomen – reproduce from Wikipedia (Dictionary.com, 2018)

As for mercury sphygmomanometers, they are considered the gold standard as compared to others. The blood pressure show by affecting the height of a column of mercury, where the column of mercury does not require recalibration. They are often used in clinical trials of drugs and in clinical evaluations of high-risk patients, including pregnant women because of their accuracy. The mercury sphygmomanometer combined with an inflated cuff and auscultation remains the gold standard for the measurement of blood pressure in children. Recently, nonetheless, concerns have emerged regarding the safety of mercury for users in the clinical environment, for technicians who have to service the instrument, and for the environment itself. Environmental mercury pollution, mainly from industrial sources such as coal fired power plants and trash incineration, enters waterways via industrial run-off or settling of airborne particulate matter. It is metabolized by microorganisms into methyl mercury, which then accumulates in fish. Due to this reason why in Malaysia ,Kementerian Kesihatan Malaysia (KKM) has urged our public and private to be mercury free by the year of 2020 (Surat Pekeliling Pihak Berkuasa Peranti Perubatan, 2017). Example of mercury sphygmomanometer is shown in figure 1.3 below.

Figure 1.3: Mercury sphygmomanometer

Another sphygmomanometer is the aneroid. It is a mechanical type with a dial and they are very common use by the doctor. Unlike mercury manometers, they may require calibration checks. Aneroid sphygmomanometers are considered safer than mercury sphygmomanometers, although inexpensive ones are less accurate. Example of aneroid sphygmomanometer shown in figure 1.4 below.

Figure 1.4: Aneroid sphygmomanometer – reproduce from Wikipedia (Booth, J , 1977)

The last type of blood pressure monitor that involves in this research study is digital blood pressure monitor as in figure 1.5. This monitor is widely used as a home monitoring devices. Digital meters employ oscillometric measurements and electronic calculations rather than auscultation. They may use manual or automatic inflation, but both types are electronic, easy to operate without training, and can be used in noisy environments. They measure systolic and diastolic pressures by oscillometric detection, employing either deformable membranes that are measured using differential capacitance, or differential piezo resistance, and they include a microprocessor. They accurately measure mean blood pressure and pulse rate, while systolic and diastolic pressures are obtained less accurately than with manual meters, and calibration is also a concern. Digital oscillometric monitors may not be advisable for some patients, such as those suffering from arteriosclerosis, arrhythmia, preeclampsia, pulsus alternans, and pulsus paradoxus, as their calculations may not correct for these conditions.

Figure 1.5: Digital blood pressure monitor – reproduce from Wikipedia (Booth, J , 1977)

Manometry, regardless of any types of devices, the use of a cuff that is sized appropriately is very important. A cuff that is too small may yield a measurement that is falsely high, whereas a cuff that is too wide may yield a measurement that is falsely low. The width of the cuff bladder should equal approximately 40% of the mid-upper-arm circumference, and the bladder should encircle at least 80% of the limb circumference (Elaine M. Urbina MD, Stephen R. Daniels MD, 2008). Figure 1.6 below show acceptable dimensions of the rubber bladder for different sizes of arms.

Cuff denomination	Arm circumference (cm)	Cuff width (cm)	Bladder length (cm)
Infant	6-15	5	15
Child	16-21	8	21
Small adult	22-26	10	24
Adult	27-34	13	30
Large adult	35-44	16	38
Thigh	45-52	20	42

Figure 1.6: Dimensions of the rubber bladder for different sizes of arms (Mogi das Ceuzes,2005)

It is important that the correct-sized cuff is used. A cuff that is too small for the size of the patient may lead to a spuriously high blood pressure reading. Figure 1.7 below show different sizes of blood pressure cuff ranging from adult to neonate.

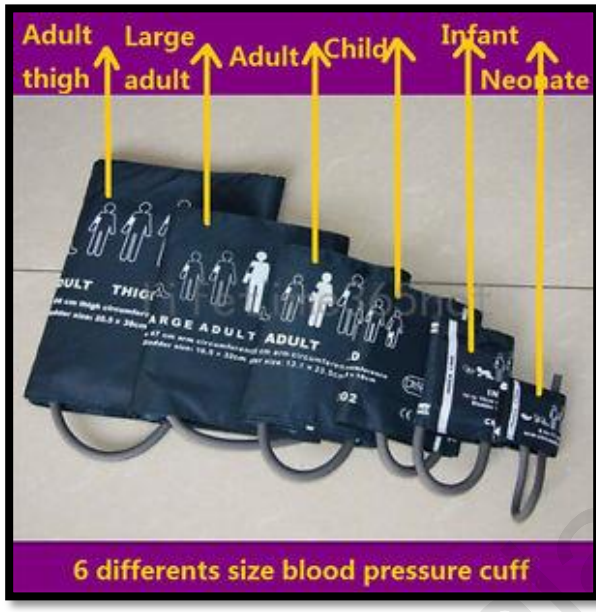


Figure 1.7: Different sizes of blood pressure cuff ranging from adult to neonate - reproduce picture from Ebay

High blood pressure is one of the biggest global health problems. Accurate blood pressure measurements are needed for medical diagnosis, and prevention and treatment of disease. High blood pressure may precede heart disease, stroke, and kidney failure. Recording blood pressure is also an important part of long-term epidemiological studies, which have confirmed the importance of high blood pressure as a risk factor in cardiovascular disease. Blood pressure measurements are taken routinely in the clinic, and anyone with high blood pressure will be measured again on each visit. There is also increased use nowadays of home blood pressure monitoring, and 24-hour monitoring while the patient goes about his or her daily routine. These provide readings which complement those taken in the clinic.

1.2 Problem Statement

Mercury sphygmomanometer are widely used by the doctors in the hospital in our country as they claimed that mercury sphygmomanometer gives them the accurate reading as compared to other types of non-mercury sphygmomanometer. In certain private hospital in Malaysia, mercury devices are being phased out of healthcare systems for ecological and safety reason.

As sphygmomanometer or best explain as blood pressure monitor is the basic device needed in all healthcare institute, it is crucial for doctors to have the best blood pressure monitor that gives them the most accurate reading of patient's blood pressure. Medical institution in Malaysia are using several types of blood pressure devices even home monitoring blood pressure can be tested by using digital one but the concern in this study is the accuracy of the measurement. Accurate reading is important because blood pressure is often measured for diagnosis since it is closely related to the force and rate of the heartbeat. However, small inaccuracies in blood pressure measurement can have considerable consequences such as hypertension that would lead to giving patient inappropriate medication.

In order to replace the mercury sphygmomanometer, this research will be conducted to determine which non mercury sphygmomanometer between aneroid and digital that is best suits to replace the mercury sphygmomanometer, thus will gives the most accurate reading in reference to the mercury one.

1.3 Objectives

The objective of this research are:

1. To compare the accuracy measurement of different types of blood pressure monitoring devices in healthcare industries.

2. To identify the best types of non-mercury sphygmomanometer to replace the mercury blood pressure.

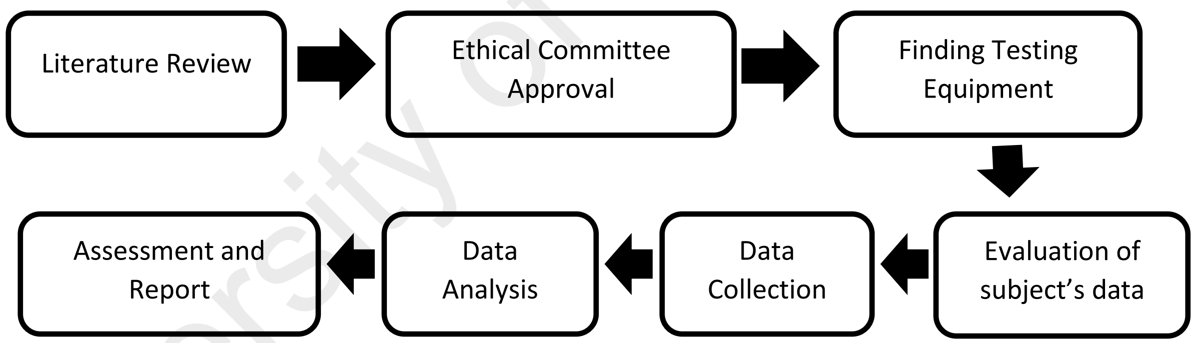
Specifically, this research will analyse the mean difference of systolic and diastolic reading blood pressure from different types of non-mercury sphygmomanometer with reference to the mercury sphygmomanometer.

1.4 Report Organization

This report consist of five chapters, which are; introduction, literature review, methodology, result and discussion and the last chapter is conclusion. In chapter one, further explanation regarding types of mercury and non-mercury sphygmomanometer are discussed. In the same chapter also comprises of problem statement and objectives of the research project. The background of the previous research studies about the accuracy of three different blood pressure monitor are discussed further in chapter two which is the literature review. In the same chapter also discussed about the methodology and calculation used to know the accuracy. The methodology includes explaining the method of the data collection and also the devices used for this research studies. Result and discussion supply a comprehensive analysis of the data collected in chapter four as well as discussed the significance, differences and similarities in the results. The last chapter is the conclusion where it summarizes all the entire research that has been done.

1.5 Scope of research

This research is conducted by using three different blood monitoring devices. 15 subjects age range from 15-30 with variety of body mass index (BMI) will be tested using all those devices for several reading within 5 minutes each test. The result of the two non-mercury devices will be compared with the mercury devices. All the data will be calculated using mean difference to analyse the differences.



CHAPTER 2: LITERATURE REVIEW

A sphygmomanometer is a device that measures blood pressure. It is composes of an inflatable rubber cuff, which is wrapped around the arm. A measuring device indicates the cuff's pressure. A bulb inflates the cuff and a valve releases pressure. A stethoscope is used to listen to arterial blood flow sounds. As the heart beats, blood forced through the arteries cause a rise in pressure, called systolic pressure, followed by a decrease in pressure as the heart's ventricles prepare for another beat. This low pressure is called the diastolic pressure (Medical Training and Simulation, 2019).

The sphygmomanometer cuff is inflated to well above expected systolic pressure. As the valve is opened, cuff pressure (slowly) decreases. When the cuff's pressure equals the arterial systolic pressure, blood begins to flow past the cuff, creating blood flow turbulence and audible sounds. Using a stethoscope, these sounds are heard and the cuff's pressure is recorded. The blood flow sounds will continue until the cuff's pressure falls below the arterial diastolic pressure. The pressure when the blood flow sounds stop indicates the diastolic pressure. Systolic and diastolic pressures are commonly stated as systolic 'over' diastolic. For example,120 over 80. Blood flow sounds are called Korotkoff sounds.

In this chapter, further discussion on the technique and methodology used in the previous research study will be explained more. There are approximately 30 related article which discussed on the accuracy of the blood pressure monitor in the market. Accuracy is crucial in measuring blood pressure in order to prevent wrong diagnose that can lead to hypertension. Choosing the most accurate BP monitor and knowing the right technique on how to measure the reading is important.

2.1 Types of Blood Pressure

2.1.1 Mercury Sphygmomanometer

This type of blood pressure monitor is the most accurate BP compared to other type. This is the reason why mercury sphygmomanometer reading will always be the referral to the other types of blood pressure monitor. The mercury sphygmomanometer has always been regarded as the gold standard for clinical measurement of blood pressure. The design of mercury sphygmomanometers has changed little over the past 50 years, except that modern versions are less likely to spill mercury if dropped. In principle, there is less to go wrong with mercury sphygmomanometers than other devices, but this should not be any cause for complacency.

2.1.2 Aneroid Sphgymomanometer

Aneroid sphygmomanometer is a mechanical types with a dial and they are

very common use by the doctor. Unlike mercury manometers, they may require calibration checks. Aneroid sphygmomanometers are considered safer than mercury sphygmomanometers, although inexpensive ones are less accurate. This blood pressure monitor also gained in popularity in clinical practice because of their portability and their reliance on techniques similar to the standard mercury sphygmomanometer. Because of this, however, they have no influence on the biases existing with the mercury sphygmomanometer. The devices have proven their accuracy when regular 6-month maintenance is in place to service the instruments.

2.1.3 Digital Blood Pressure Monitor

This type of monitor is called a home monitoring devices since it can easily be measured at home. Digital meters employ oscillometric measurements and electronic calculations rather than auscultation. They may use manual or automatic inflation, but both types are electronic, easy to operate without training, and can be used in noisy environments. Digital blood pressure monitor measures systolic and diastolic pressures by oscillometric detection. They accurately measure mean blood pressure and pulse rate, while systolic and diastolic pressures are obtained less accurately than with manual meters, and calibration is also a concern for this kind of monitor in order to get the accuracy in systolic and diastolic reading.

