Original Research Article

Comparison of blood pressure measurement with two digital sphygmomanometers

ABSTRACT

Aims: identify the correlation between systolic and diastolic blood pressure measurement with digital arm and wrist baumanometers in young adults aged 18 to 40 at the Public University of Celaya, Guanajuato, Mexico.
Study design: Observational, analytical, quantitative, correlational, diagnostics
Place of Study: Public University of Celaya, Guanajuato, Mexico.
Methodology: We included 397 participants of an age range between 18 and 40 years; which 287 were women and 110 were men; with an average weight of 65.28 ± 15.08, and of stature 1.63 ± 0.09. Two types of digital, wrist and arm baumanometers were used to measure the systolic and diastolic blood pressure to observe the effectiveness of the values recorded during the measurement.
Results: The correlation between the 3 measurements of the systolic blood pressure was repeated in the first and third measurements (r = 0.46) and varied in the second (r = 0.39), in all three the value recorded by the highest arm baumanometer was found. In the 3 measurements of the diastolic blood pressure the correlation varied (r = 0.54, r = 0.50, r = 0.59); registering the highest value in the measurement with the arm baumanometer.
Conclusion: The correlation between the measurements with the baumanometers was not perfect, however it was good, it was considered that the measurement of blood pressure with the wrist baumanometer should be done with the wrist at the level of the heart; as well as movements of arm, hand or fingers will alter the result.

Keywords: Blood pressure, Digital Baumanometer. Adults

1. INTRODUCTION

Blood pressure is the force exerted by the blood against the walls of the vessels (arteries) when being pumped by the heart, it takes into account the arterial resistance to the blood flow, the diameter of the arterial light and the blood volume of ejection also called cardiac output [1].

The instrument for measuring blood pressure is the sphygmomanometer, also known as the baumanometer, which records the values in millimeters of mercury (mmHg) by two figures. The larger figure represents systolic blood pressure (SBP); that is, the maximum pressure that is reached in the contraction phase of the myocardium and the lower figure represents the diastolic blood pressure (DBP) that occurs when the myocardium relaxes.

According to the World Health Organization (WHO) [2], blood pressure is classified into five categories according to the values recorded by the baumanometer, where arterial hypertension (AH) is organized at different levels:

Table 1. Categorization of blood pressure figures

Category	Systolic (mmHg)	Diastolic (mmHg)
Ideal blood pressure	< 120	< 80
High normal blood pressure	120-139	80-89
Mild hypertension	140-159	90-99
Moderate hypertension	160-179	100-109
Severe hypertension	≥ 180	≥ 110

Reference: World Health Organization [2]

In people aged 25 years and older, hypertension was diagnosed in 40% of the world during 2008; the number of people affected increased in the year 1980 to 600 million and in 2008 there were already 1,000 million cases [3]. Worldwide, during 2010, hypertension was diagnosed in 40% of adults; in 2012, 31.5% of people with Mexican nationality over 20 years old had already been diagnosed. It is estimated that ≈450,000 new cases are diagnosed annually in Mexico [4].

There are several factors that directly influence the figures obtained in the measurement of blood pressure, within them we can highlight non-modifiable factors such as age, genetic factors, gender and some modifiable socioeconomic factors such as excess weight, obesity, sedentary lifestyle, ingestion of alcohol, tobacco and diet.

People who suffer from hypertension have signs and symptoms that are nonspecific, which is why it is considered a difficult disease to detect, according to the WHO, most people with hypertension do not show any symptoms. Occasionally, hypertension causes symptoms such as headache, shortness of breath, dizziness, chest pain, heart palpitations and nosebleeds, but not always [1].

The detection of hypertension is carried out by measuring blood pressure using the baumanometer following the recommendations of NOM-030-SSA2-2009, which indicates that the systolic and diastolic blood pressure value recorded will correspond to the average of at least two measurements made with a minimum interval of two minutes [6]; taking into account that the person must be in a sitting position, relaxed and with the arm or wrist in which they will measure on some object and it is recommended to do it during the first hour of the morning, using the baumanometer. This study is non-invasive because the pressure exerted on the artery to interrupt the flow through it is external, and the value generated by the pressure inside the artery is equal to the pressure exerted to occlude it.

The first time this method was used was in 1827, the doctor Karl von Basch made measurements of blood pressure using a column of water, but a year later, the physiologist Jean Léonard replaced the water with mercury, in 1860, the doctor Étienne Jules Marey improved the sphygmograph and created the first sphygmomanometer. The version designed by William A. Baum in 1915 is the version that is currently used [5].

