Original Article

Arm and forearm blood pressure measurements as a function of cuff width*

Medida da pressão arterial no braço e antebraço em função do manguito

Medida de la presión arterial en el brazo y antebrazo en función del manguito

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ABSTRACT

Objective: To identify and compare arm and forearm blood pressure measurements using appropriate cuff sizes versus a usual standard cuff. **Methods**: A cross-sectional comparative study was used. Blood pressure was measured in 103 individuals using a 0.40 cuff width and 0.80 cuff length on both segments and followed by a measure with a usual standard cuff after one minute. Arm and forearm circumferences were measured at the middle point. **Results**: Significant differences indicated overestimation of diastolic blood pressure in the forearm. These differences were lower than differences reported in other studies. Korotkoff sounds were improved after Forsberg's maneuver. **Conclusion**: Although, we found an overestimation of diastolic blood pressure in forearm, other studies suggest that the use of appropriate cuff sizes in the forearm derive more accurate measures of diastolic blood pressure. There is a need to study further measurements of blood pressure in the forearm.

Keywords: Blood pressure determination/methods; Blood pressure; Arm; Forearm; Hypertension

RESUMO

Objetivo: Identificar e comparar os níveis de pressão arterial no braço e antebraço usando manguitos de dimensões apropriadas e o manguito padrão. **Métodos:** Estudo transversal com 103 indivíduos, aplicando a razão circunferência braquial (CB) /largura de manguito de 0,40 nos dois segmentos, e registros com o manguito padrão após um minuto. razão CB /comprimento do manguito de 0,80, correto ou padrão, circunferências medidas no ponto médio de cada segmento. **Resultados:** Diferenças significativas indicaram hiperestimação da pressão diastólica no antebraço, menor daquela observada em outros estudos. A manobra de Forsberg melhorou a audibilidade dos sons de Korotkoff. **Conclusão:** Os achados indicam que o manguito correto diminui a hiperestimação dos registros diastólicos observada por outros autores. O avanço no conhecimento da medida no antebraço requer outros estudos.

Descritores: Determinação da pressão arterial/métodos; Pressão arterial; Braço; Antebraço; Hipertensão

RESUMEN

Objetivo: Identificar y comparar los niveles de presión arterial en el brazo y antebrazo usando manguitos de dimensiones apropiadas y el manguito patrón. **Métodos:** Se trata de un estudio transversal realizado con 103 individuos, aplicando la razón circunferencia braquial (CB) /ancho del manguito de 0,40 en los dos segmentos, y registros con el manguito patrón después un minuto, razón CB /largo del manguito de 0,80, correcto o patrón, circunferencias medidas en el punto medio de cada segmento. **Resultados:** Diferencias significativas indicaron hiperestimación de la presión diastólica en el antebrazo, menor de aquella observada en otros estudios. La maniobra de Forsberg mejoró la audibilidad de los sonidos de Korotkoff. **Conclusión:** Los hallazgos indican que el manguito correcto disminuye la hiperestimación de los registros diastólicos observada por otros autores. El avance en el conocimiento de la medida en el antebrazo requiere de otros estudios.

Descriptores: Determinación de la presión sanguínea/métodos; Presión sanguínea; Brazo; Antebrazo; Hipertensión

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INTRODUCTION

The necessity of maintaining the blood pressure (BP) at levels of 80 by 120mmHg, to guarantee physical balance and prevent cardiovascular disorders, requires a blood pressure measurement procedure without errors. Nevertheless, the sources of errors resulting in inaccurate blood pressure readings have become a common issue in academic and health care environments[1].

Among the different sources of mistakes related to the observer (person who measures the pressure)[2], to the instrument[3], to the environment[4], and BP alterations introduced by the client himself/herself due to emotional reasons at the presence of his doctor figure[5], this paper aims to discuss the effect of the cuff size in the BP measurement. The problem identified by Von Recklinghausen in 1901, demonstrating that Riva Rocci´ sphygmomanometer cuff was too narrow and would overestimate BP readings[6], is still a challenge to be faced by the hypertension societies[7]. The 12cm cuff width proposed by the Germanic scientist and still largely used can overestimate BP readings in the large arms and underestimate in the thin ones. In an attempt to prevent such errors the *American Heart Association* (AHA) established in 1951 that the cuff width (CW) should be 20% larger than the arm diameter , which corresponds to a ration between the arm circumference (AC) / CW of 0,40[8].