2.2 Blood Pressure Measurement and Technique

To begin blood pressure measurement of the aneroid and mercury sphygmomanometer, the cuff size used must be proper. The length of the cuff's bladder should be at least equal to 80% of the circumference of the upper arm. The cuff will be wrap around the upper arm with the cuff's lower edge once inch above the antecubital fossa. The stethoscope's bell have to be press lightly over the brachial artery just below the cuff's edge. If difficulty happened in measuring by using the bell in the antecubital fossa, other method is can use the diaphragm. Rapidly inflate the cuff to 180mmHg, then release air from the cuff at a moderate

rate. Listen with the stethoscope and simultaneously observe the dial or the mercury gauge. The first knocking sound which we called Karotkoff sound the the subject's systolic pressure. When the knocking sounds disappear, that is the diastolic pressure for example 120/80 mmHg.

Aneroid and digital manometer may require periodic calibration. On obese or heavily muscled subject, a larger cuff need to be use while for a paediatric patient, use a smaller cuff. The tips for measuring the blood pressure, the cuff cannot be placed on a patient's cloth.

2.3 Previous Research Study Method

2.3.1 Mean Difference, Kappa Coefficient and Paired T-test

Common method that have been used in the previous research paper is the using of mean difference and kappa coefficient to calculate the best accurate reading between all the devices. The mean difference or more correctly define ad difference in means is a standard statistic that measures the absolute difference between the mean value in two groups in a clinical trial (Choi, S; Kim, YM ; Shin, J, 2018). It estimates the amount by which the experimental intervention changes the outcome on average compared with the control. It can be used as a summary statistic in meta-analysis when outcome measurements in all studies are made on the same scale. As in the previous research studies, the systolic and diastolic blood pressure reading were measured by using all the tested devices such as mercury or non-mercury blood pressure monitoring based on how many subject tested. It will then calculate to get the mean average for each diastolic and systolic reading (Bashkar Shahbabu, Aparajita Dasgupta, Kaushik Sarkar, Sanjaya Kumar Sahoo, 2016). Figure 2.1 below show the example to get the mean average of the blood pressure monitoring reading.

Means & Mean Difference of Blood Pressure (Systolic and Diastolic): Mercury Sphygmomanometer verses aneroid sphygmomanometer and Mercury sphygmomanometer verses digital sphygmomanometer (n=218).

Blood Pressure	Mercury: Mean (SD)	Aneroid: Mean (SD)	Digital: Mean (SD)	Mercury vs aneroid: Mean difference (SD)	Mercury vs digital: Mean difference (SD)
Systolic	139.7 (17.9)	138.2(17.6)	146.9(18.4)	1.5(3.2)*	-7.2(10.1)*
Diastolic	77.9 (9.4)	76.1 (9.1)	79.9(10.7)	1.8(2.9)*	-2.0(8.3)*

Figure 2.1: Mean average of the blood pressure monitoring reading

(Bashkar Shahbabu, Aparajita Dasgupta, Kaushik Sarkar, Sanjaya Kumar Sahoo, 2016)

Some of the research study conducted is to determine and compare the accuracy of non-mercury instruments and their ability to correctly diagnose hypertension. To diagnose the hypertension correctly between the tested devices, the kappa coefficient is used (Bashkar Shahbabu, Aparajita Dasgupta, Kaushik Sarkar, Sanjaya Kumar Sahoo, 2016). Cohen's kappa coefficient (κ) is a statistic which measures inter-rater agreement for qualitative (categorical) items. It is generally thought to be a more robust measure than simple percent agreement calculation, as κ takes into account the possibility of the agreement occurring by chance. There is controversy surrounding Cohen's kappa due to the difficulty in interpreting indices of agreement. Some researchers have suggested that it is conceptually simpler to evaluate disagreement between items. This is particularly important because such classification needs to be very accurate so that all the diseased get the opportunity in receiving treatment and the non-diseased are not exposed to hazards related to cost and adverse effects of drugs and mental agony because of wrong diagnosis.

Kappa is calculated by using some formula. The formula for kappa is as equation 2.1 below:

$$\text{Kappa} = \frac{(\text{Observed Agreement} - \text{Expected Agreement})}{1 - \text{Expected Agreement}} \quad \ldots\ldots. (2.1)$$

The other formula is to calculate the observed and expected agreement of the data. The formulas are as equation 2.2 and 2.3 below:

$$\text{Observed Agreement} = \frac{(a + d)}{N} \quad \ldots\ldots. (2.2)$$

$$\text{Expected Agreement} = \frac{(\text{Expected (a)} + \text{Expected (d)})}{N} \quad \ldots\ldots. (2.3)$$

While to calculate the expected cell frequencies, the formula as in figure 2.2 shows below:

		Clinical Diagnosis		
		Positive	Negative	Total
SussStat	Positive	(a+b)(a+c)/N	(a+b)(b+d)/N	a+b
	Negative	(c+d)(a+c)/N	(c+d)(b+d)/N	c+d
		a+c	b+d	N

Figure 2.2: Expected cell frequencies formula

When two measurements agree by chance only, kappa = 0. When the two measurements agree perfectly, kappa = 1.

2.3.2 Invasive Mean Arterial Pressure

One of the study found that the technique use to get the accuracy of an oscillometric blood pressure monitor in an anesthetized pigs is that they are using the invasive mean arterial pressure (Reed R, Barletta M, Grimes J, Mumaw J, Park HJ , Giguere S, Azain M, Fang X, Quandt J, 2018). The mean arterial pressure is an average blood pressure in an individual during a single cardiac cycle. Mean arterial pressure calculation usually accurate compared to systolic blood pressure calculation. MAP can only be measured directly by invasive monitoring it can be approximately estimated using a formula in which the lower (diastolic) blood pressure is doubled and added to the higher (systolic) blood pressure and that composite sum then is divided by 3 to estimate MAP. Most of the hospital used NIBP to check patient's blood pressure. One of the studies found that NIBP is very unreliable at measuring systolic blood pressure while it very accurate at measuring MAP. This is because NIBP machines actually measure is the MAP (Kelly

Grayson, 2019). Graph in figure 2.3 and 2.4 below shows the example of the previous studies conducted on the systolic blood pressure and the mean blood pressure (MAP).

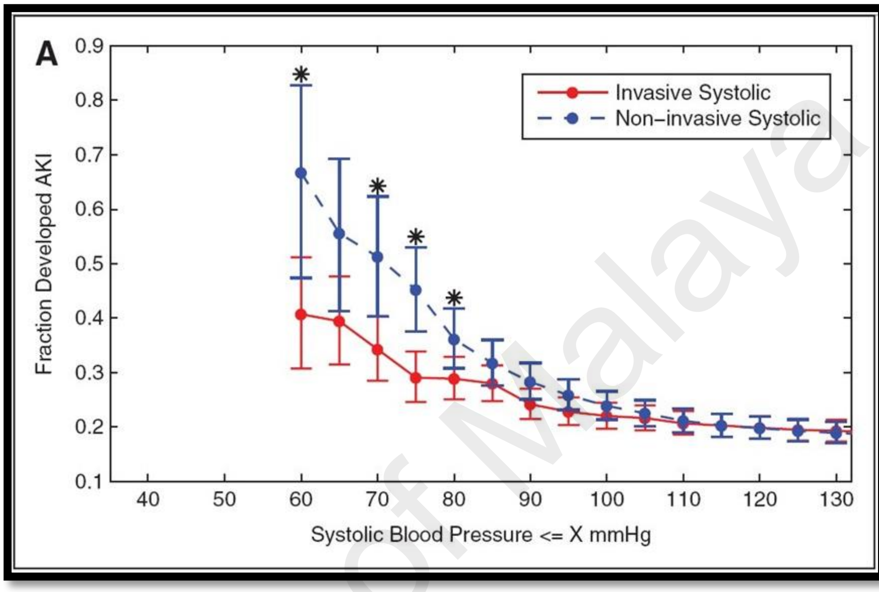


Figure 2.3: Systolic blood pressure (Kelly Grayson, 2019)

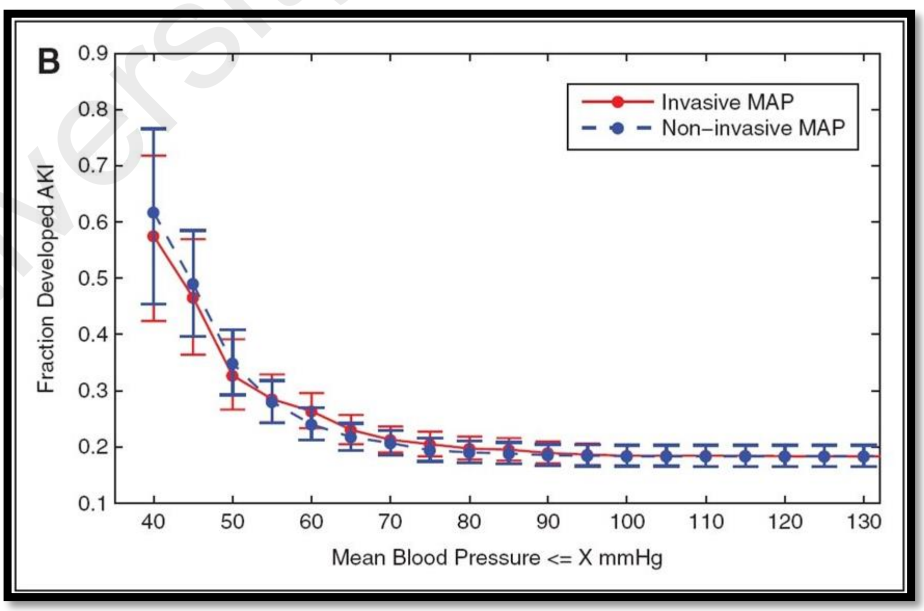


Figure 2.4: Mean Blood Pressure (MAP) (Kelly Grayson, 2019)

Both figures above clearly shown that MAP is the most accurate that systolic blood pressure when using NIBP where those devices are widely used in hospital. Mean arterial pressure is the blood pressure which derived by calculation. The formula of the MAP is in equation 2.4 below.

$$MAP = \frac{SBP + 2\,(DBP)}{3} \quad \ldots\ldots. (2.4)$$

2.3.3 Confirmatory Factor Analysis

In some research, to develop a model estimating "true" blood pressure, confirmatory factor analysis were used to compare the probability of correctly classifying participants' blood pressure status using differing numbers and types of office blood pressure readings (Ian M Kronish Donald Edmondson Daichi Shimbo Jonathan A ShafferLawrence R Krakoff Joseph E Schwartz, 2018). Confirmatory factor analysis (CFA) is a special form of factor analysis, most commonly used in social research. It is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct or factor. As such, the objective of confirmatory factor analysis is to test whether the data fit a hypothesized measurement model. This hypothesized model is based on theory and or previous analytic research. In confirmatory factor analysis (CFA), researchers can specify the number of factors required in the data and which measured variable is related to which latent variable. Confirmatory factor analysis

(CFA) is a tool that is used to confirm or reject the measurement theory (Statistics Solutions (2013)).There are some procedure on how to get this CFA which are:

1) Defining individual construct
2) Developing the overall measurement model theory:
3) Designing a study to produce the empirical results
4) Assessing the measurement model validity

Figure 2.5 below show the example of the previous research studies using the confirmatory factor analysis.

