Validity of a Wrist Digital Monitor for Blood Pressure Measurement in Comparison to a Mercury Sphygmomanometer

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Abstract

Background: **Valid measurements of blood pressure, both at clinical and community settings, are essential for monitoring this variable at the population level.**

Objective: **To evaluate the validity of a wrist digital monitor for measuring blood pressure among adolescents in comparison to a mercury sphygmomanometer.**

Methods: **A validation study was carried out in the city of Pelotas, Southern Brazil. Blood pressure was measured twice using two different sphygmomanometers; an OMRON wrist digital and a desktop BD mercury one. Half of the sample was measured first with the digital manometer and subsequently with the mercury one, whereas the remaining half was evaluated in the opposite order. Agreement between both measures was evaluated using the Bland and Altman method.**

Results: **120 adolescents aged 14 to 15 years were included (50% of each sex). Mean systolic blood pressure among boys was 113.7 mmHg (SD 14.2) when using the mercury manometer and 115.5 mmHg (SD 15.2) when using the digital one. Equivalent values for diastolic blood pressure were 61.5 mmHg (SD 9.9) and 69.6 mmHg (10.2), respectively. Among girls, the mean systolic blood pressure was 104.7 mmHg (SD 10.1) when using the mercury manometer and 102.4 mmHg (SD 11.9) when using the digital device. Values for diastolic blood pressure were 60.0 mmHg (SD 10.4) and 65.7 mmHg (SD 7.7), respectively.**

Conclusions: **The digital device showed a high level of agreement with the mercury manometer when measuring systolic blood pressure. The level of agreement was lower for diastolic blood pressure. The use of correction equations may be an alternative for studies using this wrist digital monitor in adolescent patients. (Arq Bras Cardiol 2010; 94(3):345-349)**

Key words: **Blood pressure monitors; blood pressure determination; sphygmomanometers; validation studies; adolescent.**

Introduction

An accurate assessment of blood pressure is very important for the diagnosis and treatment of hypertension. The importance of attaining the diagnosis of high blood pressure and its continuous monitoring are well known. Therefore, several equipments have been available for the measurement of blood pressure, not only to be used by specialized individuals, but also by the population itself. In this sense, wrist digital monitors have been increasingly used, instead of mercury and aneroid devices, which require a trained professional to operate them[1,2].

Although digital monitors are much easier to use when compared to the mercury sphygmomanometers, it is essential to establish their reliability and validity. There is some evidence in the literature that wrist digital monitors are reliable and accurate when compared with other devices, such as the aneroid or mercury devices[3,4]. It seems that this type of equipment can replace the others in some contexts, such as at home or in epidemiological studies within the community[5]. However, most studies so far included only adults, and therefore, the validity of these methods among adolescents in unclear.

The aim of the present study was to test the validity of a wrist digital monitor against that of a mercury sphygmomanometer – the gold standard - in a convenience sample of adolescents living in Pelotas, southern Brazil.

Methods

A sample of 120 adolescents aged 14 to 15 years from five public schools of the city had their blood pressure measured with two different sphygmomanometers – a desktop BD

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mercury and a wrist digital (OMRON HEM 629, Beijing, China) - by two trained technicians. A Tycos stethoscope was used with the mercury sphygmomanometer. The students were allowed to rest for 10 minutes prior to the measurements. Their height was measured twice using a stadiometer accurate to 0.1 cm (Seca, Birminghan). All adolescents were sitting on a chair with support for their backs and arms, with the legs uncrossed, and the right arm and wrist were used for the measurements. Each adolescent had his/her blood pressure measured twice with one minute of difference between each measurement; thus, venous congestion was prevented and the variability of BP was kept to a minimum[6].

For half of the sample, the mercury sphygmomanometer was used first; for the remaining half, the opposite order was used. This selection was carried out randomly. The technicians used both sphygmomanometers (mercury and digital) alternatively, which prevented the first and second observer from seeing each other's measurements. The digital monitor was used following the manufacturer's instructions contained in the user's manual and special attention was paid to the position of the monitor, which should be at the level of the heart[7]; the mercury sphygmomanometer was used according to the technique recommended by the American Heart Association[8]. The average of the measurements by each technician was calculated and this value was considered for the analyses; the same was done for height.

