The introduction of a simulated model using a sphygmomanometer blood pressure measurement and evaluation of error for the model to different cuffs

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Abstract— **Measurement of blood pressure by using of a sphygmomanometer is the common practice in medical centers. So evaluation of how to measurement, accuracy and realization conditions to increase it is very important. In this research, the effects of different Cuff lengths used in sphygmomanometer were evaluated and its error has been compared with the reality of it. this study done on thirty patient by using of sphygmomanometer Piezoelectric Transducer Pulse ,flow meter and then in the laboratory model with providing sufficient conditions was close to reality, the effects of Cuff length in different diameter of arms and amount of error determined.**

Evaluation of results on sample show 129.722 mm Hg pressure is systolic pressure end of regular waves of sphygmomanometer happens in the pressure of 78.889 mmHg that is diastolic pressure. In this situation, Flow and pulse reach to its initial value. With Comparison of wood with different dimensions was seen that in the wood with 27 cm circumference, complete closure occurs and two stick figures with 23 and 35 cm circumference with low-noise have similar conditions and thus the rage of 23-35 cm can be considered as a reliable range and considered an average between systolic and diastolic pressure as a correct pressure and the condition of two woods with the 21.5 and 38cm circumference with high noise is the same. The results show that the gap from 14.5 to 23 cm circumference and 35 cm above, the measurement has an error, or is false entirely and in the gap 23-35cm can be have reliable measured. Despite the differences in wood and real arm, also the results obtained from the observations apply to the reality.

Index Terms— **blood pressure measurement, laboratory model, the arm pressure**

I. INTRODUCTION

The earliest recorded attempts at measurement of arterial blood pressure were done in 1773 by a scientist named Stephen Hales. He used a tube with open end that was entered directly into an artery in the neck of a conscious horse. Non-invasive blood pressure measurement is done with a device called a sphygmomanometer that is blood pressure cuff. The first use of Sphygmomanometry to measure blood pressure were reported by Korotokoff in 1905, but the technique for the relationship between direct and indirect measurements of animals not confirmed to 1912 So that a similar relationship was established for humans **[1]**. Using a sphygmomanometer to measure blood pressure is the common method and evaluation of this type of measurement is very important. Since in this method pressure measured with hearing the sound and the sound frequency range is less than HZ200, is not easy to hear and examine the necessary conditions for increased accuracy is important. Including those can help increase the accuracy in the use of appropriate length cuff. To study the method of blood pressure measured by a sphygmomanometer, at first it is necessary to state the cardiovascular system, blood pressure and its principle measurement. The onset of one heart beat to the next, the only once blood pumps to out of the heart, is called a heart cycle. In per heart Cycles is a contraction phase (systole) and relaxation phase (diastole). Pressure resulting from this force, at the time of contraction of the left ventricle (systole), is 120 mmHg. The blood that enters to the aortic with pressure has the pressure of 120 mm Hg that is called systolic pressure. In the diastolic time that Ventricular is at rest, ventricle pressure is almost zero although the blood not enters into the aorta, the pressure is 80 mmHg and is called diastolic pressure. Sphygmomanometer principles measurement are that this system includes an elastic cuff which on the one hand is connected to a manometer and on the other side, a small hand pump air that it can be air into or out of the armband. Cuff is closed on the brachial artery (brachial) **[2]**. Stethoscope is placed under bag on the ends of the artery, by a hand pump, enter air into the bag until the number shows indicator is further than individual systolic pressure predicted **[2]**. This pressure compresses arterial to the bone beneath that brings cord blood vessel **[3]**. At this time, no sound is heard through the phone and not is felt the individual pulse. With this function, actually the artery is closed **[2]**. Then by the pump, air will discharge gradually that rate about mmHg / s 3 is the best situation **[2]**. So blood began to move in vessel. In fact, when first systolic pressure greater than the pressure cuff, stethoscope operator started to hear some sounds that have been occurs by the first blood flow pushed through the obstruction. To appreciate korotokoff attempts, this sound is called korotokoff sounds. When the pressure in the cuff is reduced, audible korotokoff sounds pass through the 5 phases, with the first strike organized by the blood flow is heard through the stethoscope, the pressure recorded by the manometer that is called systolic pressure. The sounds continued until the cuff pressure is low and the sound reduced as the blood flow around the obstruction becomes more uniform. Transition period from choking sounds (IV) to silent (V) is diastolic pressure. Krtkf sounds disappeared when the cuff pressure is reached below the diastolic pressure **[4]**.