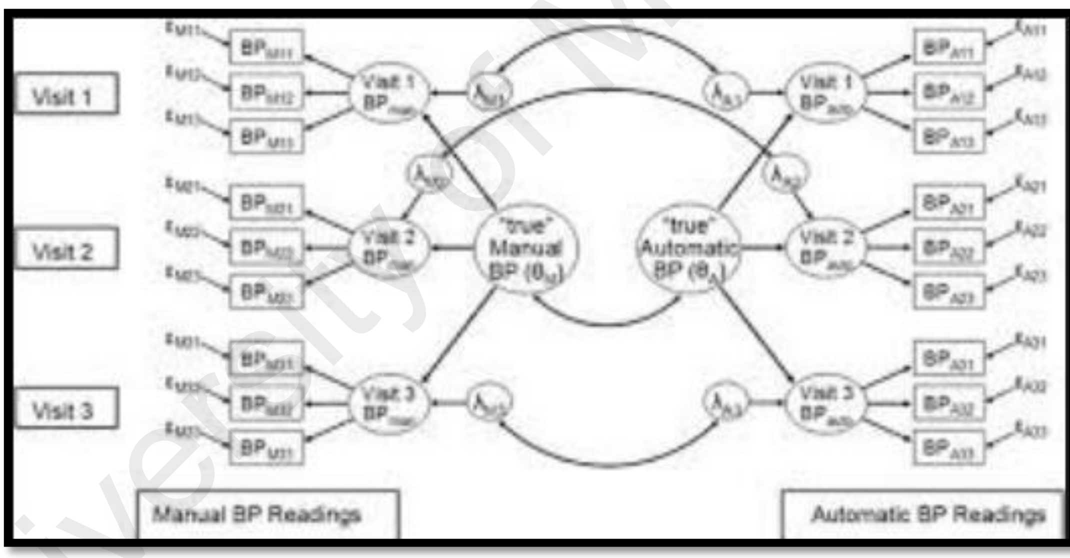


Figure 2.5: Confirmatory factor analysis (American Journal of Hypertension, Volume 31, Issue 7, July 2018)

Usually, statistical software like AMOS, LISREL, EQS and SAS are used for confirmatory factor analysis. In AM, OS, visual paths are manually drawn on the graphic window and analysis is performed. In LISREL, confirmatory factor analysis can be performed graphically as well as from the menu. In SAS, confirmatory factor analysis can be performed by using the programming languages (Statistics Solutions ,2013)

2.3.4 Linear Mixed Model

Some of the studies used this linear mixed model technique to get the accuracy. For this study, six BP monitors were used. The Welch Allyn 767, the Omron M7 , Withings Wireless Blood Pressure Monitor, iHealth BP5 ,QardioArm and the iHealth BP7. All devices bear a Conformite´ Europe´enne (CE) mark and are approved by the Food and Drug Administration (FDA). The Withings Wireless Blood Pressure Monitor, QardioArm, iHealth BP5 and iHealth BP7 are all automated oscillometric devices that are smartphone-compatible. These four BP monitors communicate with the smartphone via Bluetooth. Inflation and deflation is automated and started by a command from the smartphone. Results of measurements are sent to the device's dedicated smartphone application (Roderick W Treskes1, Ron Wolterbeek2, Enno T van der Velde1, Danie¨lle C Eindhoven1 and Martin J Schalij1, 2017) Linear mixed models or sometimes called multilevel models or hierarchical models, depending on the context, are a type of regression model that take into account both variation that is explained by the independent variables of interest like fixed effects, and variation that is not explained by the independent variables of interest which is random effects. Since the model includes a mixture of fixed and random effects, it's called a mixed model. These random effects essentially give structure to the error term. Linear mixed models are an extension of simple linear models to allow both fixed and random effects, and are particularly used when there is non- independence in the data, such as arises from a hierarchical structure. Figure 2.6 below show a scatterplot of the 258 measurements by the tested devices in previous studies.

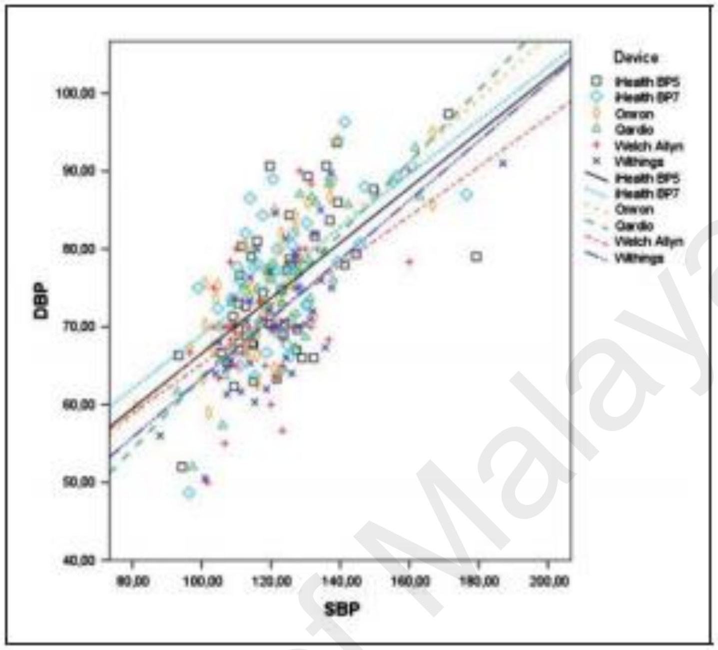


Figure 2.6: Scatterplot of the 258 measurement of the tested devices (Roderick W Treskes1 , Ron Wolterbeek2 , Enno T van der Velde1 , Danie¨lle C Eindhoven1 and Martin J Schalij1 , 2017)

2.4 Summary

Table 2.1: Related studies to the research

	Research title	Authors	Methodology	Pros	Cons	Remarks
1	The quest for accuracy of blood pressure measuring devices	O'Brien, E ; Stergiou, GS Turner, MJ	1) regulatory requirement for mandatory independent validation of all BP measuring devices using a universal protocol 2) accreditation of laboratories for the performance of BP device validations 3) online evaluation of validation studies with detection of protocol violations prior to publication of results 4) establishment of an independent scientific forum for the listing of accurate BP measuring devices.	1) Get the best accurate result of BP 2) Prevent wrong diagnose such as hypertension	1) The outcomes of the endeavors of all these groups are dependent on the accuracy of BP measurements	Have fully published articles but this studied liased with the validation protocols
2	Comparison of the accuracy and errors of blood pressure measured by 2 types of non-mercury sphygmomanometers in an epidemiological survey	Choi, S ; Kim, YM ; Shin, J ; Lim, YH ; Choi, SY ; Choi, BY ; Oh, ; Lee, HM ; Woo, KJ	1) Mean Difference 2) Kappa Coeeficient	1) Not complicated procedure 2) Easy to find which blood pressure is more accurate	1) A lot of data need to be analysed	Have fully published articles completed with data and report which is easy to follow the procedure

3	Accuracy of an oscillometric blood pressure monitor in anesthetized pigs	Reed, R; Barletta, M ; Grimes, J ; Mumaw, J ; Park, HJ ; Giguere, S; Azain, M ; Fang, X ; Quandt, J	1. Invasive blood pressure (IBP) and noninvasive blood pressure (NIBP) measurements were taken using a DRE Waveline Pro multiparameter monitor at four different time points in 17 pigs undergoing injectable anesthesia on both the thoracic and pelvic limbs. 2. Find invasive systolic arterial pressure (SAP) and invasive diastolic arterial pressure (DAP) to get the invasive mean arterial pressure (MAP)	1. NIBP measurements underestimated IBP measurements	1. Tested on animals	No full published article
4	A Comparison of the Diagnostic Accuracy of Common Office Blood Pressure Measurement Protocols	Ian M Kronish , Donald Edmondson, Daichi Shimbo, Jonathan A Shafer, Lawrence R Krakoff, Joseph E Schwartz	1.enrolled a sample of 707 employees without known hypertension or cardiovascular disease 2. obtained 6 standardized BP readings during each of 3 office visits at least 1 week apart week apart 3. using mercury sphygmomanometer and Bp TRU oscillometric devices (18readings per participant) for a total of 12,645 readings. 4. used confirmatory factor analysis to develop a model estimating “true” once BP that could be used to compare the	1. Higher number of visits give accurate result 2. Get the best accurate result of BP	1. A lot of analysis to be done 2. Too many subject and sample	Have full published paper, thus easy to follow the procedure and method used

			reading.			
5	Comparison of the diagnostic accuracy of four smartphone-compatible blood pressure monitors in post-myocardial infarction patients	Roderick W Treskes, Ron Wolterbeek, Enno T van der Velde	1.Patients who were followed up for acute myocardial infarction were asked to participate during their outpatients clinic visit 2. six blood pressure devices wereapplied after 5 minutes of rest 3. Four devices were smartphone-compatible 4. One device was an automated oscillometric device and the other device was a handheld aneroid sphygmomanometer (reference device) 5. All measurements were compared using a linear mixed model.	1. good alternative to enable self - measurement of blood pressure by patients of blood pressure by patients 2. First experiment that used the smartphone	1. Hard to find the smartphone compatible 2. Pricey	No full published paper
6	New photoplethysmogram indicators for improving cuffless and continuous blood pressure estimation accuracy	Wan-Hua Lin , Hui Wang , Oluwarotimi Williams Samuel , Gengxing Liu , Zhen Huang and Guanglin Li	1.a number of new indicators were extracted for photoplethysmogram (PPG) recordings 2. a linear regression method was used to construct BP estimation models based on the PPG indicators and pulse transit time (PTT). 3. BP estimation models was evaluated by the PPG recordings from 22 subjects when they performed mental arithmetic stress	1. algorithm designed to be unobtrusive, miniaturized, portable and wearable, and could be used for long-term monitoring 2. could provide a timely alarm when acute	1. accuracy of these BP estimation algorithms are not precised	Completed published articles

			and Valsalva's manoeuvre tasks	clinical events occur in daily life		
7	Validation of the AVITA BPM64 upper-arm blood pressure monitor for home blood pressure monitoring according to the European Society of Hypertension International Protocol revision 2010	Kang, YY; Chen, Q; Liu, CY; Li, Y; Wang, JG	1.Systolic and diastolic BPs were measured sequentially in 33 adult Chinese (14 women, mean age 47.0 years 2. Used a mercury sphygmomanometer (two observers) and the AVITA BPM64 device (one supervisor) 3. A total of 99 pairs of comparisons were obtained from 33 participants for judgments in two parts with three grading phases	1.Not complicated procedure 2. Easy to get the blood pressure monitor 3. Easy monitoring from home	1. Less number of participants involved	No full published paper
8	The accuracy of Space Labs 90207 in blood pressure monitoring in patients with atrial Fibrillation	Eliza Miszkowska-Nagórna □, Jolanta Neubauer-Geryk, Jacek Wolf, Melanie Wielicka, Grzegorz Raczak, Krzysztof Narkiewicz	1.Patients were reassessed within one week after effective cardioversion (SR; n = 29) 2. performed in 47 hemodynamically stable patients aged 63 ± 12 yo with paroxysmal or persistent Afib 3. BP was measured using Y-tube onnection allowing for simultaneous measurements on the same arm with Space Labs 90207 and referral method. 4. Mean values were tested with	1. Not complicated procedure	1. diastolic blood pressure tended to be slightly overestimated when assessed with Space Labs 90207 in patients with both, AFib and SR	No full published paper but the procedure can be easily followed

			paired t-tests 5. Results were confronted with AAMI, and ESH-IP criteria.			
9	Comparison of non-invasive blood pressure monitoring using modified arterial applanation tonometry with intra-arterial measurement	Jarkko Harju, Antti Vehkaoja, Pekka Kumpulainen, Stefano Campadello, Ville Lindroos, Arvi Yli-Hankala, Niku Oksala	1.28 patients who underwent elective surgery requiring arterial cannulation were analysed 2. Patients were monitored postoperatively for 2 h with standard invasive monitoring and with a study device comprising an arterial tonometry sensor (BPro) added with a three-dimensional accelerometer to investigate the potential impact of movement	1. Not using much subject/sample 2. Not complicated procedure	1. inaccurate readings in method comparison between the devices based on recommendations by Association for the Advancement of Medical Instrumentation (AAMI).	No full published paper and need to get the ethics committee approval to conduct the studies

10	Comparison of Home Blood Pressure Measurement Devices on Artificial Signals	Jan Havlík, Markéta Sušánková	1.compare selected devices for the self-measurement in the home conditions 2. The devices were evaluated using the blood pressure simulators. 3. For each device and each type of blood pressure signal, the absolute and the relative errors of the diastolic and the systolic pressures were evaluated.	1. Easy to get the home monitoring blood pressure 2. No subject or sample needed	1. Inaccurate reading of the result 2. Result showed measurement error	No full published paper
11	Comparison of blood pressure monitoring by applanation tonometry and invasively assessed blood pressure in cardio logical patients	G. Greiwe, S. Hoffmann, L. Herich, M. S. Winkler, C. J. Trepte, C. R. Behem, M. Petzoldt, D. A. Reuter, S. A. Haas	1. Subject include of Patients suffering from highly impaired left ventricular function atrial fibrillation or severe aortic valve stenosis 2. Arterial blood pressure was recorded by applanation tonometry (T-Line 400, Tensys Medical USA) and an arterial line in awake or anaesthetised patients. 3. Discrepancies in mean (MAP), systolic (SAP), and diastolic (DAP) arterial pressure between the two methods were assessed as bias, limits of agreement and percentage error 4. Used 31 patients and a total of 27,900 measurements analyzed	1. Easy to differentiate the result	1. applanation tonometry method is not reliable in ICU patients with severe cardiac comorbidities 2. More data to be analyzed	1. No full journal 2. Data analysis and calculation can be use as reference