The statistical analyses included a description of blood pressure variables using percentiles, means and standard deviations. Spearman's correlation coefficients were calculated for systolic and diastolic blood pressure, by comparing the digital and mercury manometers. Agreement was measured using the Bland and Altman[9] method. Mean differences and standard deviations were calculated. We also performed sensitivity, specificity, predictive values and kappa analyses for the categorical outcome 'pre-hypertension', defined in accordance with The Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents[10]. All analyses were performed for boys and girls separately, except for the categorical analyses, because results were very similar for both sexes.

The Ethical Committee of the Federal University of Pelotas Medical School approved the study protocol, and informed consents were obtained.

Results

Of the 120 adolescents included in the study, 60 were boys. Mean age was 14.7 years (SD 0.46), ranging from 14.0 to 15.9 years. Mean height was 1.64 m (SD 0.8) in the whole sample, 1.67 m (SD 0.8) among boys and 1.61 m (SD 0.6) among girls. Table 1 presents descriptive data on blood pressure. Mean systolic blood pressure for boys was 113.7 mmHg (SD 14.2) when using the mercury manometer and 115.5 mmHg (SD 15.2) when using the digital one. Equivalent values for diastolic blood pressure were 61.5 mmHg (SD 9.9) and 69.6 mmHg (10.2), respectively. For girls, the mean systolic blood pressure was 104.7 mmHg (SD 10.1) when using the mercury manometer and 102.4 mmHg (SD 11.9) when using the digital device. Values for diastolic blood pressure were 60.0 mmHg (SD 10.4) and 65.7 mmHg (SD 7.7), respectively. Median values (50th percentile) were very similar for systolic blood pressure, but substantially different for diastolic blood pressure.

Figure 1 shows the agreement between the two devices for measuring systolic blood pressure in the overall sample. Spearman's correlation coefficient was 0.74. The mean difference (digital – mercury) was -0.3 mmHg (SD 9.2) and it was not statistically different from zero (P=0.75). Figures 2 and 3 present these data for boys and girls separately. The mean difference was positive for boys (1.8 mmHg; P=0.15) and negative for girls (-2.3 mmHg; P=0.03).

Figure 4 presents the agreement between the two manometers when measuring diastolic blood pressure in the whole sample. Spearman's correlation coefficient was 0.47. The mean difference was 6.9 mmHg (SD 9.8) and it was highly statistically significant (P<0.001). When results are stratified by sex (Figures 5 and 6), results are consistent with those observed in the whole sample; the mean difference was 8.0 mmHg (SD 10.4) in boys and 5.8 mmHg (SD 9.2) in girls.

Of the 120 adolescents measured, 21 were classified as pre-hypertensive, according to the mercury manometer. Out of these, 17 (81.0%) were correctly classified according to the digital device (sensitivity). Of the 99 adolescents who were below the pre-hypertension cut-off, 88 (88.9%) were correctly identified by the digital device (specificity). Positive and negative predictive values were 60.7% and 95.7%, respectively. The overall percent of agreement was 87.5% and the kappa value was 0.62. Because only five adolescents were classified as hypertensive by the mercury manometer, we chose not to present analyses for this variable.

Based on the validity results presented in this study, the following correction equations were created to be applied when the digital monitor is used in adolescents aged 14-15 years.

Boys

SBP mercury = 59.269 + (0.772*SBP digital) – (0.198*age in months)

DBP mercury = 18.598 + (0.454*DBP digital) + (0.065*age in months)

Girls

SBP mercury = 22.721 + (0.637*SBP digital) + (0.095*age in months)

DBP Mercury = -25.673 + (0.751*DBP digital) + (0.207*age in months)

We tested the applicability of these equations in a database of the 1993 Pelotas (Brazil) birth cohort, in which over 4,000 adolescents aged 14-15 years were interviewed in 2008 and had their blood pressure measured using the digital device.