In this study, firstly, testes was done on30 samples by using a sphygmomanometer and then have paid to explain the experimental system for the design of laboratory

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sphygmomanometry models and determine the appropriate length for the cuff.

II. Material and Methods

AD Instrument devices are: sphygmomanometer (MLT1100), Piezoelectric Transducer Pulse (MLT1010), blood flow meter (ML191). First, a brief explanation is given on any device.

MLT1100 sphygmomanometer to measure systolic and diastolic blood pressure, is associated with a BP Transducer to convert pressure into an electrical signal. Transducer Pulse (MLT1010) has a piezoelectric element to convert to the active force surface Transducer, to an electrical signal. Transducer can be connected directly to the input BNC any powerlab. The force exerted on the active surface of Transducer changes because of expansion and contraction around the finger. This force is proportional to the change in blood pressure which can be detected by Transducer. Table 1 shows the characteristics of this Transducer. Laser Doppler flow metry (LDF) was done a quasi-continuous measurement of blood cells in the skin and other tissues. Indeed Micro vessels flux Consequence of the average velocity of the cells and the concentration of blood cells in a small volume of tissue to be determined under the light of a laser beam.

Table 1. Specification of MLT0670 Transducer

Specifications	Value
Operating pressure range	-50 to +300 mmHg
Excitation	2 to 10 V DC
Sensitivity	5 $\mu V/V/mmHg$
Non-linearity and hysteresis	± 1 mmHg
Operating temperature	+15 °C to +40 °C
Weight	26 g
Time Response	10000 μs

Measuring instruments put in individual place on the left hand, accordingly, the cuff sphygmomanometer approximately 2 cm above the elbow closed tightly around the arm. Below the cuff, flow meter probe approximately set to flow through arteries by a special adhesive and Transducer pulse is closed to the index finger (usually the best place to measure the pulse). After ensuring proper connection, open the Software Chart for Windows TM, V5.0.1 and done sphygmomanometry. Page of software consists of 3 channels. The first channel is located above , is related to the Transducer piezoelectric pulse, a second channel in the middle , is related to the sphygmomanometer and the third channel in the bottom, is related to the flow meter .these Have pointed that to simulate arterial hemodynamics laboratory, three general components are needed:

- Pump with the ability to create the pump pulse rate as the production rate of the heart;
- elastic tube with geometrical and mechanical characteristics similar to the artery;
- System for collecting and processing information required for the registration parameters.

According to the above three components, to conduct this research designed and built a laboratory system that Schematic view of the experimental designed in this project, is presented in Figure 1. Three main components are expressed in the schematic below:

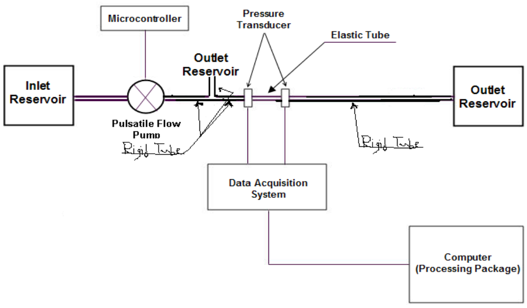

Figure 1- Schematic view of the experimental system

The mechanism of pump is consist of a Servomotor, a gearbox, a power Screw (that one piston is mounted on and moves inside a cylindrical tank) and Control space (Which consists of a microcontroller) **[5].** Elastic tube is used as the brachial artery and has its properties and is examined as the under pressure part. The reason for using the rigid elements before and after the elastic tube is isolation of the under pressure part in upper and lower parts **[6]**.