12	Comparison of oscillometric, Doppler and invasive blood pressure measurement in anesthetized goats	Olga Szaluś-Jordanow, Michaø Czopowicz, Agata Moroz, Marcin Mickiewicz,Magdalena Garncarz, Emilia Bagnicka, Tadeusz Frymus, Jarosøaw Kaba	1.Goats were anesthetized with the intravenous mixture of xylazine and ketamine 2. BP was measured simultaneously with the three methods in each goat with 7 measurements on average taken 3. Includes 122 goats of two Polish local breeds (Polish White Improved and Polish Fawn Improved) which are 67 adult females, 35 adult males, and 20 two-month-old female kids	1. Oscillometry may be regarded as an alternative to invasive BP measurement in large-scale scientific studies involving adult goats	1. unable to obtain Doppler blood pressure measurements because they could not localize the dorsal metatarsal artery with the Doppler probe 2. More data to be analyzed 3. Tested on animals	Can follow some of the methods and data analysis
13	Discovery of New Blood Pressure Phenotypes and Relation to Accuracy of Cuff Devices Used in Daily Clinical Practice	Picone, DS, Schultz, MG , Peng, XQ,Black, JA, Dwyer, N, Roberts-Thomson, P ; Chen, CH, Cheng, HM,Pucci, G Wang, JG	1. Intra-arterial BP was measured at the ascending aorta and brachial and radial arteries in 126 participants (61 10 years; 69% male) coronary angiography. 2. Central-to-peripheral systolic BP (SBP) transmission (SBP amplification) was defined by mmHg SBP increase between the aorta-to-brachial or brachial-to-radial arteries 3. Standard cuff BP was measured 4 different times using 3 different devices	1. Prevent misclassification of blood pressure at first place	1. Used a lot of data to analyze 2. Complicated procedure	No full journal

14	Accuracy of Blood Pressure Measurement Devices in Pregnancy	Natalie A. Bello, Jonathan J. Woolley, Kirsten Lawrence Cleary, Louise Falzon, Bruce S. Alpert, Suzanne Oparil,Gary Cutter, Ronald Wapner, Paul Muntner, Alan T. Tita, and Daichi Shimbo	1Two independent investigators determined eligibility, extracted data, and adjudicated protocol violations.	1. Prevent the inaccurate BP measurement in pregnant women	1.No full procedure given	No full journal and no complete procedure given
15	Clinical accuracy of the Omron M3 Comfort® and the Omron Evolv® for self-blood pressure measurements in pregnancy and pre-eclampsia – validation according tothe Universal Standard Protocol	Topouchian J, Hakobyan Z , Asmar J, Gurgenian S , Zelveian P , Asmar R	1.the Evolv and the M3 Comfort, measure BP at the brachial level using the oscillometric method. 2. Validation of each device included 45 pregnant women in the second and third gestational trimester of whom 15 had pre-eclampsia, 15 had gestational hypertension and 15 were normotensives. 3. BP differences between the observer and the device BP values were classified into three categories (≤5, ≤10, and ≤15	1. Not complicated procedure 2. Easy to get the accuracy of both types of blood pressure 3. Easy to get the tested device in market	1. Not much data used - hard to analyze data	No full journal published but all the procedure and result given which can be followed easily

			mmHg) 4. the mean BP differences (test vs reference) and its SD were calculated.			
16	Validation of a smartphone auscultatory blood pressure kit Accutension XYZ-110 in adults according to the ANSI/AAMI/ISO 81060-2:2013 standard	Chu, G; Zhang, Z; Xu, MD; Huang, DN; Dai, QY	1. Participants and methods Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured simultaneously on the same arm in 85 Chinese adults (female : male= 48 : 37) with a mean age of 43.2 years 2.Used the mercury sphygmomanometer (two observers) and the Accutension XYZ-110 device (one supervisor). 3. The ANSI/AAMI/ISO 81060-2:2013 standard for the validation of BP measuring devices in adults was followed precisely	1. Not complicated procedure 2. Less subject needed 3. Easy to get the accuracy of the blood pressure test	1. Using smartphone which is pricey	No full journal published but still can follow the procedure

			4. A total of 255 comparison pairs were obtained for analysis.			
17	Validation of the AVITA BPM17 wrist blood pressure monitor for home blood pressure monitoring according to the European Society of Hypertension International Protocol revision 2010	Yuan-Yuan Kang, Qi Chen, Chang-Yuan Liu, Yan Li and Ji-Guang Wang	1.Study participants were between 21 and 82 years of age. 2. They were recruited from among hypertensive patients (n =25), including inpatients and outpatients, in Ruijin Hospital (Shanghai, China) and from among volunteers (n =8) 3. collect information on medical history and measured body height, body weight, and arm and wrist circumferences.	1. Easy procedure to get the accuracy of the blood pressure AVITA BPM17 2. Easy to get the tested device in market	1. Hard to analyze the data since less subject was used	Full published journal which easy to follow the procedure and method
18	An Assessment of the Accuracy of Home Blood Pressure Monitors When Used in Device Owners	Ringrose, JS (Ringrose, Jennifer S.), Polley, G (Polley, Gina), McLean, D (McLean, Donna), Thompson, A(Thompson, Ann), Morales, F (Morales, Fraulein), Padwal, R	1.Eighty-five consecutive consenting subjects >= 18 years of age, who owned an oscillometric home BP device (wrist or upperarm device), with BP levels between 80-220/50-120 mm Hg, and with arm circumferences between	1.Not complicated method used 2. Easy to get the home monitoring blood pressure	1. Result showed not accurate reading	No full published journal

		(Padwal, Raj)	25-43 cm 2. Device measurements from each subject's home BP device were compared to simultaneous 2-observer auscultation using a mercury sphygmomanometer 3. group mean comparisons were conducted using paired t-tests. 4. The proportion of patients with device-to auscultatory differences of >= 5, 10, and 15 mm Hg were tabulated and predictors of systolic and diastolic BP differences were identified using linear regression.			

19	Accuracy of Automated Blood Pressure Measurement in Children	George S. Stergiou, Nadia Boubouchairopoulou, and Anastasios Kollias	1.Deviced is tested to 30 children aged 5 to 15 years 2. The BHS protocol has specific inclusion criteria for children, in regard to their age, sex, and entry BP distribution 3. The mean BP difference between test device and reference measurements and its standard deviation were calculated	1.avoidance of misdiagnosis and over- or under treatment to the patients 2. Less data and subject used	1.The accuracy of this ambulatory and home monitoring devices is limited	Full published jounal with complete method and procedure to be followed
20	Validation of the BPUMP BF1112 upper-arm blood pressure monitor for home blood pressure monitoring according to the European Society of Hypertension International Protocol revision 2010	Qi Chen, Yuan-Yuan Kang, Yan Li and Ji-Guang Wang	1.Study participants were men and women between 25 and 82 years of age, and were recruited from among the staff and hypertensive patients in Ruijin Hospital 2. collect information on medical history, and measured body height, body weight, and arm circumference. 3. The selected participants were	1. Easy procedure to get the accuracy of the blood pressure AVITA BPM17 2. Easy to get the tested device in market	1. Hard to analyze the data since less subject was used	Full published paper but this is just the same as journal no. 17. Only the tested blood pressure different.

			categorized according to three systolic BP ranges (≤ 129, 130–160, and ≥161mmHg) and three diastolic BP ranges (≤79,80–100, and ≥101mmHg) required by the ESHIP2010			
21	Prognosis accuracy of day versus night ambulatoy blood pressure	Jose Boggia MD, Yan Li MD, Lutgarde Thijs, Tine W Hansen, Masahio KIKUYA, Kristina Bjorklund-Bodegard, Tom Richart, Takoyoshi Ohkubo, Tatiana Kuznetsova	1.24 hour blood pressure monitoring in 7458 people(mean age 56.8 years) 2. Calculated multivariate-adjusted hazard ratios for daytime and nightime blood pressure and systolic night-to-day ratio	1. Used only 1 blood pressure monitoring 2. Not complicated procedure	1. Article is not the same accuracy of blood pressure as I want	No full published article. The accuracy of the blood pressure measurement is slighly different as what I wanted
22	Accuracy of blood pressure measurement by Dinamap monitor in infants and children	Myung K Park, Shirley M Menard	1.29 patients in the Dinamap Group with a median age of 18 months (range 1 months to 16 years) and 20 patients in the auscultatory group with a median age of 3.5 years (ranges 3 months to 16 years) 2. The direct artery pressure were recorded on a strip chart and the	1.Procedure showing how to get the radial artery pressure and also mean pressure 2. Procedure can be followed easily	1. Only tested for infants and children	Full published article and easy to follow procedure, analysis of data as well as calculation

			range of pressure were obtained for systolic, diastolic and mean pressures. 3. The range of the direct readings was converted to a weighted single reading 4. Comparison were made between the direct and indirect readings			
23	Comparison of the oscillometric blood pressure monitor (BPM-100 Beta) with the auscultatory mercury sphygmomanometer	Gurdial S Mattu, Thomas L Perry J, James M Wright	1.Means, standard deviations and ranges were calculated for all the demographic data such as age, arm size, heart rate and blood pressure 2. The agreement between the BPM-1OO Beta and the mean of two observers(the reference) was determined and expressed as the mean as well as the percentage of differences falling within 5,10 and 15 mmHg	1. Easy to get the best accurate reading of the blood pressure monitor (BPM-100 Beta) 2. Procedure can be easily followed	1. Limited in tendency to underestimate higher systolic blood pressure but can be change by changing the minor algorithm	No full published paper but still the procedure can be easily followed

			3. Total up to 92 subjects recruited			
24	The BpTRU automatic blood pressure monitor compared to 24 hour ambulatory blood pressure monitoring in the assesment of blood pressure in patients with hypertension	Linda Beckett, Marshall Godwin	1.A quantitative analysis comparing blood pressure measured by the BpTRU device with the mean daytime blood pressure on 24 hour ABPM 2. Subjects are the adult primary care patients who are enrolled in two randomized controlled trials on hypertension 3. The main outcomes were the mean of the blood pressure measured at three most recent office visit	1. Not much analysis needed. Data analysed on the mean average only	1. Result reading need to be reconfirmed with the 24 hour ABPM 2. Reading not really accurate	No full published paper

25	A comparison of indirect blood pressure monitoring techniques in the anethetized cat	Nigel A Caulkett, Shauna L Cantwell, Doreen M Houston	1.Cats were anesthetized with isoflurane 2. The inspired concentration isoflurane was adjusted to produce mild hypotension, moderate hypotension, and severe hypotension 3. Indirect pressure measurement were obtained from the thoracic limb and compared with concurrent direct measurement using regression analysis and a modification of Bland and Altman's techniques	1. Only oscillometric technique gives accurate result 2. All three techniques underestimated systolic pressure	1. Tested on animals	Procedure remains the same even the experiment is tested on animals
26	Accuracy of a continuous blood pressure monitor based on arterial tonometry	Takayuki Sato, Masanori Nishanaga, Akiko Kawamoto, Toshio Ozawa, Horoyoshi Takatsuji	1.Performed in 20 normotensive subjects and 10 hypertensive patients 2. Tonometric and intra-arterial blood pressure were simultaneously recorded at supine rest and duing a valsava maneuver and tilting test	1. Less subject needed for this studies	1. Different studies and more to frequency of blood pressure 2. Limited capacity for recording the higher frequency intra-arterial waveform and for responding to the relatively rapid and large transient changes on blood	No fully published article

					pressure	
27	Comparison of automated oscillometric versus auscultatory blood pressure measurement	Johanna Landgraf, Stanley H Wishner, Roberts A Kloner	1.BP was measured from the same site and cuff in 33 consecutive patients seen in a routine cardiology office 2. Using a simultaneous connection to an automated oscillometric and a mercury manometer technique 3. The mean systolic and diastolic BP were measured	1. Easy procedure to follow 2. The studies are almost the same	1. Result showed has clinical implications including the concepts that patients whose BP appears to be under control using the oscillometric technique	No fully published article. The studies conducted are almost the same as what I want
28	Validation of three oscillometric blood pressure devices against auscaltutory mercury sphygmomanometer in children	Sik-Ning Wong, Rita Yn Tz Sung, Lettie Chuk-Kwan Leung	1.132 children were studied (44 for each device: 67 boys, 65 girls) 2. Each underwent seven sequential BP measurement on the right arm resting in the sitting position, alternately with the mercury sphygmomanometer and simultaneously by two independent, trained	1. Procedure not complicated but a lot of data need to be analysed	1. Must be conducted in hospital 2. Only Datascope pass the studied 3. Studied only for children	No fully published article and studied conducted only on children

			observers and the test device by third observer 3. Device used are Welch Allyn Vital Sign Monitor, Dinamap Procare-120 and Datascope Accutorr Plus			
29	Comparison of auscultatory hybrid and automated sphygmomanometers with mercuy sphygmomanometer in hypertensive pregnant women: Parallel validation studies	Gregory K Davis, Lynne M Roberts, George J Mangos, Mark A Brown	1.Two parallel validation studies were carried out in 340 pregnant women, 170 with hypertensive disorder and 170 normotensive women. 2. An auscultatory hybrid sphygmomanometer, A&D UM-101, and a professional automated oscillometric device for office and clinic use, Omron HEM-907 were tested 3. Nine sequential BP recordings were taken alternating between the mercury sphygmomanometer and the study device 4. Three different readings between	1. Easy to analysed data because this studies used a large number of subject to be tested	1. Tested only on pregnant women	No fully published paper. Same procedure as other comparison article.