Today there are different types of sphygmomanometers which have a very similar functionality have a bracelet that is placed on the arm or wrist, at the bottom have a camera that is inflated with a manual knob or automatically inflate generates a pressure over the artery and prevents blood circulation, when the pressure is higher measures the SBP and when reaching the maximum level it is gradually deflated by the relief valve and there is a small turbulent and noisy blood flow that thanks to the Stethoscope is auscultated and is what is known as Korotkoff sounds.

Baumanometers are classified according to the way they are used, manual and digital sphygmomanometers; The first class in turn are divided into 2 types: the mercury baumanometer consisting of a cell with mercury anchored to a tube that has a scale ranging from 0 to 300 mmHg [5], this is considered the most accurate since It should not be calibrated before use, but it is currently forbidden to use because mercury is a heavy metal and is neurotoxic and considered an environmental pollutant [7].

The other manual type is the aneroid or analog sphygmomanometer that instead of a mercury cuvette uses a needle that is pushed by inner springs, the needle is inside a sphere graduated in mmHg [5], this unlike the previous one is needed calibrate every 6 months apart that in order to use it requires a stethoscope to be able to listen to the patient's Korotkoff sounds.

The digital sphygmomanometers also called oscillometric are divided according to the location of the body where the tension is measured ergo in the arm or wrist, unlike manual digital ones are very easy to use because they do not depend on a stethoscope besides the fact that anyone with no previous experience can use them, this is why it has become so popular today; in both types the operation is the same; the bracelet swells and deflates automatically and shows the results obtained on its screen [5].

The difference between them is the location of where the blood pressure is taken, in case of using the arm, the cuff should be placed at the level of the heart in the same way as the manual blood pressure meter, on the other hand the wrist is placed on a centimeters of the hand.

Although they differ only in location, there are currently many questions regarding the effectiveness and accuracy of the measurement of the wrist baumanometer, since several publications mention that the blood pressure measurements taken on the wrist are usually greater and less precise than those taken in the upper arm. This is because the arteries of the wrist are narrower than and not as deep under the skin as those in the upper arm [8].

However, it is considered that the reliability of the measurement of blood pressure with wrist devices, which has not been previously evaluated in real life circumstances in the general population, depends on the correct position of the wrist device at heart level according to the American Heart Association [9].

This is a method widely used in the home of people who need a continuous check because of its easy use and that in some cases people have a very large arm mainly in obese patients or it can be painful in older adults.

Considering all of the above, just as the health of people with hypertension depends on constant monitoring of the measurement of their blood pressure, a comparison of the effectiveness of both types of digital baumanometers should be considered, since they are currently the most used.

The objective was to identify the correlation between the measurement of systolic and diastolic blood pressure with digital arm and wrist baumanometers in young adults from 18 to 40 years of age from the public University of Celaya, Guanajuato, Mexico.

2. METHODOLOGY

2.1 Study design

An observational, analytical, quantitative, correlational, and diagnostic study was designed.

2.2 Place and Universe of the study

The universe was undergraduate students related to health in a public university in Celaya, Guanajuato, Mexico, with a population of 1910 students.

Simple random sampling was carried out until the sample size was completed.

2.3 Selection of participants

2.3.1 Inclusion criteria

Men or women 18 years of age or older who voluntarily accepted to participate in the study, signed the informed consent and were registered students in the institution.

2.3.2 Exclusion criteria

Those students who did not accept to participate.

2.4 Variables

2.4.1 Sociodemographic

Age, discrete quantitative variable; number of years completed from the date of birth; its scale of measurement is in years and it is summarized with frequencies and percentages.

Gender, dichotomous categorical variable; they are the phenotypic characteristics that differentiate men from women; its measurement scale is male or female and is summarized with frequencies and percentages.

Marital status, nominal categorical variable; it is the state of the physical persons determined by their relations of couple, coming from the marriage, that establishes certain duties and rights; his scale of measurement is single, married, divorced, widowed, separated, free union; it is summarized with frequencies and percentages.

Weight, continuous quantitative variable; is the body mass expressed in kilograms; it is measured on an altimeter, Medidata® digital, without shoes with as little clothes as possible; Its measurement scale is in kilograms and is summarized with mean and standard deviation.

Height, continuous quantitative variable; is the measurement from the feet to the parietal region of the scalp, expressed in meters; it is measured in scale with altimeter, Medidata® digital, without shoes, in erect position and facing forward; Its measurement scale is in meters and it is summarized with mean and standard deviation (s).