Since this pump cant simulation of pumping action of the heart and vascular system around the brachial artery exactly, a three way before the elastic tube, instead of the vessel before it was used that with closing the tube with cuff, the used oil in the pump out of the way such as the condition of the body, with the closure of the artery with cuff, blood crossing from other routes, creating and also prevent the oil return. Designing, data collection and processing Experimental system based on the measurement of arterial pressure wave that for this purpose, two manometer installed at the beginning and end of elastic tube that have the ability to Pressure Measurement in Real-Time. Now the collection is ready to test, which its outline can be seen in Figure 2.

Figure 2. General view of the laboratory system

Another hypothesis was considered for sphygmomanometry model, such as sections of the wood used instead to show the importance of cuff size instead of arms. Wood is chosen because in the sphygmomanometer it is assumed that the pressure of external cuff is equal the pressure of arterial wall, While the cuff pressure of the cuff through soft tissue and blood vessels transferred to the artery. In order to simplify the assumptions in this experiment, used the wood body with high rigidity to remove the soft tissue and cuff pressure is transferred directly to the elastic tube. Thus, according to Figure 3, it can be said that the pressure of the elastic tube is equal with cuff pressure and the pressure of the upper and lower sections of the elastic tube is assumed to be zero.

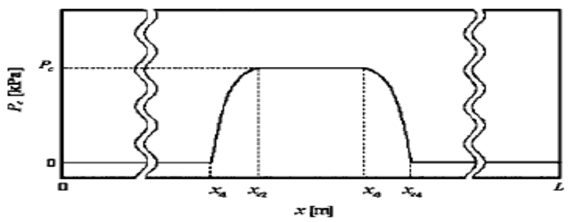

Figure3. The distribution of the output pressure measured by cuff **[6]**

Methods is that the elastic tube placed on the wood and cuff closed around it so far of its inflating bag placed above tube, then inflated cuff slowly. To measure the systolic and diastolic pressures, Figure 8, the cuff pressure changes from 0 to 150 mm Hg and the waveform of the input pressure set of 120 mm Hg to 80 mm Hg elastic tube. In the following figure, Simultaneous changes are seen.

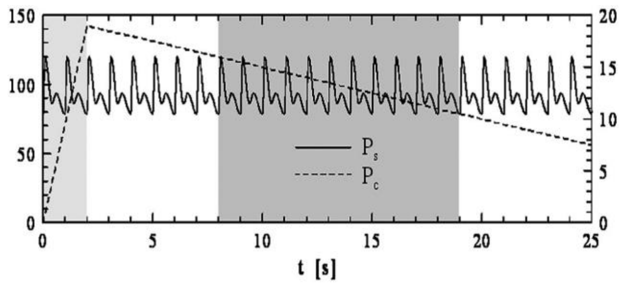

Figure8. Changes in the pressure fluctuation and cuff pressure **[2].**

The light struck is audibled in the middle korotokoff sounds**.** At the beginning of the shadow space, cuff pressure with a maximum inlet wave pressure (120 mm Hg) and the end zone, the cuff pressure at the inlet pressure wave pressure(80 mmHg) are intersected that are systolic and diastolic pressures respectively.
Carefully in Figure 9 can be seen that the middle shadow space in this figure, that is the output voltage waveform, simultaneously is connected to the shadow region in Figure 8. Figure 9, due to the cuff closure reduced pressure (indeed closed elastic tube) and twice to open the cuff pressure is high.