			mercury and study device were calculated for each women for SBP and DBP			
30	A comparison of two sphygmomanometers that may replace the traditional mercury column in the healthcare workplace	William J Eliott, Patrick E Young, Laura DeVivo, Jeffry Felstein, Henry R Black	1.Two independent observers performed simultaneously triplicate blood pressure readings for 512 participants 2. The average difference and standard deviation of the difference comparing the mercury column vs the aneroid and automated devices were calculated for each of the three paired systolic and diastolic blood pressure readings	1. Data used to analyse only average difference and standard deviation 2. Not complicated procedure	1. Studied must be conducted in hospital 2. Large participants needed	No fully published articles

CHAPTER 3: METHODOLOGY

This chapter describes the steps and procedure, types of testing devices, subject recruitment and ethical approval that have been done to get all the findings which includes types of devices use and how is the procedure to get the correct reading of systolic and diastolic by using the stethoscope.

3.1 Types of testing devices use

3.1.1 Mercury Sphygmomanometer Spirit CK-403

Figure 3.1: Mercury sphygmomanometer CK-403

One of the testing devices used in this research study is table top mercury sphygmomanometer and the model is Spirit CK-403 as shown in figure 3.1 above. This type of devices is claimed to be one of the accurate blood pressure measurement as compared to other type of devices. To measure the systolic and diastolic measurement on the tested subject, a stethoscope is needed to hear both of the systolic and diastolic sound. For this measurement, one expertise of the clinical application has been asked to measure the reading.

3.1.2 Aneroid sphygmomanometer Spirit CK-110

Figure 3.2: Aneroid Sphygmomanometer CK-110

This type of devices is another kind of mercury sphygmomanometer but it is without mercury as in figure 3.2 above. The measurement on how to get systolic and diastolic reading more or less is just the same like how we measured on mercury sphygmomanometer. Stethoscope is crucial to get the measurement for this device, hence it is important to get the person who is expertise on clinical application to do the measurement using the stethoscope. Steps and procedures will be further explained in point 3.4 below.

3.1.3 OMRON Digital Blood Pressure HEM-7120

Figure 3.3: Omron HEM-7120 Digital Blood Pressure Monitor

This kind of blood pressure monitor as what is shown in figure 3.3 above is claimed to be less accurate since the measurement is based on the machine itself. Not like the other two devices, the measurement is based on human expertise. Hence, this device is user friendly that most of the people will used this as their home monitoring system since it is very easy and simple to use. This devices comes with the cuff and don't even need the stethoscope to hear any sound.

3.1.4 Stethoscope

Figure 3.4: Litmann Stethoscope

Stethoscope is needed when using the mercury and aneroid sphygmomanometer. Figure 3.4 shows the stethoscope used in this research project. It is an acoustic medical device for auscultation, or listening to the internal sounds of an animal or human body. It typically has a small disc-shaped resonator that is placed against the chest, and two tubes connected to earpieces as seen in figure 3.4 above. It is often used to listen to lung and heart sounds. In combination with a sphygmomanometer, it is commonly used for measurements of blood pressure. Systolic and diastolic reading for mercury and aneroid sphygmomanometer have to be measured by using this by hearing the tapping sound.

3.2 Test Subject

Total of 15 subjects were involve in this research studies. The ages range of the tested subject are within 15 years old to 30 years old ages where most of the subject are in median ages range which is 26 years old. All the participants are differentiate based on their sex, weight, height, body mass index (BMI) and also medical history if the subject have ever undergone any accident, surgeries or other related medical history. Table 3.1 below shows subject's demographic data.

Table 3.1 Subject's Demographic Data

No	Name	Age	Sex	Weight (KG)	Height (CM)	BMI	Medical History/Prerequirement
1	Subject 1	26	M	75	170	26.0	NA/ Active in sport
2	Subject 2	26	F	40	156	16.4	NA/ Non active
3	Subject 3	15	F	52	158	20.8	NA/ Non active
4	Subject 4	26	M	78	165	28.7	Smoking / Non active
5	Subject 5	26	F	56	156	23.0	Pregnant / Non active

6	Subject 6	26	F	50	161	19.3	NA/ Active in sport
7	Subject 7	26	F	55	161	21.2	NA / Non active
8	Subject 8	28	M	72	170	24.9	NA / Non active
9	Subject 9	26	F	74	158	29.6	Breastfeed mom / Non active
10	Subject 10	25	F	45	157	18.3	NA / Non active
11	Subject 11	26	M	78	171	26.7	Smoking / Active in sport
12	Subject 12	26	M	115	169	40.3	Smoking / Obese
13	Subject 13	21	F	50	163	18.8	NA / Underweight
14	Subject 14	30	F	75	159	29.7	NA / Overweight
15	Subject 15	28	M	76	169	26.6	Smoking / Overweight

3.3 Measuring Systolic and Diastolic BP

Systolic and diastolic reading is measured when a cuff is wrapped around a patient's upper arm and inflated, the brachial artery is occluded for example blood flow through the artery has been stopped. As the cuff is gradually deflated, blood flow is re-established and accompanied by sounds of "tapping" or thumbing that can be detected with a stethoscope held over the brachial artery just below the cuff. When the first sound of "tapping" is heard, that signifies the systolic pressure and when the "tapping" ceases, that signifies the diastolic pressure. This is basically how the systolic and diastolic are measured by using the stethoscope for mercury and aneroid sphygmomanometer. The ‘tapping’ sound is called the Karotkoff’s sound. Traditionally, these sounds have been classified into five different phases (K-1, K-2, K-3, K-4, K-5) and are shown in the figure 3.5 below (Stephanie Monk,2010).

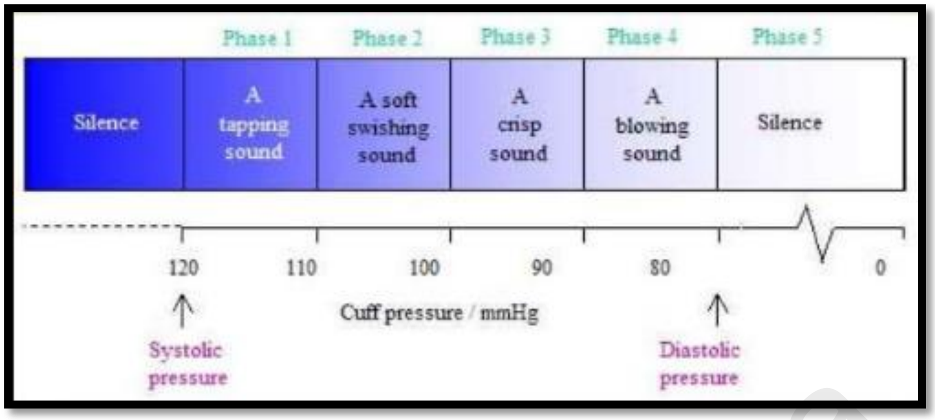


Figure 3.5: Five different phases of K-sound

Where, K-1 (Phase 1) is The appearance of the clear "tapping" sounds as the cuff is gradually deflated. The first clear "tapping" sound is defined as the systolic pressure. For K-2 (Phase 2), the sounds in K-2 become softer and longer and are characterized by a swishing sound since the blood flow in the artery increases .In K-3 (Phase 3), the sounds become crisper and louder in K-3 which is similar to the sounds heard in K-1. Next is the K-4 (Phase 4), in this phase, as the blood flow starts to become less turbulent in the artery, the sounds in K-4 are muffled and softer. The last phase is the K-5 (Phase 5). In K-5, the sounds disappear completely since the blood flow through the artery has returned to normal. The last audible sound is defined as the diastolic pressure.

3.4 Steps and Procedure

3.4.1 Measurement Using Mercury Sphygmomanometer

To begin the measurement of blood pressure, a proper size of cuff is needed. For this research, all the subjects are adult. The cuff used are all in the standard size. Mathematically, the length of the cuff's bladder should be at least equal to 80% of the circumference of the upper arm as shown in figure 3.6 below.

Figure 3.6 : Placement of cuff and location of pulse

The cuff will be wrapped around the upper arm with the cuff's lower edge one inch above the anticubical fossa. The stethoscope's bell is lightly press over the brachial artery just below the cuff's edge as shown in the same figure 3.6 above. Next step is to inflate the cuff rapidly to 180mmHg, then release air from the cuff at moderate rate 3mm/sec as shown in figure 3.7 and 3.8 below.

Figure 3.7: Inflation of cuff

Figure 3.8: Deflation of cuff

The knocking sound has to be listen with the stethoscope and must be observe the dial or mercury gauge simultaneously. The first knocking sound is the subject’s systolic pressure. When the knocking sound disappear, that will be the subject’s diastolic pressure. Figure 3.9 below show example of measurement by using the mercury sphygmomanometer.

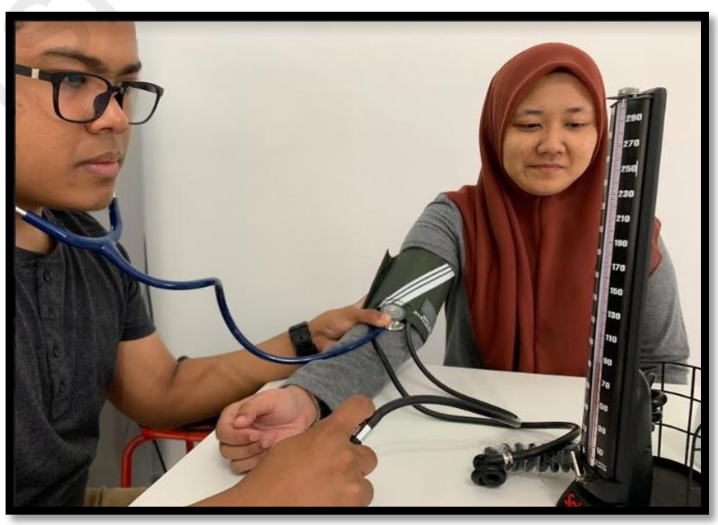
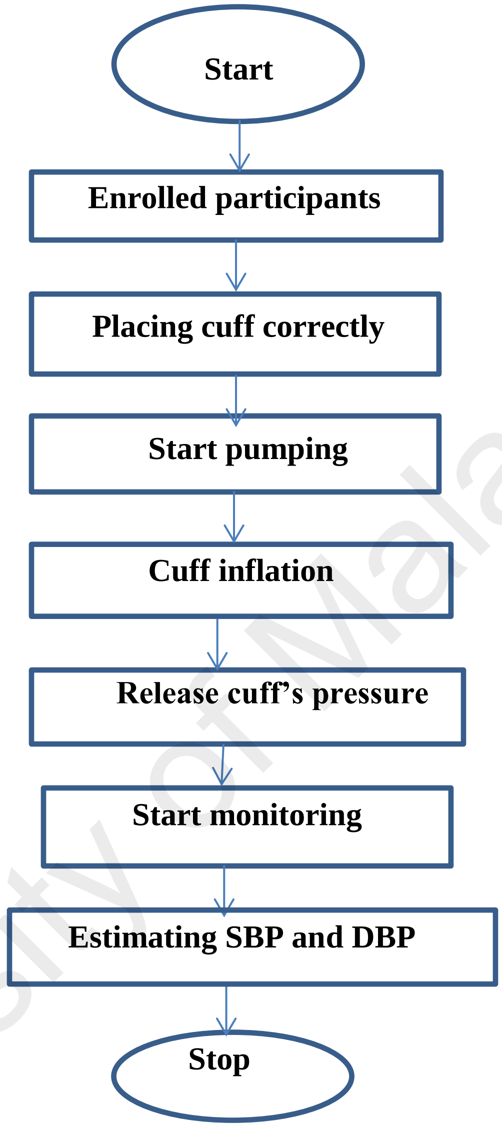


Figure 3.9: Example of measurement using the mercury sphygmomanometer

3.4.1.1 Flowchart of the Measurement



3.4.2 Measurement Using Aneroid Sphygmomanometer

The steps and procedure to measure the blood pressure using aneroid sphygmomanometer are actually the same as what we measure the mercury type. The different is only the device used as shown in figure 3.10 below.