The associations observed among the metabolic syndrome, diabetes and hypertension, have leaded to researcher´ efforts to find solutions for the problem of false high levels at obese people. In 1956, it was suggested that the errors generated by measurement in the very large arms would favor the proposal of using the forearm as an alternative site[9]. However, the overestimated diastolic BP registers and the Korotkoff Sounds inaudibility at this local created a controversial discussion regarding the radial auscultation[10-11] since the sixties, what resulted in the forearm abandonment as an alternative measurement site.

The increase of obesity rates throughout the world in the last decades[12] brought up the old cuff size controversy. Cuffs larger than the standard cuff would prevent false or imprecise diagnosis of hypertension in persons with large arms. The blood pressure overestimation due to narrow cuffs leading to overtreatment results in important side effects (fall offs, etc) as a consequence of blood pressure levels decrease. The market development of different devices as pulse monitors has stimulated other BP measurement studies in the forearm, being some authors favorable[13] and others contrary to use this site as alternative to upper arm.[14].

It was not detected in the mentioned studies, however, the use of cuffs width 40% of the arm or forearm circumference. Besides that several of them apply pulse monitors. In the studies trying to validate forearm measurements, only the standard cuff 13cm large and 23cm long was used at the arm and forearm. The use of just one cuff size in both sites may have introduced an important methodological bias to the comparisons made. In what regards the inaudibility of the Korotkoff Sounds in some individuals, a procedure was concisely described to be applied in order to enhance and make the auscultation possible in a situation of sound absence[15], and has been recently tested by the authors of this study[16].

Arm blood pressure measurement is impractical in catheterized people, or in those presenting upper arm lesions. The radial artery can be easily accessed as an alternative site. However, it has been demonstrated unprepared and lack of knowledge to perform the measurement at alternative sites[17], which results in waste of time and lack of professional nurse competence.

The differences between the measurement in radial and brachial arteries are still insufficiently established in the literature, and no studies have adopted the theoretical reference of the AHA (AC/CW 0,40), which leaves room for further research. Considering that currently the invasive procedures are not indicated, which BP values could be recorded in auscultatory measurements using appropriate cuff size in arm and forearm?

OBJECTIVE

To identify and compare arm and forearm blood pressure readings as a function of standard cuff width and correct cuff width (CCW: AC/CW = 0,40).

METHODS

A cross sectional study was performed with a convenience sample, initially constituted of 103 volunteers of a university in São Paulo State countryside: 94 students, 5 employees, and 4 faculty members, equivalent to 35.6%, 50% and 30.7% of these categories, respectively. The study subjects‘ selection criteria were: ages between 17 and 50, absence of arterial diseases diagnosis, or arm limitations, absence of pharmacological treatments which use vessel-active drugs, or pregnancy. The data collection occurred after the project approval by the superior education institution Ethics Committee, in a city in São Paulo’s countryside, in compliance with Resolution n.º 196/96, and having the participants signed the Informed Consent Term (ICT).

Instruments and equipment used – A clinic file type of questionnaire, containing items and questions regarding demographic data and BP measurements. A double stethoscope to train two observing nurses, aneroid

sphygmomanometers Tycos®, tested against the mercury manometer, a kit with 5 different cuff widths, ranging from 7.5 to 13 cm; stethoscopes Litmam® and a tape measure Fiberglass®, chairs with backboards and supports for the correct arm position.

Blood pressure measurement – The SCW and CCW measurements were performed at one-minute intervals, according to 1993 AHA guidelines[18], to Arcuri's protocol for CCW use[19], and to the recommendations of the V Brazilian Statement for Hypertension[20]. In cases of lack of sounds in the forearm, the Forsberg[15] maneuver was applied. It consists of a request for the participant to close the right fist and to use the counter lateral hand to press over the cuff. After approximately one minute, the site would be released from the compression. At that moment the pressure would start being measured again.

After the measurement procedure explanation by the observer, the ICT signature by the volunteer, and demographic data register in the clinic file, the participant was requested to seat comfortably at the chair prepared for the procedure. The right arm was positioned over the support, so as to be at the level of the heart (at the 4th intercostal space level). The participant was asked to rest and relax for five minutes. The arm circumference was measured at the medium point of acromium and olecranum, and the forearm one between at the medium point of olecranum and styloid process of the ulna and radio. By analogy, the same circumference and blood pressure measurement criteria were used in both the arm and forearm. At each site, blood pressure was measured with the SCW and after one minute with the CCW. The subject was asked to remain relaxed during all the measurement procedure, without moving or talking, mainly at the moment of cuffs exchange. In all brachial and radial measurements, the systolic pressure was registered at the first Korotkoff Sound and the diastolic at the fifth.