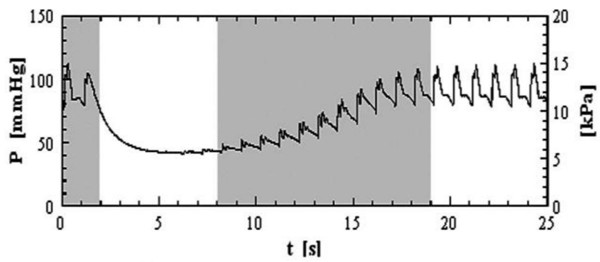

Figure 9. Downstream pressure in the cuff **[6]**

Top of the middle shadow zone that the pressure wave starts again, is the systolic pressure space that in this point, cuff pressure is equal to the systolic pressure and the end of zone that the pressure wave returns to prototype is the diastolic pressure. In this point, the cuff pressure is equal to the diastolic pressure. Important point is that because the measurement condition is not exactly identical with the body and various errors are in the measurement (such as the difference of wood with real arm, spill contingency, etc.) for each wood with a single test cannot found accurate result. Therefore, experiments were performed on each sample 10 times, and then the mean values obtained were compared between samples. Another assumption, sinusoidal waveform in lieu brachial artery waveforms that they have great similarities. Arterial pressure waveform and the pressure applied waveform are seen in figures 4 and 5.

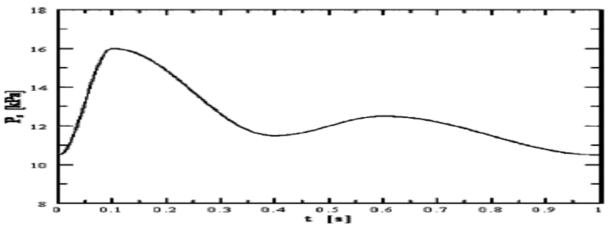

Figure4. Brachial Artery Pressure changes during a heartbeat

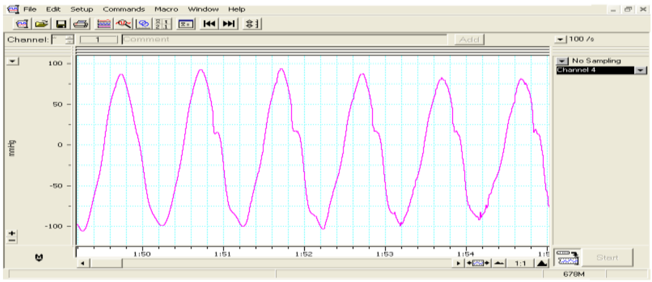

Figure 5. The pressure waveform used in the experiments
To simulate the real blood flow in Brachial artery, the oil was used as the fluid pump, to close the Reynolds number = Re and Womersley number $R\sqrt{\frac{\omega}{\upsilon}}$ = N_w (ρ the density, u the velocity, D the diameter of the pipe, μ the viscosity of fluid dynamics, R the radius of the tube, ω frequency Zavyh¬Ay fluctuations, υ viscosity static fluid) blood flow in arterial and fluid flow in an elastic tube, these two conditions were close to each other **[7].**

III. Results

In this section we discussed about the results of tests carried out on the samples and the results of done tests .The obtained result about a sample is shown in Figure 6.

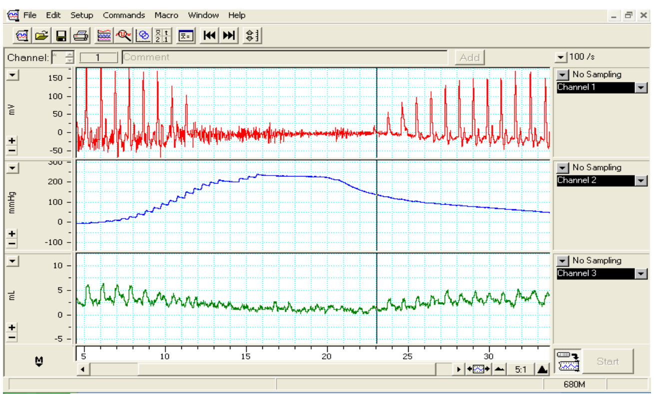

Figure 6. The results of tests on a sample by three instrument
Figure 6 shows, by gradual increase in pressure, flow and pulse decrease gradually that as the closure of the brachial artery, then with reduction of the cuff pressure is shown that

when the pressure reach to the systolic pressure, open the artery slowly and blood flow begins.
This site is specified in figure and in this site, regulation of sphygmomanometer waves, Start of regular pulses index finger and re-establish artery flow is occurs together. The coincidence of these waves on the next figure show more accurately. All this waves indicates that the pressure 129.722 mm Hg is systolic pressure and the end the regular waves of pressure sphygmomanometer occurs in 78.889 mm Hg that is diastolic pressure.