BMI, continuous quantitative variable; is the body mass expressed in Kg / m^2; its measurement scale is in Kg / m2; and it is summarized with media and s.

2.4.1 Independent

Measurement of systolic blood pressure; is the hydrostatic force of the blood on the arterial walls that results from the contraction of the heart, it is measured with a humeral digital baumanometer with an adult bracelet, it is measured three times with an interval of two minutes and the average systolic blood pressure is obtained; its measurement scale is in mm Hg; it is summarized with media and s.

Measurement of dyastolic blood pressure; it is the hydrostatic force of the blood on the arterial walls that results from the relaxation of the heart, it is measured with a humeral digital baumanometer with an adult bracelet, it is measured three times with an interval of two minutes and the average of the diastolic blood pressure is obtained; its measurement scale is in mm Hg; it is summarized with media and s.

2.4.3 Dependent

Measurement of systolic blood pressure; is the hydrostatic force of the blood on the arterial walls that results from the contraction of the heart, it is measured with a Rossmax LC 150 digital wrist baumanometer with an adult bracelet, it is measured three times with an interval of two minutes and the average of systolic blood pressure; its measurement scale is in mm Hg; it is summarized with media and s.

Measurement of dyastolic blood pressure; it is the hydrostatic force of the blood on the arterial walls that results from the relaxation of the heart, it is measured with a digital wrist baumanometer with an adult bracelet, it is measured three times with an interval of two minutes and the average blood pressure is obtained diastolic; its measurement scale is in mm Hg; it is summarized with media and s.

2.5 Procedures

After the approval of the protocol by the Bioethics Committee, authorization was requested to the University directors to contact the students. They were informed of the study objectives and their potential benefits and risks; the questions they had to ask were answered; they were asked to sign the informed consent. Those who agreed to participate answered the general questionnaire about sociodemographic data and proceeded to the measurement of blood pressure. To start the procedure, the participant was kept at rest for 10 minutes; the participant's wrist was placed at the height of the heart and remained in that position during the measurements, after the rest period, the wrist baumanometer bracelet Rossmax LC 150 was placed on the non-dominant wrist and the measurement was made; after the initial reading, the bracelet was removed and after two minutes, the second measurement was made; the bracelet was removed again for two minutes and replaced for the third measurement.

At the end of the third measurement with the wrist baumanometer the participant was kept at rest for 10 minutes and the first blood pressure measurement was performed with the digital arm baumanometer; it was removed, 2 minutes were waited and the second measurement was made and again 2 minutes later the third measurement was made.

2.6 Sample size

Assuming there is a Pearson’s r of 0.5 between the measurements of the two baumanometers, the minimum sample size is 37 subjects with 95% precision and 90% power (Epidat 4.1, 2014, Xunta de Galicia, Spain; Pan American Health Organization (PAHO-WHO), CES University, Colombia).

2.7 Statistical analysis

For the sociodemographic variables, descriptive statistics were used. To identify the correlation and possible linear relationship, Pearson's r, linear regression equation, t test, *P* value, and 95% confidence intervals are used. Also, we calculated ANOVA between each two measures. To demonstrate the statistical significance of the results, the value of *P* was set at .05. The statistical analysis was performed in STATA 13.0 ® (Stata Corp., Colege Station, TX, USA).

RESULTS AND DISCUSSION

A higher rate of women was found, indicating a frequency of 287 of the participants, their residence was more frequent in the urban area with a frequency of 313 than was expected due to the place where the participants were recruited; more than 90% of the participants shared the single marital status, however there are, although in minimal amounts, people in each category (Table 2).

In another study conducted in Greece where the sample used was 81 having a higher frequency for females with 43 participants (54%). The study covers a correlation between two types of digital strain gauges for the arm and arm [10].

Table 2. Characteristics Categorical sociodemographic sample

Variable		f	%
Gender	Man	110	27.71
	Woman	287	72.29
Residence	Urban	313	78.84
	Suburban	57	14.36
	Rural	27	6.80
Civil status	Single	377	94.96
	Married	14	3.53
	Separate	1	0.25
	Divorced	1	0.25
	Free union	4	1.01

The average age was 21.41 years which was expected to be students of higher level (Table 3), compared to the study in Greece [10] and Italy [9] where the average age was 56.7 ± 11, 8 years and 49.3 ± 15.4 respectively; another variable also involved in the investigation was the average weight and height was 65.28 kg ± 15.08 and 1.63 m ± 0.09 respectively, this indicates that the weight in this sample was not very high although there were participants up to 171 kg, these values differ of the means of the investigation of the study in Greece [10] where a value of or 168.1 ± 9.6 cm and 79.2 ± 18 kg of height and weight respectively was recorded. The average BMI corresponds to the adequate mean in the sample although there was a BMI of up to 55 kg / m2 (Table 3); On the other hand, in the study in Greece [10], it reached a value of 27.8 ± 5 kg / m2; the highest value can be observed in the study of Greece due to the higher value in weight.