RESULTS

From the 103 individuals who agreed to participate in the research, it was not possible to listen to the Korotkoff Sounds in 31 of them due to the absence or poor quality sounds. The Forsberg Maneuver application propitiated great audibility in 11 of them, resulting in a final sample of 83 volunteers.

Demographic data: from the 83 volunteers, 77% were females aged 17 to 33, covering 74% of the total initial sample, indicating a population constituted of young individuals; 81% had white skin, 62% of the subjects were in the normal body mass index category between 18.5 and 24.9. Most of the volunteers did not practice sports during the week (74,7%), and those who practice physical exercises, only did it sporadically. The rate of 86.4% of the subjects did not use tobacco, and 53.3% reported having hypertension cases in the family.

The arm circumference reached a high average for the age group, 29.5cm, being the minimum value 23cm and maximum 39cm. The overweight in 20% of the sample, added up to the fraction of obese people, contributed to the AC average values increase. The standard deviation of 3.6cm is justified by the normal variation that occurs in the arm dimensions of some lean women with thin arms and the large arms of obese subjects participating in the sample.

Figures 1 and 2 allow a comparison of the values between the systolic blood pressure (SBP) at the arm and forearm as function of the cuff employed and Figures 3 and 4 allow the same comparison for the diastolic blood pressure (DBP).

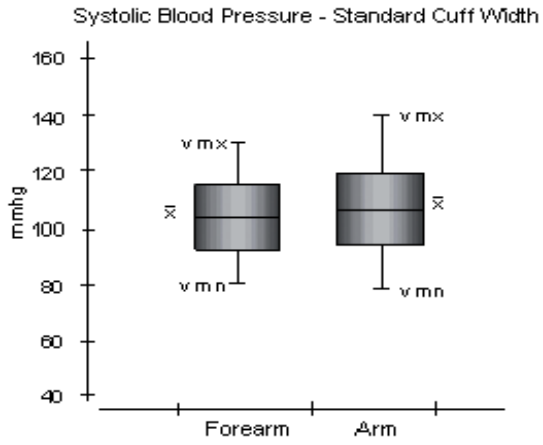

Figure 1 – Arm and forearm systolic blood pressure with the standard cuff width (SCW): mean ($\bar{x}$); maximum value (mx v); minimum value (mn v).

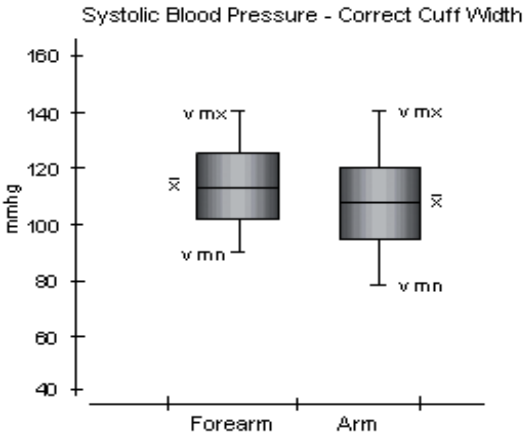

Figure 2 – Arm and forearm systolic blood pressure with the correct cuff width: mean ($\bar{x}$); maximum value (mx v); minimum value (mn v).

The analysis of Figures 1 to 4 reveals that the standard cuff width registers are lower both for the systolic and diastolic levels, with no significant differences between arm and forearm, which differs from some studies and is similar to others. However, regarding the comparison between the two register sites using the correct cuff widths, significant differences were found, reaching 5.7 mmHg in systolic ($p< 0.05$) and 7.6 mmHg in diastolic DBP ($p< 0.05$) readings, values of BP considered enough to change the hypertension classification and diagnosis in *guidelines*(20). The highest levels registered at the forearm confirm the overestimation observed by other authors. It is noteworthy, though, that the standard deviation in the arm is higher than in the forearm, as well as the discrepant maximum and minimum values.