Table 1 - **Descriptive data on blood pressure measurement in adolescents.**

BP-related variables	Mercury manometer		Digital manometer	
	Boys	Girls	Boys	Girls
Systolic BP				
5th percentile	93.0	88.5	95.8	82.3
10th percentile	96.5	91.5	98.8	87.3
25th percentile	101.5	99.0	103.3	94.3
50th percentile	114.0	102.0	114.3	101.0
75th percentile	122.0	110.5	124.0	111.3
90th percentile	131.0	119.0	138.8	118.5
95th percentile	139.5	122.0	142.3	122.0
Mean	113.7	104.7	115.5	102.4
Standard deviation	14.2	10.1	15.2	11.9
Diastolic BP				
5th percentile	47.5	42.5	54.5	52.8
10th percentile	49.5	47.5	58.3	56.8
25th percentile	55.0	53.0	62.3	60.8
50th percentile	60.5	60.5	69.5	65.0
75th percentile	67.0	67.5	75.5	70.8
90th percentile	74.0	73.5	82.3	76.3
95th percentile	81.0	76.5	86.8	79.8
Mean	61.5	60.0	69.6	65.7
Standard deviation	9.9	10.4	10.2	7.7

BP - blood pressure

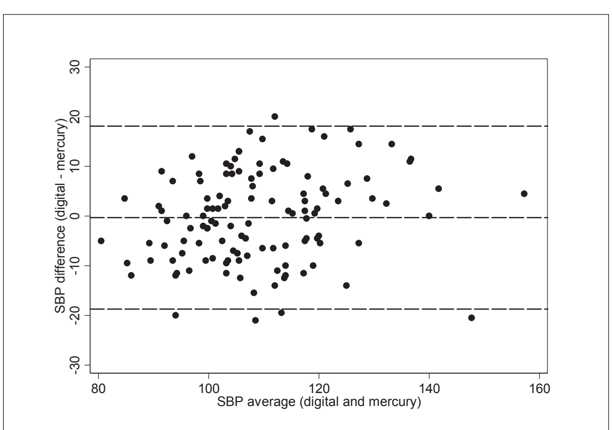

Figure 1 - Bland and Altman plot measuring the agreement between mercury and digital systolic blood pressure.

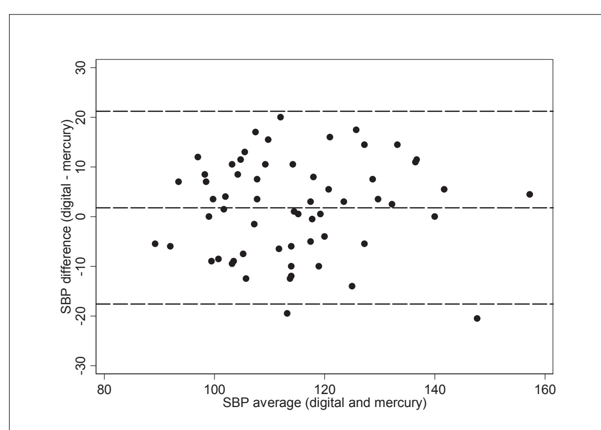

Figure 2 - Bland and Altman plot measuring the agreement between mercury and digital systolic blood pressure in boys.

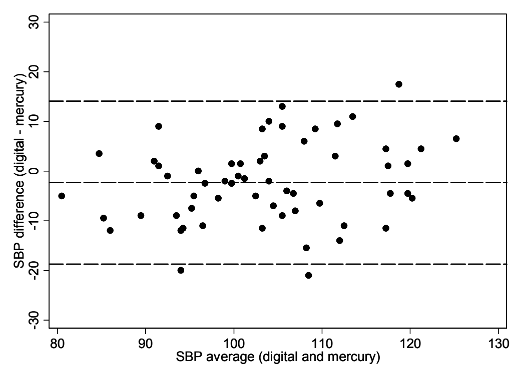

Figure 3 - Bland and Altman plot measuring the agreement between mercury and digital systolic blood pressure in girls.