Figure 3.10: Placement of aneroid sphygmomanometer

The placement of the aneroid sphygmomanometer have to be same level as human's heart as shown in figure 3.10 above in order to get accurate reading. This measurement is easy as compared to mercury because the clinical expertise can hear the tapping sound and also can observe the needle at the meter. The first knocking sound is the subject's systolic pressure. When the knocking sound disappear, that will be the subject's diastolic pressure. Figure 3.11 below show example of measurement by using aneroid sphygmomanometer.

Figure 3.11: Example of measurement using aneroid sphygmomanometer

3.4.2.1 Flowchart of the measurement

Basically, the procedure to measure the diastolic BP and systolic BP for both mercury and aneroid sphygmomanometer is just the same. The different is only the uses of different devices. Hence, the flowchart for this measurement is just the same as what as shown in point 3.4.1.1.

3.4.3 Measurement Using Digital Blood Pressure Monitor

This is the most simplest measurement of blood pressure as compared to other two devices. Hence, this is the reason why this electronic BP has been chosen by all the people to be their home monitoring system. Nowadays, most of the clinics and hospitals used this kind of blood pressure monitor.

There have only two steps in measuring BP using this devices. The first step is to locate the pulse at the right place as shown is figure 3.12 below which is the same step as measured with mercury and aneroid sphygmomanometer.

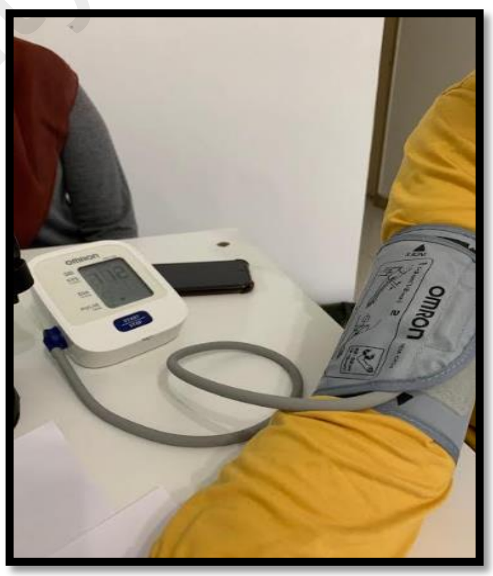
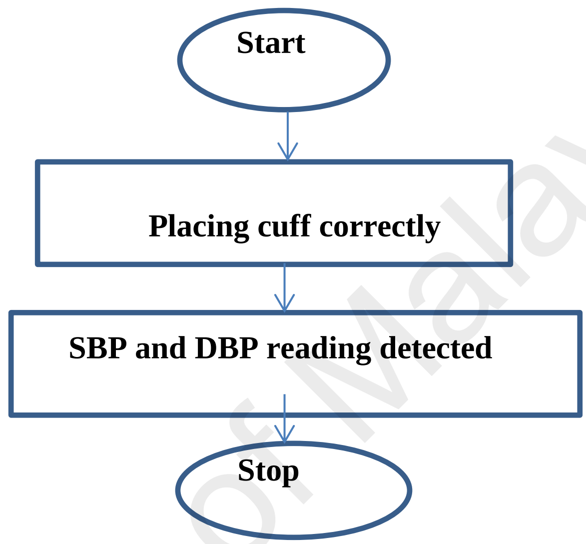


Figure 3.12: Example of using Digital Blood Pressure Monitor

The last step is to press the start button. The cuff will inflates itself and start pumping the blood. It will then deflate and the reading of systolic and diastolic blood pressure will appear at the screen.

3.4.3.1 Flowchart of the measurement



3.5 Repeated Test

In this research study, the measurement for aneroid sphygmomanometer and digital blood pressure monitor has been repeated for three times within 5 minutes interval each subject. Unlike the mercury sphygmomanometer, the measurement only done once because that reading will be the referral reading to both aneroid and digital monitor.

3.6 Ethical Approval

The experimental protocol for this work was approved by the Ethical Community of the University Malaya Medical Centre (UMMC), Kuala Lumpur Malaysia. Written informed consent was granted by the participants from the authors for the publication. Approval ID: 829:15.

CHAPTER 4: RESULT AND DISCUSSION

This chapter provides the relevant data that have been collected from all the testing devices from the total of 15 subject's data measurement. The total of 3 test were taken within 5 mins interval for each test by using the aneroid sphygmomanometer and also the digital blood pressure monitor. Table 4.1 below shows the test 1 subject's data measurement by using all the three tested devices.

4.1 Test 1 Result Comparing Mercury, Aneroid and Digital Devices

Table 4.1 Test 1 overall data measurement

Type Of BP	Mercury BP		Digital BP		Aneroid BP	
Name	SBP	DBP	SBP	DBP	SBP	DBP
Subject 1	100	68	101	66	100	70
Subject 2	98	64	99	64	100	60
Subject 3	110	82	92	65	110	82
Subject 4	124	88	120	83	128	80
Subject 5	110	68	93	67	108	68
Subject 6	120	82	103	77	112	64
Subject 7	110	74	101	68	118	70
Subject 8	130	90	127	89	132	82
Subject 9	114	80	100	68	120	82
Subject 10	112	64	94	57	108	68
Subject 11	114	82	96	53	124	82
Subject 12	126	88	132	95	132	90
Subject 13	106	64	93	66	108	64
Subject 14	108	66	96	62	98	66
Subject 15	126	90	112	70	124	88
AVERAGE	**113.87**	**76.67**	**103.93**	**70**	**114.8**	**74.4**

From the overall result, the mean average value for each testing device measurement was calculated. The mercury sphygmomanometer mean value will be the referral data to both aneroid sphygmomanometer mean value and the digital blood pressure monitor mean value in order to compare the accuracy. The result will be filter separately between aneroid device and the digital device as referred to the mercury device that are shown below.

Table 4.2 Test 1 data measurement for mercury BP vs aneroid BP

Type Of BP / Name	Mercury BP		Aneroid BP	
	SBP	DBP	SBP	DBP
Subject 1	100	68	100	70
Subject 2	98	64	100	60
Subject 3	110	82	110	82
Subject 4	124	88	128	80
Subject 5	110	68	108	68
Subject 6	120	82	112	64
Subject 7	110	74	118	70
Subject 8	130	90	132	82
Subject 9	114	80	120	82
Subject 10	112	64	108	68
Subject 11	114	82	124	82
Subject 12	126	88	132	90
Subject 13	106	64	108	64
Subject 14	108	66	98	66
Subject 15	126	90	124	88
AVERAGE	**113.87**	**76.67**	**114.8**	**74.4**

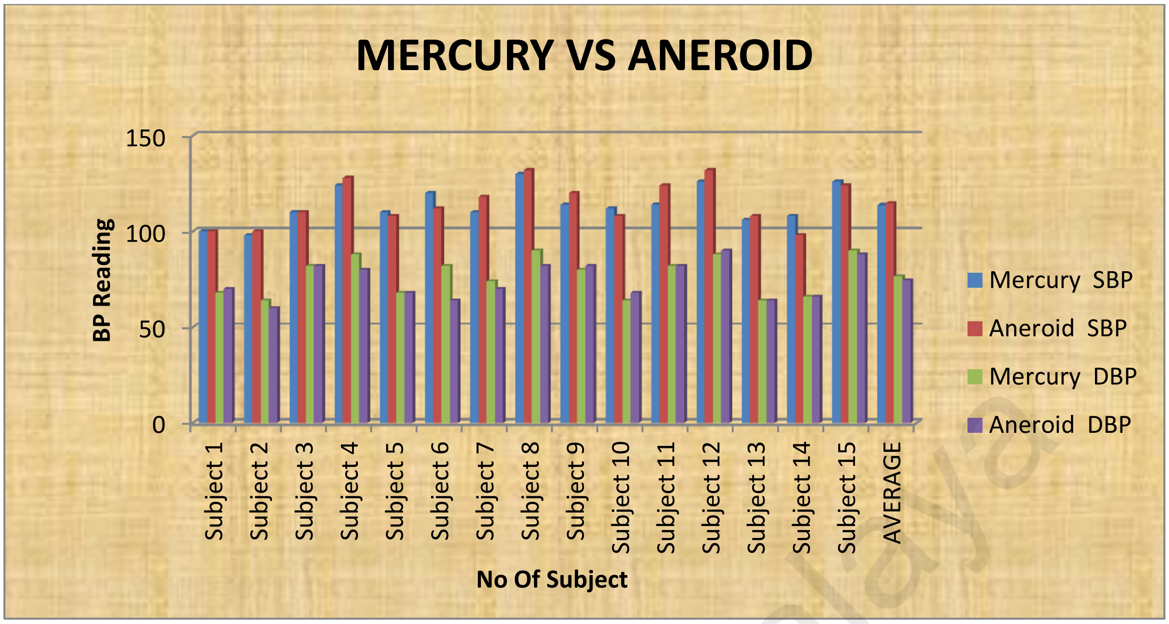


Figure 4.1: Test 1 Graph data comparison of mercury BP vs aneroid BP

Both data from table 4.2 and also figure 4.1 show the differences between mercury sphygmomanometer and aneroid sphygmomanometer. The results for the mean average value also show only slightly differences between this two data. The percentage differences between this two data for both systolic and diastolic reading were shown in the table 4.3 and table 4.4 below.

Table 4.3 Test 1 SBP Percentage differences of mercury BP vs aneroid BP

Average SBP Mercury	Average SBP Aneroid	% Of Differences
113.87	114.8	0.0072

Table 4.4 Test 1 DBP Percentage differences of mercury BP vs aneroid BP

Average DBP Mercury	Average DBP Aneroid	% Of Differences
76.67	74.4	-0.039

To conclude the test 1 result for data measurement between mercury sphygmomanometer and aneroid sphygmomanometer, the result for both SBP and DBP reading shows only slightly different. For SBP reading, the % difference was only 0.0072% while for DBP reading was 0.039%.

From the data, the differences can be because of the noisy environment. As this test were conducted in a franchise, the environment there might be affected the hearing of the SBP and DBP of the clinical expertise. That is the reason why there is a slightly difference on the tested result.