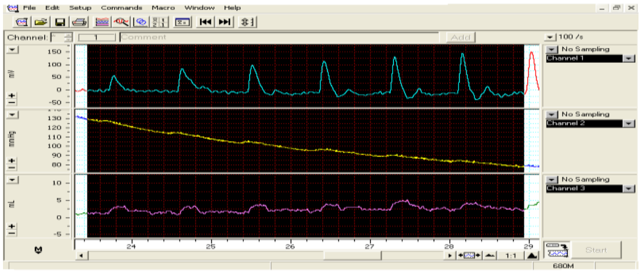

Figure 7. Evaluated test results.

In vitro model, the width of cuff inflating bag about 40% of the upper arm circumference (about 12 to 14 cm in adults and middle) [3], and the lengths of inflating bag should be about 80% of the upper arm circumference (Roughly the size of the arm circumference contain) [8]. The Research suggests that use the cuff to measure the blood pressure on the arm with high circumference, Results exaggerated and about arms with lower circumference, the results are underestimated [9].About the cuff used in the experiment (with a width of 14 cm and a length of 27.5 cm-inflating bag (sizes is standard)), the maximum circumference of the arm that can use from this to measure blood pressure accuracy, is 35 cm but in any case there is a minimal size. For this purpose, The 7 wood were used with 14.5, 21.5, 23, 27, 35, 38, 40.5 cm circumference and the pressure wave forms were compared. In this study, the output window displays results regulate in such that shows a sphygmomanometer pressure wave, the wave pressure gradient, pressure wave measured by the transducer (P1, Indeed this wave is input that should not takes effect from close cuff) and pressure wave transducer measured by the second transducer (P2 tihs wave is pressure wave at the end of the elastic tube that is certainly place affected to close cuff) . Although the numbers were vary in each instance on a sample, but change in wave are close together on the same sample in all experiments. The first sample was wood to environment 14.5 cm that test results shown in Figure 10.

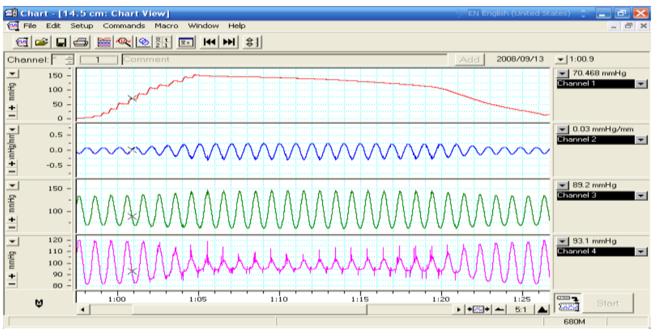

Figure 10 - Diagram voltage, pressure and flow rate by wood to environment 14.5 cm.

Because the cuff is too large for this environment With increasing pressure cuff to 150 mmHg, The only noise arises on the pressure wave and its amplitude is low But not close completely elastic tubing and also because changes pressure P2 wave is not detection and unreliable, can not be considered Systolic and diastolic blood pressure point. Indeed, such is that adult cuff be closed around the arm of a child and in fact is not heard no sound in this case. The in Figure 11 shown test results by wood to environment 21.5.