Table 3. Quantitative sociodemographic characteristics of the sample

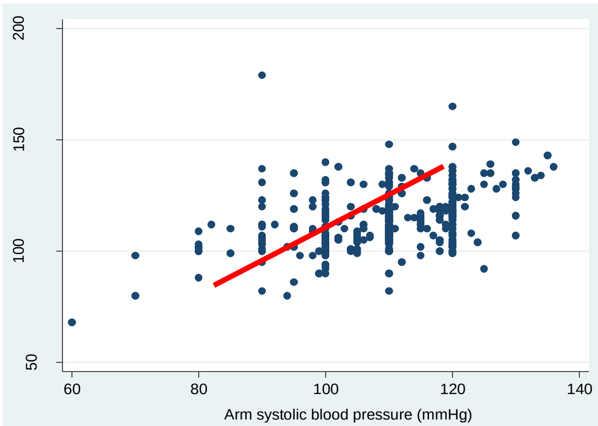
Variable	Range	Mean ± SD.

Age (years)	17 - 51	21.41 ± 3.08
Weight (kg)	38.7 - 171.2	65.28 ± 15.08
High (m)	1.17 - 1.98	1.63 ± 0.09
Body mass index (kg/m^2)	16.1 - 55.37	24.41 ± 4.40

Having a sample of 397 the correlation between the measurement of the systolic blood pressure with the digital arm and wrist baumanometer varied in the second measurement carried out having a value of 0.39 unlike that obtained in the first and third measurements where the correlation it was 0.46; taking into account that the measurement of the SBP had different values in the three measurements and differed according to the type of baumanometer used, highlighting that the value measured by the wrist baumanometer was smaller having the largest difference in the first measurement (Figure 1).

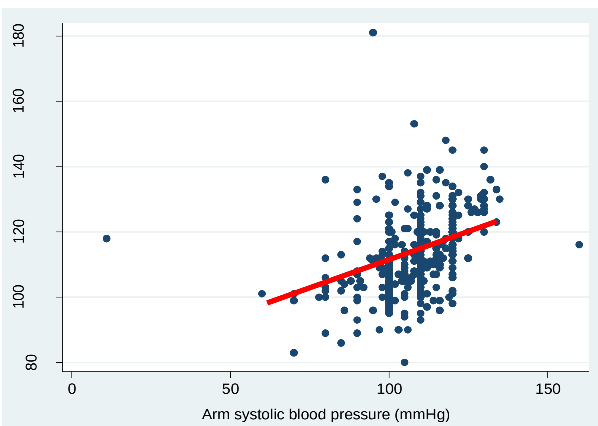
In the study conducted in Greece, an average of the SBP measured in the arm of 132.4 ± 13.0 mmHg was recorded, being greater than the values measured in the wrist 127.2 ± 11.7 mmHg; being able to observe the measurement between both had a difference of ≥10 mm Hg [10]. These values are similar to those obtained in the research emphasizing that the values recorded by the wrist baumanometer are greater.

In contrast to the values obtained, the results of a study about the poor reliability of the self-measurement of wrist blood pressure in the home by Edoardo Casiglia et al., in Italy; in which they used a sample of 721 unselected subjects using wrist balanters (UB-542) and arm (UA-767 Plus) they found a discrepancy between the measurement in two different places because in the office, the systolic blood pressure was 2.5 % lower in the wrist than in the arm (P = 0.002), while in the home, the systolic and diastolic blood pressures were higher in the wrist than in the arm + 5.6% and + 5.4%, respectively; P <0.0001 for both [9].