Table 4.5 Test 1 data measurement for mercury BP vs digital BP

Type Of BP / Name	Mercury BP		Digital BP	
	SBP	**DBP**	**SBP**	**DBP**
Subject 1	100	68	101	66
Subject 2	98	64	99	64
Subject 3	110	82	92	65
Subject 4	124	88	120	83
Subject 5	110	68	93	67
Subject 6	120	82	103	77
Subject 7	110	74	101	68
Subject 8	130	90	127	89
Subject 9	114	80	100	68
Subject 10	112	64	94	57
Subject 11	114	82	96	53
Subject 12	126	88	132	95
Subject 13	106	64	93	66
Subject 14	108	66	96	62
Subject 15	126	90	112	70
AVERAGE	**113.87**	**76.67**	**103.93**	**70**

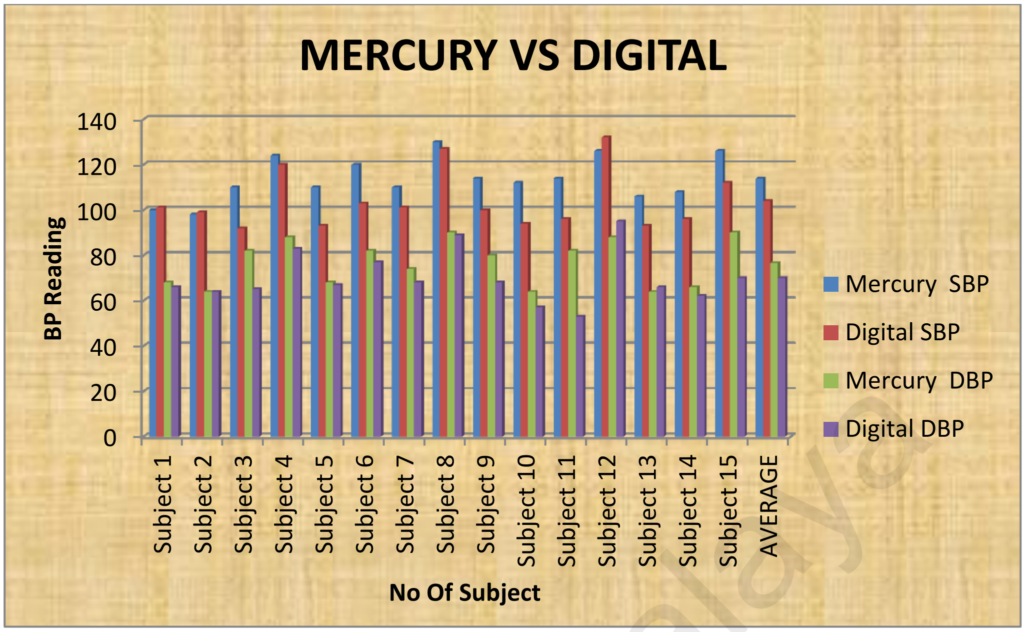


Figure 4.2: Test 1 Graph data comparison of mercury BP vs digital BP

Both data from table 4.5 and also figure 4.2 show the differences between mercury sphygmomanometer and the digital blood pressure monitor. The results for the mean average value also show some differences between this two data that will be presented in percentage of difference table 4.6 and 4.7 below.

Table 4.6 Test 1 SBP Percentage differences of mercury BP vs digital BP

Average SBP Mercury	Average SBP Digital	% Of Differences
113.87	103.93	-0.076

Table 4.7 Test 1 DBP Percentage differences of mercury BP vs digital BP

Average DBP Mercury	Average DBP Digital	% Of Differences
76.67	70	-0.11

To conclude the test 1 result for data measurement between mercury sphygmomanometer and digital blood pressure monitor, the result for both SBP and DBP reading shows some different. For SBP reading, the % difference was 0.076% while for DBP reading was 0.11% which is greater than the aneroid's differences. The reason why the differences is greater than the aneroid because the digital blood pressure monitor will not be as accurate if the body is moving when in used. Also, an irregular heart rate will make the reading less accurate.

Percentage of differences can be clearly seen between the two devices. Aneroid device only shows a bit difference for both SBP and DBP but not for digital device. The differences were a bit higher for digital devices as compared to the aneroid device's data. In conclusion for test 1 data measurement, the aneroid sphygmomanometer is more accurate that the digital blood pressure monitor.

In 5 minutes interval, the test for aneroid sphygmomanometer and digital blood pressure monitor are repeated. It will then be repeated again in another 5 minutes interval in order to get the most accurate data. The total repeated test for this research study are 3 test including the 1st test.

4.2 Test 2 Result Follow Up Result From Test 1

Table 4.8 Test 2 overall data measurement

Type Of BP	Mercury BP		Aneroid BP		Digital BP	
Name	SBP	DBP	SBP	DBP	SBP	DBP
Subject 1	100	68	110	60	100	61
Subject 2	98	64	110	58	91	58
Subject 3	110	82	100	78	94	75
Subject 4	124	88	118	84	124	77
Subject 5	110	68	108	70	97	65
Subject 6	120	82	114	68	97	64
Subject 7	110	74	110	68	95	75
Subject 8	130	90	132	82	125	79
Subject 9	114	80	116	82	115	75
Subject 10	112	64	110	64	86	62
Subject 11	114	82	118	68	107	58
Subject 12	126	88	124	82	130	83
Subject 13	106	64	104	68	106	67
Subject 14	108	66	104	68	100	62
Subject 15	126	90	122	74	120	70
AVERAGE	**113.87**	**76.67**	**113.33**	**71.6**	**105.8**	**68.73**

Table 4.9 Test 2 Data measurement for mercury BP vs aneroid BP

Type Of BP	Mercury BP		Aneroid BP	
Name	SBP	DBP	SBP	DBP
Subject 1	100	68	110	60
Subject 2	98	64	110	58
Subject 3	110	82	100	78
Subject 4	124	88	118	84
Subject 5	110	68	108	70
Subject 6	120	82	114	68
Subject 7	110	74	110	68
Subject 8	130	90	132	82
Subject 9	114	80	116	82
Subject 10	112	64	110	64
Subject 11	114	82	118	68
Subject 12	126	88	124	82
Subject 13	106	64	104	68
Subject 14	108	66	104	68
Subject 15	126	90	122	74
AVERAGE	**113.8666667**	**76.66666667**	**113.3333333**	**71.6**

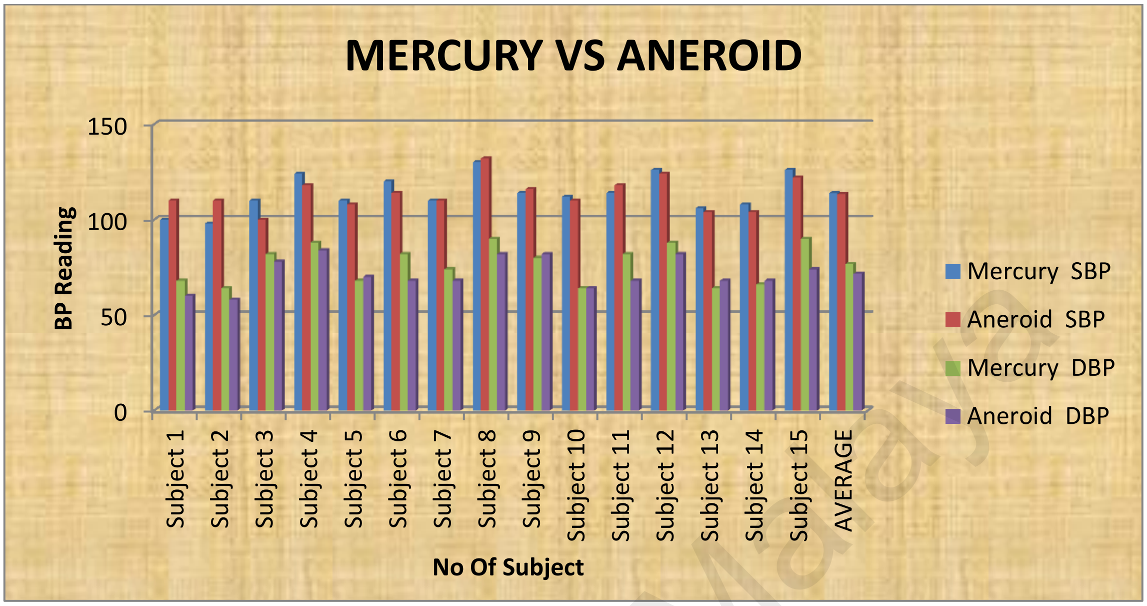


Figure 4.3: Test 2 Graph data comparison of mercury BP vs aneroid BP

Table 4.8 above show the overall data measurement for test 2 before it is filter separately between aneroid and mercury devices. Both data from table 4.9 and also figure 4.3 show the differences between mercury sphygmomanometer and aneroid sphygmomanometer for test 2. The results for the mean average value also show some differences for the DBP reading. The percentage differences between this two data for both systolic and diastolic reading were shown in the table 4.10 and 4.11 below.

Table 4.10 Test 2 SBP Percentage differences of mercury BP vs aneroid BP

Average SBP Mercury	Average SBP Aneroid	% Of Differences
113.87	113.33	-0.004

Table 4.11 Test 2 DBP Percentage differences of mercury BP vs aneroid BP

Average DBP Mercury	Average DBP Aneroid	% Of Differences
76.67	71.6	-0.086

To conclude the test 2 result for data measurement between mercury sphygmomanometer and aneroid sphygmomanometer, the result for both SBP and DBP reading shows only slightly different on the DBP value. For SBP reading, the % difference was only 0.004% while for DBP reading was 0.086% which is a bit higher from the test 1 DBP's value.

The result show unstable reading as compared to test 1 result because some of the subject were eating and drinking during the 5 minutes interval. Doing some activities even eating also can affect the reading that makes the reading not consistent from test 1.

Table 4.12 Test 2 Data measurement for mercury BP vs digital BP

Type Of BP	Mercury BP		Digital BP	
Name	SBP	DBP	SBP	DBP
Subject 1	100	68	100	61
Subject 2	98	64	91	58
Subject 3	110	82	94	75
Subject 4	124	88	124	77
Subject 5	110	68	97	65
Subject 6	120	82	97	64
Subject 7	110	74	95	75
Subject 8	130	90	125	79
Subject 9	114	80	115	75
Subject 10	112	64	86	62
Subject 11	114	82	107	58
Subject 12	126	88	130	83
Subject 13	106	64	106	67
Subject 14	108	66	100	62
Subject 15	126	90	120	70
AVERAGE	**113.87**	**76.67**	**105.8**	**68.73**

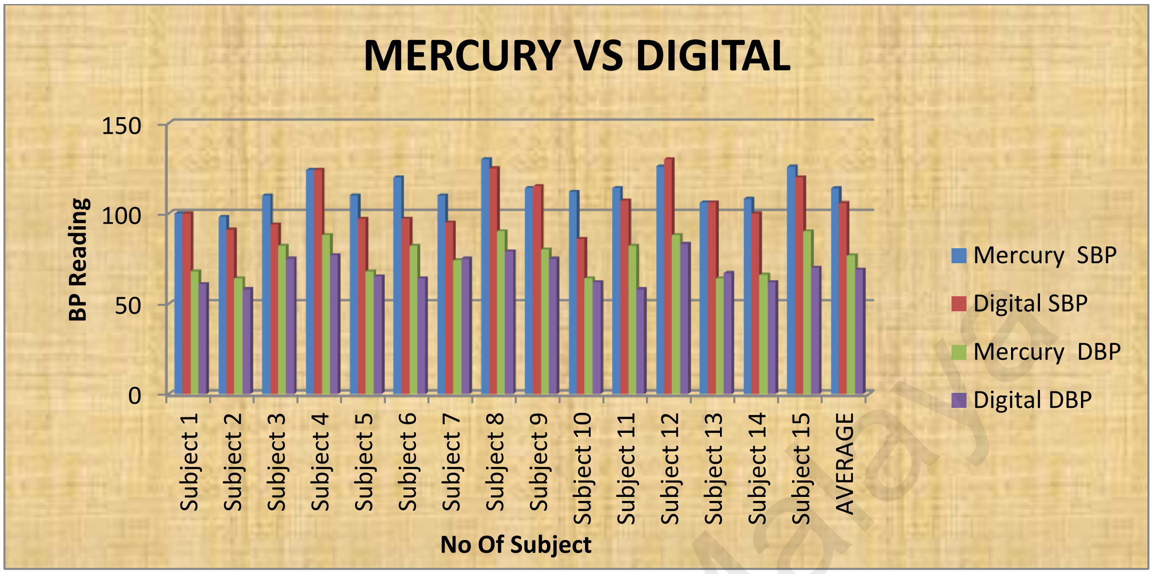


Figure 4.4: Test 2 Graph data comparison of mercury BP vs digital BP

Both data from table 4.12 and figure 4.4 shows the differences between mercury sphygmomanometer and the digital blood pressure monitor for test 2 measurement. The results for the mean average value show some differences compared to the test 1 value between this two data that will be presented in percentage of difference table 4.13 and table 4.14 below.

Table 4.13 Test 2 SBP Percentage differences of mercury BP vs digital BP

Average SBP Mercury	Average SBP Digital	% Of Differences
113.87	105.8	-0.062

Table 4.14 Test 2 DBP Percentage differences of mercury BP vs digital BP

Average DBP Mercury	Average DBP Digital	% Of Differences
76.67	68.73	-0.136

To conclude the test 2 result for data measurement between mercury sphygmomanometer and digital blood pressure monitor, the result for both SBP and DBP reading shows some different. For SBP reading, the % difference was 0.062% which is slightly lower than test 1 value, while for DBP reading shows the percentage differences of 0.136% which is more higher than test 1 value.