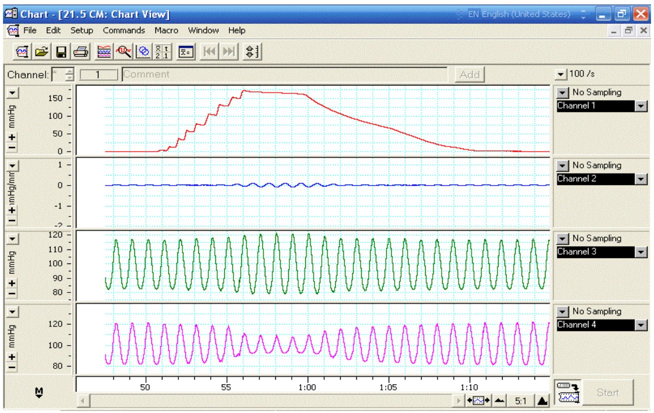

Figure11. Diagram voltage, pressure and flow rate by wood to environment 21.5 cm.

According to Figure 11 can be seen because Close the cuff pressure, wave amplitude decreased output and changes in the visible range, but amplitude is not gone completely (i.e elastic tube not closed completely), but Can be found The systolic and diastolic pressures from Gradual change this waves that after ten times of experiments obtained the average number and are expressed in Table 1.
The in Figure 12 has shown test results by wood to environment 23.

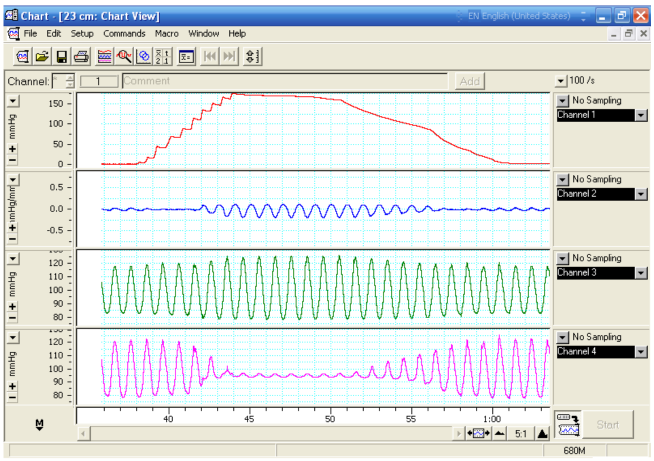

Figure12. Diagram voltage, pressure and flow rate by wood to environment 23 cm.

According to Figure 12, the discharge pressure wave amplitude decreased more than the previous case namely, elastic tube is closed more but The figure waves shows that the tube is not closed completely.
The in Figure 13 shown test results by wood to environment 27.

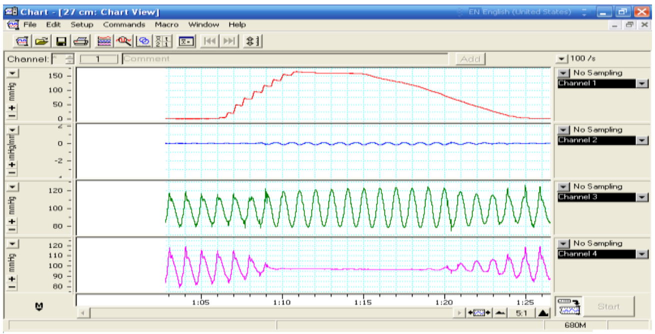

Figure13. Diagram voltage, pressure and flow rate by wood to environment 27 cm.

In this example can be seen that reduced pressure completely and is not ride the wave on this, this means that is closed the elastic tube completely.

The in Figure 14 shown test results by wood to environment 35.

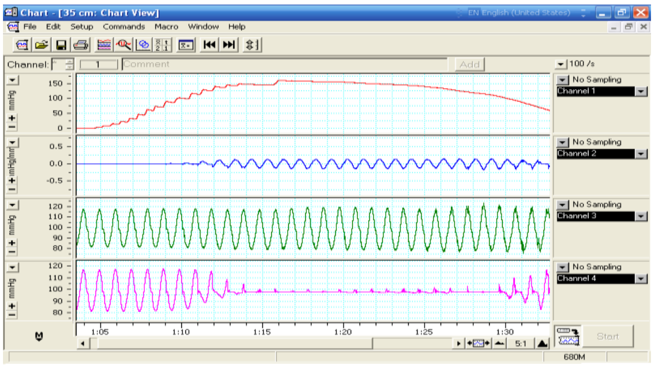

Figure14. Diagram voltage, pressure and flow rate by wood to environment 35 cm.