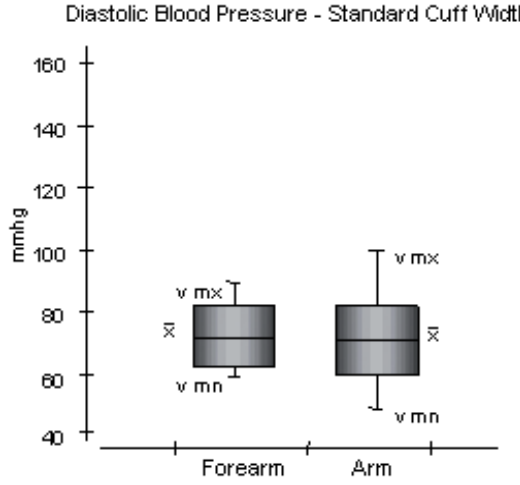

Figure 3 – Arm and forearm diastolic blood pressure with the standard cuff width (SCW): mean ($\bar{x}$); maximum value (mx v); minimum value (mn v).

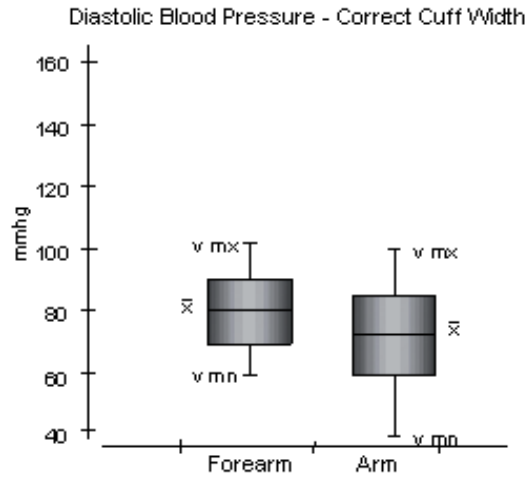

Figure 4 – Arm and forearm diastolic blood pressure with the correct cuff width (CCW): mean ($\bar{x}$); maximum value (mx v); minimum value (mn v).

DISCUSSION

The analysis of the demographic characteristics reveals the predominance of young females in the sample, which was expected for a study made in a Nursing Department, where most of the students are females. From the ethnic point of view, 80% of white people would be expected. It is remarkable to verify the participation of only one yellow volunteer in a city located in São Paulo countryside, a state with a relevant percentage of such ethnic groups.

Systolic blood pressure – The comparison of blood pressure levels registered by the SCW did not result in significant statistical differences, probably due to the AC large width, close to 30cm, for which the SCW is ideal. It is also necessary to consider in studies of this nature, that the overestimation for large arms and the underestimation for thin arms, as indicated by the standard deviation (corrected), maximum and minimum values, may increase or decrease the average values, respectively. If the number of subjects with thin arms is equivalent to the number of subjects with large arms, part of the values that are too discrepant may be nullified when calculating the difference between the blood pressure averages.

The similar results obtained at the arm as a function of the cuff width, differ from the ones observed in a study conducted at São Paulo University (USP) campus in 1985[19], where the students had thinner arms than the ones who participated in this study. Differences higher than 10mmHg were observed between the registers of SBP with the SCW and the CCW. The demographic analysis reveals other two differences between the two populations in discussion: the strong presence of Japanese descendant students in the USP, around 9% in a sample of 900 adults, versus approximately 1% in the Araras. As observed in the Asian biotype, many Japanese people and their descendants, mainly females, have thinner or smaller arms than the European descendants, as it was noticed among the studied students of São Paulo city.

Another aspect is the difference between the body mass index in the two compared samples studied in 1983 and in 2006. It was verified that 20% of young individuals presented overweight and most of them were sedentary. It is known that the obesity indexes have doubled for children and have tripled for adolescents. Changes in the behavior of young individuals has been characterized by an increase of beer, sandwich, and snacks consumption, as it was certified by a recent study related to children's obesity prevention[21]. Furthermore, students become beer consumers in pubs localized near many universities.

The levels of SBP in several participants did not reach 110 mmHg and were even lower than the ones registered by the CCW from the study in 1983, whose mean was close to this value. It is possible that the season (sum-

mer) when the data collection was performed has contributed to such results, due to the high temperature of those days, which may have interfered in the vascular compliance and slightly decreased the pressure levels. The authors of the present study consider a bias the lack of control over the environmental temperature, a variable that is not controlled in most of the epidemiologic studies. Another aspect that deserves to be highlighted is the subjects prepare for the ´BP measurement procedure, requesting physical end mental relaxation for 5 minutes, which allows the pressure to reach levels close to steady state ones. The volunteers familiarity with the environment and with the observers may have also contributed to prevent an increase in alertness, and besides that, the population was young.