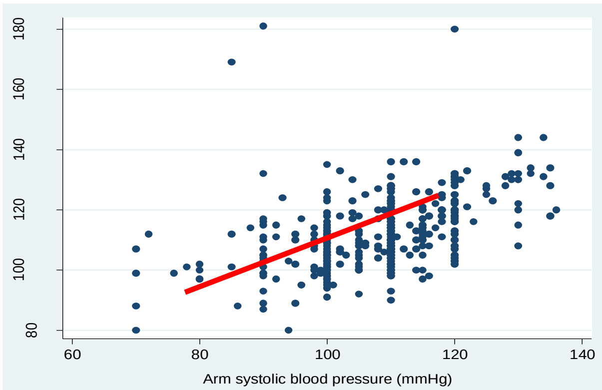
Measurement 1

n=397
r = 0.46
Wrist systolic blood pressure (mmHg) =59.00 + 0.50 Arm systolic blood pressure (mm Hg)
t= 10.16 *P*=.0001
IC95% 0.40 to 0.60
Anova F=3.76, *P*=.00001



Measurement 2

n=397
r = 0.39
Wrist systolic blood pressure (mmHg) =72.87 + 0.37 Arm systolic blood pressure (mm Hg)
t= 8.47 *P*=.0001
IC95% 0.28 to 0.45
Anova F=3.73, *P*=.00001



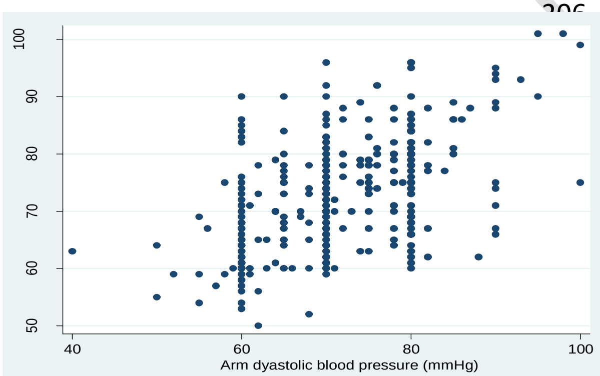
Measurement 3

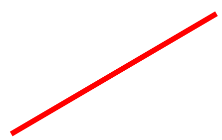
n=397
r = 0.46
Wrist systolic blood pressure (mmHg) =59.86 + 0.48 Arm systolic blood pressure (mm Hg)
t= 10.50 *P*=.0001
IC95% 0.39 to 0.57
Anova F=4.16, *P*= .00001

Figure 1. Correlation and linear regression among blood pressure systolic in arm and wrist

Repeating the sample of 397 the correlation between the three measurements of the PAD varied, the highest obtained was in the third measurement; it is noteworthy that the measurement of the PAD by the digital wrist baumanometer is greater than that measured by the arm baumanometer [Figure 2].

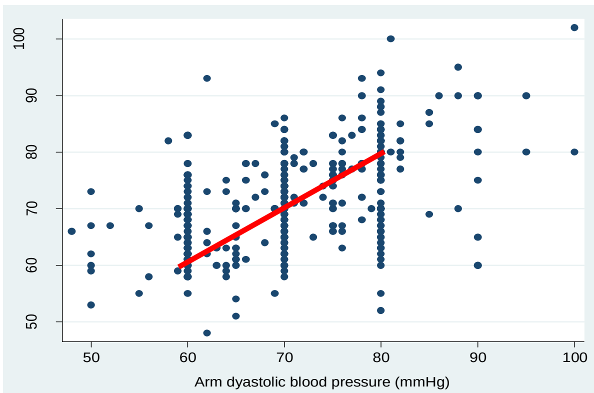
The opposite was observed in the investigation in Greece where the average of the PAD measured in the arm of 79.7 ± 9.1 mmHg being higher compared to the values measured in the wrist 77.5 ± 9.7 mmHg, being the measurement in the arm the highest value [10] These values are similar to those obtained in the Edoardo Casiglia et al., study in Italy [9], where systolic and diastolic blood pressures were greater in the wrist than in the arm (+ 5.6% and + 5.4%, respectively; P <0.0001 for both). Unlike both studies, Casiglia et al., did not obtain significant differences (-0.7% for diastolic).