This environment was selected as final size of the environment, measured by the cuff. In Figure 14, according to the output voltage wave form is observed that elastic tube is not closed due to the noise of the waves, but the errors are not significant.

To further investigate, the maximum size is measured by the cuff, also two other environment were tested.

The in Figure 15 shown test results by wood to environment 38.

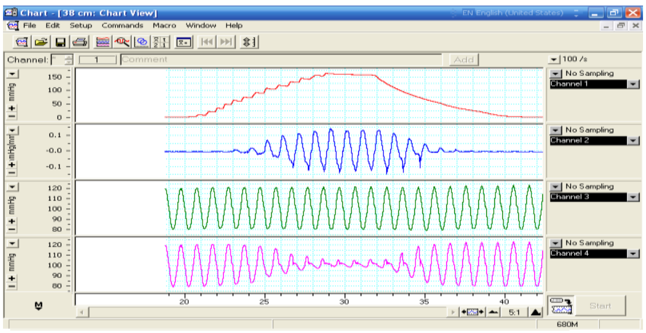

Figure15. Diagram voltage, pressure and flow rate by wood to environment 38 cm.

As is evident is reduced from the amplitude of the output voltage and has visible changes but the elastic tube is not closed completely.

The in Figure 16 shown test results by wood to environment 40.5.

Figure16. Diagram voltage, pressure and flow rate by wood to environment 40.5 cm.

The graph of voltage, pressure and flow rate of 40.5 cm circumference.

The results of tests on the sample is the same with the wood with 14.5 cm circumference that the range is reduced only slightly, but the changes are not visible and therefore it is not sufficient for this size.

IV. Discussion and Conclusion

By comparing the woods with different dimensions is seen in the wood with 27 cm circumference ,the complete closure occurs and the shapes of two woods with low-noise and 23 and 35 cm circumference are in the same conditions. And therefore the range of 23 to 35 cm could be reliably estimated range for the cuff and an average is considered between systolic and diastolic pressure as a correct pressure and the conditions of two woods with 21.5 and 38 cm circumference with high noises, is the same. Therefore between these two pressure mean values were considered for comparison. Table 1 shows the systolic and diastolic pressure values.

Table 1. The average of systolic and diastolic pressures depending on the woods circumference.

The average of systolic pressure (mmHg)	The average of diastolic pressure (mmHg)	Circumference (cm)
143.402	73.4185	21.5
130.135	69.7976	23
132.882	68.7159	27
135.205	81.00491	35
139.434	80.935	38
The measurement is wrong	The measurement is wrong	40.5 and 14.5
132.741	73.1728	23 and 35
141.4177	77.1768	21.5 and 38

The first point is that the inlet pressure wave was 120 over 80 mmHg but the values obtained an average was 70 over 130 mmHg that the reason for this difference, errors in measurement and its difference with the body, which does not present a problem. About two woods with 21.5 and 38 circumference, the amount of systolic error was 6.54 percent and about diastolic pressure was 5.47 percent. An increase of approximately 10 mm Hg in systolic pressure could be due to not fully closed elastic tube in the maximum pressure of cuff, with the opening of the tube, the inlet pressure is added to the profile pressure in the elastic tubing and the resulting is higher systolic pressure. Whereas about the diastolic pressure, the error is less (approximately 4 mm Hg) Because of the tube in the pressure of cuff is completely is opened and the outlet pressure is nearly the same as before and this happens almost on its own pressure. About two woods with 14.5 and 40.5 circumference other conditions are as well as and the measurements is not accurate, because the tube is closed very low and the outlet pressure profile are not reliable variations. Therefore in these cases, the measurement of the cuff is not true. Despite the difference between real wood and arm, the obtained results with the observations is almost close to reality.

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