As to the comparison between the levels of SBP registered at the arm and forearm as a function of the cuff width, the differences are higher when measuring with the CCW. In a study using the SCW, the authors[22] verified significant differences between the levels of BP in the brachial and radial arteries, and the systolic levels average was 6 mmHg lower at the forearm. In three extremely obese people, the systolic differences reached levels between 60 and 140 mmH.

The fact that the SCW was inappropriate to be used in the forearm due to its width should result in underestimated SBP readings. However, it did not occur in this and in other studies, for most of the subjects. The lack of knowledge on how to measure the BP at the forearm makes it impossible to understand better the observed phenomenon. There is specific literature regarding the studies that associate high pressure levels with changes in the forearm blood flow, which may be provoked by the application of different stimulus, like thermal[23-24]. Nevertheless, such studies were never mentioned by the authors who studied the forearm pressure measurement.

Diastolic blood pressure – The DBP registers differ from the SBP's at the arm and forearm, reaching significant statistic levels for the CCW measurement, due to the overestimation of the diastolic pressure at the forearm. Takes attention, though, the relevant standard deviation for the SCW registers at the arm, probably due to some obese subjects with larger arms.

In Rytand and Boyer's[22] study the diastolic levels were 6 mmHg higher at the forearm, but the differences found in the studied patients ranged from 20 to 85 mmHg. By comparing intra-arterial registers with indirect registers at the arm and forearm, some authors[9] concluded that in individuals that were too obese, the forearm registers represented the intra-arterial levels better. Such statement is contrary to other authors'[25], whose comparisons between direct and indirect registers in 1987 resulted in the abandonment of the forearm measurement due to a relevant DBP overestimation.

When measuring the pressure in the brachial and radial arteries, Tachovsky[26] obtained lower systolic and higher diastolic values in the forearm, 7.5 mmHg and 14.10 mmHg, respectively. The author also used the Forsberg maneuver, although not much is informed on this matter. Another resource was the use of an infant stethoscope, stating that its diaphragm better adapts at the forearm auscultation site. Another author[10] that used the infant campanula described the exact site it has to be allocated: *"the bell is placed over the junction of the superficial palmar branch and the main trunk of the radial artery*", which correspond to the radial pulse site". The enhanced audibility with the infant stethoscope campanula was also verified in another study[27].

The BP differences in arm and forearm were also studied in a weekly prospective study, where it verified a correlation index of 0.75 to systolic and 0.72 to diastolic BP values. Such results allowed the conclusion that the forearm measurement is a good indicator for most patients, and should be used when it is not possible to perform the measurement procedure at the arm. Nevertheless, similar indexes (0.73 and 0.67 respectively) were observed in another Brazilian study[14] comparing the forearm readings with those registered by *Finapres.* The significant higher BP readings led the authors to consider the forearm measurement inadvisable because it could increase the hypertension prevalence in obese individuals[28]. The *American Heart Association* blood pressure measurement Committee considers the forearm measurement possible, but reminds that it is not largely used due to the possibility of obtaining false high diastolic values[29].

The usage of SCW and CCW resulted in smaller differences than the ones observed by other authors. The increase in DBP at the forearm remains being a challenge to be overcome, once many aspects that make the measurement controversial were not properly studied. The accumulated knowledge so far does not allow a clear comprehension of the difficulties that occur at the forearm, even decades after the forearm BP measurement had been suggested as an attempt to solve problems regarding the standard cuff inadequacy at large arms. BPM is the nursing procedure most performed in the world. The authors stimulate the teaching of the forearm blood pressure measurement in the Nursing Graduation Course, by considering a matter of professional competence. Several times, the brachial artery measurement is not feasible and there is a lack of knowledge to perform it in alternative sites.

CONCLUSIONS

The findings of this study confirm a significantly higher diastolic blood pressure level at the forearm registers, which was observed mainly when using cuffs widths that corresponded to 40% of the arm and forearm circum-

ferences. The authors recognize the need for other studies with the referred method, as multi-centric studies. It is important to improve the knowledge about the Korotkoff Sounds auscultation in the radial artery and at other alternative sites, taking into account the relevant number of very large arms or other conditions that make impossible the blood pressure measurement procedure to be performed in the upper arm.

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