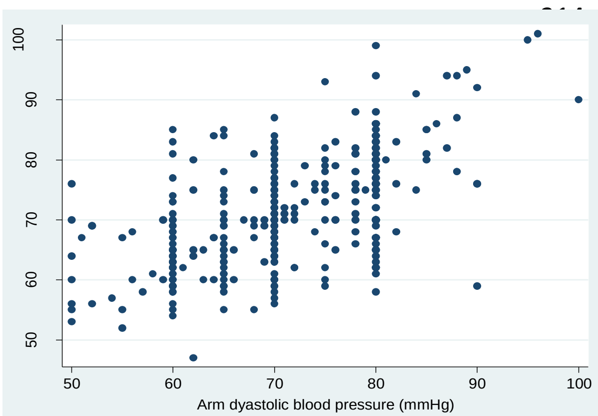
Measurement 1

n=397
r = 0.54
Wrist diastolic blood pressure (mmHg) = 32.03 + 0.56 Arm diastolic blood pressure (mm Hg)
t= 12.78 *P*=.0001
IC95% 0.48 to 0.65
Anova F=5.55, *P*= .00001



Measurement 3

n=397
r = 0.59
Wrist diastolic blood pressure (mmHg) = 29.10 + 0.59 Arm diastolic blood pressure (mm Hg)
t= 14.48 *P*=.0001
IC95% 0.51 to 0.67
Anova F=5.95, *P*= .00001



Measurement 2

n=397
r = 0.50
Wrist diastolic blood pressure (mmHg) = 36.48 + 0.49 Arm diastolic blood pressure (mm Hg)
t= 11.61 *P*=.0001
IC95% 0.41 to 0.58
Anova F=5.44, *P*= .00001

Figure 2. Correlation and lineal regression among blood pressure diastolic in arm and wrist

According to the three measurements of the systolic blood pressure with the digital wrist and arm baumanometer, the mean difference was obtained for each measurement; the difference between the values obtained in each measurement with each type of baumanometer was positive, and a P value (0.00001) indicative of the mean difference is not equal to 0, demonstrating that the values obtained with the wrist baumanometer were greater (Table 4).

According to the three measurements of the diastolic blood pressure, the first one coincides with the positive value in the difference of the measurements with both types of baumanometer having a value of *P*=.02, different from 0, indicating that the value obtained in the measurement with the baumanometer of wrist was greater; in comparison to the second and third measurements in which the *P*-value were .16 and .73, indicates that there is not difference between mean of differences in both measures the two types of baumanometers (Table 4).

Table 4. Mean differences between systolic and diastolic blood pressure measurements with wrist and arm baumanometer

Measures	**Range**	**$\bar{x}_d \pm S$**	**t**	**df**	***P*-value**
Systolic 1	-33 a 89	4.60 ± 12.79	7.17	396	0.00001
Systolic 2	-44 a 107	4.64 ± 13.57	6.81	396	0.00001
Systolic 3	-22 a 91	4.28 ± 12.29	6.94	396	0.00001
Diastolic 1	-26 a 30	1.05 ± 8.73	2.40	396	0.02
Diastolic 2	-30 a 31	0.61 ± 8.69	1.40	396	0.16
Diastolic 3	-31 a 26	0.14 ± 8.05	0.35	396	0.73

S= standard deviation, $\bar{x}_d$= mean of difference, df= degrees of freedom

With respect to the results obtained from blood pressure measurements with digital wrist and arm baumanometers, a similarity was found in the values of systolic blood pressure in the study conducted in Greece, where in both studies the values recorded by the digital wrist baumanometer were greater than those recorded by the arm baumanometer; these results differ with the study conducted by Edoardo Casiglia et al., in Italy, where lower values were found using the wrist baumanometer.

The results coincided with the first measurement of the diastolic blood pressure since the values recorded by the digital wrist baumanometer were higher than those recorded by the arm baumanometer, however for the second and third measurements the values recorded by both types of baumanometer They were almost similar but not exactly the same. Conversely, studies conducted in Greece and Italy recorded lower values of diastolic blood pressure with the digital wrist baumanometer.

This reflects the dissimilarity that exists in the measurement of blood pressure using the digital wrist and arm baumanometers, where the values can vary upwards or downwards.

The research had strengths as they were the response of the participants to agree to be part of the investigation, none was rejected since all met the requirements and measurements.

Among the weaknesses is the fact that, although it was supervised, that the wrist with the baumanometer placed at the height of the participant's heart and that they did not move their fingers or their hand, a measurement bias could be possible.

CONCLUSION

The correlation between the measurement with the digital wrist and arm baumanometers was not perfect, however it was good (r = 0.50), it was considered that the BP measurement with the wrist baumanometer should be done with the wrist at the level of the heart; placing it below or above, as well as movements of arm, hand or fingers will alter the result.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

CONSENT

All participants signed the consent form.

ETHICAL APPROVAL

Reviewed and approved by the research and bioethics committees of the division of health sciences and engineering of the Celaya-Salvatierra campus of the University of Guanajuato, with the registry **CIDCSIC-0911204**.

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