Same reason why the reading appear not consistent as tested in first time because of the subjects are not resting in 3-5 minutes. To obtain an accurate blood pressure measurement, it is important to relax and rest quietly before the reading is taken. Some of the subject even talk while taking the measurement and eat during the 5 minutes interval. Any activities such as talking or eating can affect the SBP measurement 10-20mmHg

In test 2 overall result, the value for SBP and DBP for both aneroid and digital devices show some different and more clearly seen on the digital blood pressure monitor's result. This is because, the measurement is done by the machine itself and thus, the result may not be the same as in the first test. That is the reason why the percentage of differences for the digital devices in test 2 is different as compared to test 1.

After another 5 minutes interval, test 3 was conducted on the aneroid sphygmomanometer and the digital device.

4.3 Test 3 Result

Table 4.15 Test 3 overall data measurement

Type Of BP / Name	Mercury BP		Aneroid BP		Digital BP	
	SBP	DBP	SBP	DBP	SBP	DBP
Subject 1	100	68	110	70	96	51
Subject 2	98	64	110	68	94	68
Subject 3	110	82	100	70	94	58
Subject 4	124	88	124	82	119	79
Subject 5	110	68	108	64	101	63
Subject 6	120	82	108	64	104	66
Subject 7	110	74	108	70	102	70
Subject 8	130	90	132	88	126	82
Subject 9	114	80	114	80	92	67
Subject 10	112	64	108	66	91	63
Subject 11	114	82	122	68	105	65
Subject 12	126	88	124	86	128	95
Subject 13	106	64	108	64	100	72
Subject 14	108	66	108	66	114	64
Subject 15	126	90	124	88	115	75
AVERAGE	**113.87**	**76.67**	**113.87**	**72.93**	**105.4**	**69.2**

Table 4.16 Test 3 Data measurement for mercury BP vs aneroid BP

Type Of BP / Name	Mercury BP		Aneroid BP	
	SBP	DBP	SBP	DBP
Subject 1	100	68	110	70
Subject 2	98	64	110	68
Subject 3	110	82	100	70
Subject 4	124	88	124	82
Subject 5	110	68	108	64
Subject 6	120	82	108	64
Subject 7	110	74	108	70
Subject 8	130	90	132	88
Subject 9	114	80	114	80
Subject 10	112	64	108	66
Subject 11	114	82	122	68
Subject 12	126	88	124	86
Subject 13	106	64	108	64
Subject 14	108	66	108	66
Subject 15	126	90	124	88
AVERAGE	**113.87**	**76.67**	**113.87**	**72.93**

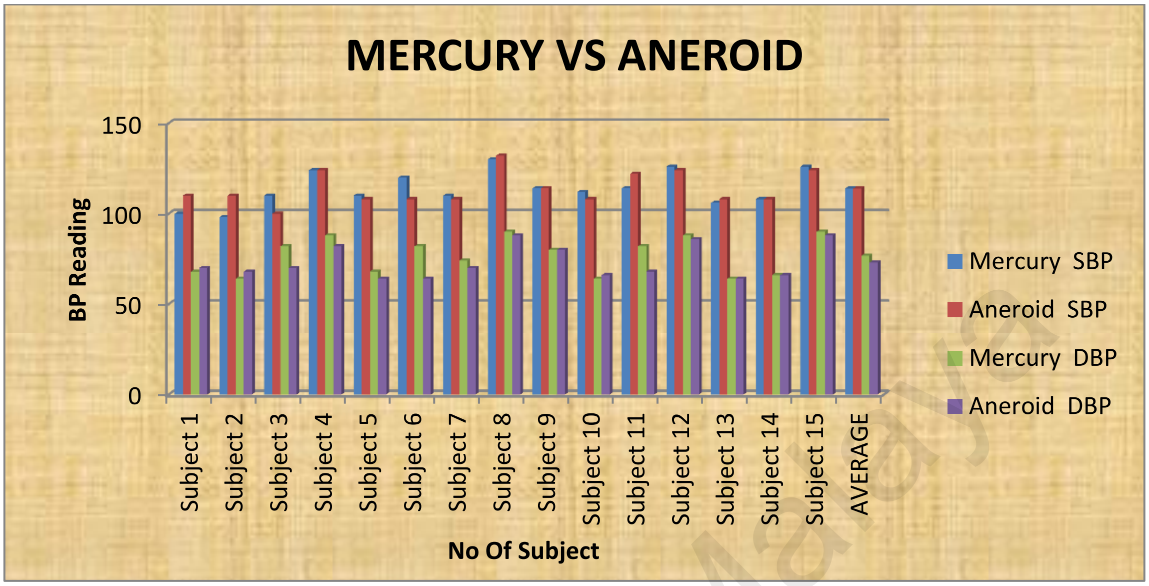


Figure 4.5: Test 3 Graph data comparison of mercury BP vs aneroid BP

Table 4.15 above show overall data measurement for test 3 result before it is filter separately between aneroid and digital devices. Both data from table 4.16 and also figure 4.5 show the differences between mercury sphygmomanometer and aneroid sphygmomanometer for test 3. The results for the mean average value also show some differences for the DBP reading while for SBP reading, the mean value appear exactly the same compared to mercury sphygmomanometer. The percentage differences between this two data for both systolic and diastolic reading were shown in the table 4.17 and 4.18 below.

Table 4.17 Test 3 SBP Percentage differences of mercury BP vs aneroid BP

Average SBP Mercury	Average SBP Aneroid	% Of Differences
113.87	113.87	0

Table 4.18 Test 3 DBP Percentage differences of mercury BP vs aneroid BP

Average DBP Mercury	Average DBP Aneroid	% Of Differences
76.67	72.93	-0.064

To conclude the test 3 result for data measurement between mercury sphygmomanometer and aneroid sphygmomanometer, the result for both SBP and DBP reading shows only different on the DBP value. For SBP reading, there is no different between mercury devices and aneroid devices while for DBP reading was a bit different from test 2 which is 0.064%. No difference in SBP reading might be because of the different testing environment which is not noisy as compared to the test 1 result. Thus, it is easy for the clinical expertise to hear the tapping sound of the SBP and DBP.

Table 4.19 Test 3 Data measurement for mercury BP vs digital BP

Type Of BP	Mercury BP		Digital BP	
Name	SBP	DBP	SBP	DBP
Subject 1	100	68	96	51
Subject 2	98	64	94	68
Subject 3	110	82	94	58
Subject 4	124	88	119	79
Subject 5	110	68	101	63
Subject 6	120	82	104	66
Subject 7	110	74	102	70
Subject 8	130	90	126	82
Subject 9	114	80	92	67
Subject 10	112	64	91	63
Subject 11	114	82	105	65
Subject 12	126	88	128	95
Subject 13	106	64	100	72
Subject 14	108	66	114	64
Subject 15	126	90	115	75
AVERAGE	**113.87**	**76.67**	**105.4**	**69.2**

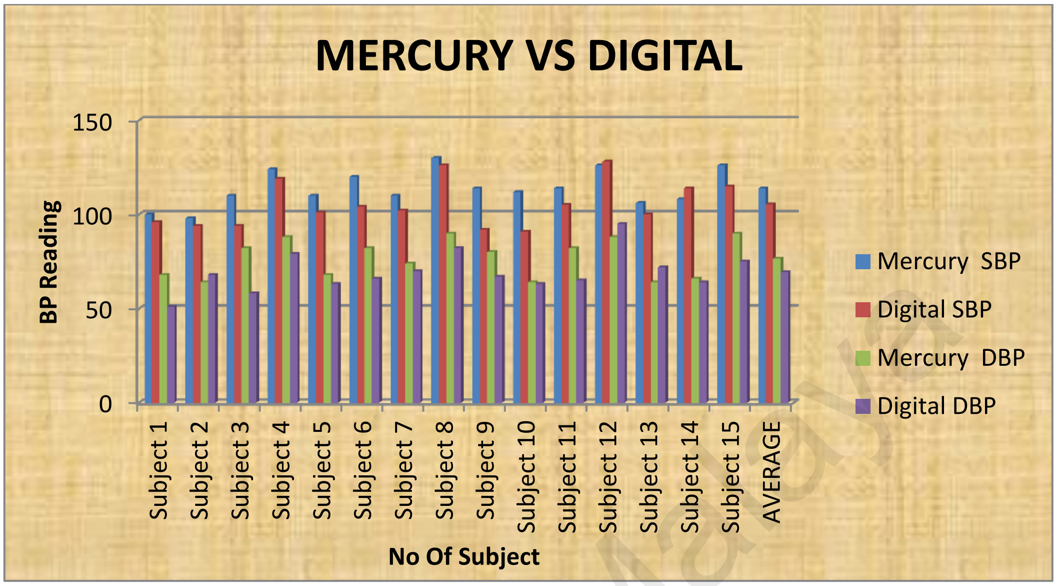


Figure 4.6: Test 3 Graph data comparison of mercury BP vs digital BP

Both data from table 4.19 and figure 4.6 shows the differences between mercury sphygmomanometer and the digital blood pressure monitor for test 3 measurement. The results for the mean average value show some differences compared to the test 1and test 2 value between this two data that will be presented in percentage of difference table 4.20 and 4.21 below.

Table 4.20 Test 3 SBP Percentage differences of mercury BP vs digital BP

Average SBP Mercury	Average SBP Digital	% Of Differences
113.87	105.4	-0.065

Table 4.21 Test 3 DBP Percentage differences of mercury BP vs digital BP

Average DBP Mercury	Average DBP Digital	% Of Differences
76.67	69.2	-0.127

To conclude the test 3 result for data measurement between mercury sphygmomanometer and digital blood pressure monitor, the result for both SBP and DBP reading again show different value from test 1 and test 2. For SBP reading, the % difference was 0.065% which is slightly the same as test 2 value, but for DBP reading shows the percentage differences of 0.127% which is a bit lower than the SBP value in test 2.

Overall, for test 3 result, the value for SBP and DBP for aneroid show not much different as compared to test 1 and test 2 but for digital blood pressure monitor, the value in all test show the unstability measurement. This is because, some of the subjects are smoking person. The tobacco products all contain nicotine which will temporarily increase the blood pressure as well as taking caffeine. One of the subject just had a coffee before the measurement was done. The other reason why the measurement is different is having arm, back or feet unsupported. From Stephanie Monk,(2010)on the hypertension, the study said if the back is not supported, the diastolic blood pressure measurement may be increase by 6mmHg while crossing the legs has shown to increase the SBP by 2-8mmHg. The positioning of the upper arm below the heart level will also result in higher measurements, whereas positioning the upper arm above the heart level will give lower measurements. These differences can increase and decrease the SBP 2mmHg for every inch above or below the heart. So, it is very important to sit properly with arm, back and feet fully supported.

For overall result from test 1 until test 3, the finding shows aneroid sphygmomanometer is the best accurate devices as compared to digital blood pressure monitor as the reading are much more approached the reading of the mercury devices which is the referral devices.

CHAPTER 5: CONCLUSION

5.1 Conclusion

As a conclusion, from the result itself can clearly see the difference between aneroid sphygmomanometer and the digital blood pressure monitor as referred to the mercury sphygmomanometer. To conclude which devices is accurate, from this research study, it has found that aneroid sphygmomanometer is more accurate as compared to the digital blood pressure monitor. This is acceptable because most of the previous research study also found out that aneroid device is the best used to replace the mercury devices. The challenge is that to do the measurement by using the aneroid devices, it has to be someone in clinical application who is expert to do the measurement. To do the home monitoring by using the aneroid device will be hard. It is acceptable to use the digital blood pressure monitor since it is user friendly to be used but the measurement will not be accurate as aneroid sphygmomanometer. Thus, this research has achieved the objective where aneroid sphygmomanometer is the most accurate devices comparing to the mercury devices, as well as can replace the mercury sphygmomanometer that are still existing in some of the healthcare institute.

5.2 Study Limitation and Future Work

This study has several limitations. One of the limitations is the shortage of tested subject. For this research, the tested subject supposedly is 20 subject, but the no of subject used in this study were only 15 subjects. The data will be slightly not accurate because the more the tested subject used for the study, the more accurate the data will it be. Time constraint also is one of the listed limitation. Less than 6 months to get all the data measurement is a bit hard for a part time student because the time has to be divided between working and studying. Clinical application should know the bad side of the mercury devices to the environment and change the mind set to aware the risk when using those devices.

Further research is required to increase the number of tested subject so that the data will be bigger and the accuracy to get the reading can be achieved. Method on how to get the best result like using the paired T-test also have to be added in future research.

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