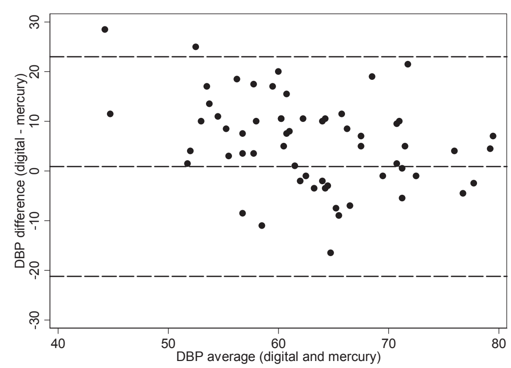

Figure 6 - Bland and Altman plot measuring the agreement between mercury and digital diastolic blood pressure in girls.

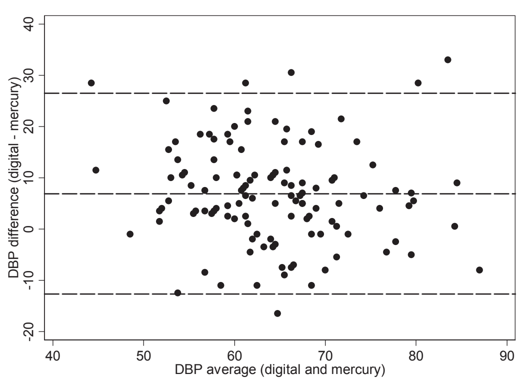

Figure 4 - Bland and Altman plot measuring the agreement between mercury and digital diastolic blood pressure.

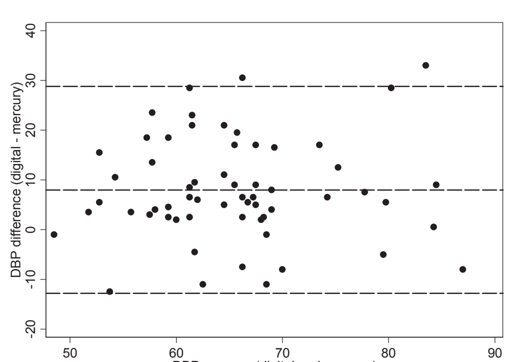

Figure 5 - Bland and Altman plot measuring the agreement between mercury and digital diastolic blood pressure in boys.

We regressed systolic and diastolic blood pressure measured by the digital device on body mass index (BMI). Afterwards, we regressed the corrected values of blood pressure using the equations proposed. The magnitude of the association between blood pressure and BMI was consistently attenuated when the correction was applied. For instance, in the whole sample, the regression coefficient for systolic blood pressure was 1.08, whereas it was 0.76 when the correction was applied. The equivalent values were 0.73 and 0.45 for diastolic blood pressure.

Discussion

Blood pressure monitoring is essential, both at the clinical and at the population level. If blood pressure values are under control, there is a decreased risk of morbidity and mortality due to cardiovascular disease[11]. However, blood pressure monitoring has been challenging, because aneroid and mercury manometers are expensive and require a trained health professional to use them[12]. As an alternative, digital devices have received growing attention, and well-known health associations are recommending their use[13-15]. Regardless of the recommendations, the validity of digital monitors needs to be confirmed prior to their widespread utilization.

Most validation studies of digital monitors carried out so far were restricted to adults[6,7,12,14,16]. However, hypertension in adolescence, one of the possible consequences of the obesity epidemics, is a growing public health concern. In a sample of adolescents living in Southern Brazil, we aimed to help filling this literature gap. In summary, our data shows that the digital monitor provides accurate data on systolic blood pressure, but overestimates diastolic pressure. This is different from most of the studies in adults, in which systolic blood pressure tends to be more overestimated using the digital device in comparison to diastolic pressure.

In order to correct the values obtained by the digital device, we propose four separate equations (systolic and diastolic blood pressure, boys and girls). This is essential because the magnitude of the overestimation in diastolic blood pressure was considered relevant in the context of public health. There is no agreement on which is the limit to be considered acceptable for digital devices. Some authors have proposed that average errors below 5 mmHg, with standard deviation below 8 mmHg, are acceptable among adults. In our sample, the mean error was only 0.3 mmHg for systolic pressure, but 6.9 mmHg for diastolic blood pressure. For this reason, we believe that the use of correction equations is necessary in studies among adolescents within the age range used in the present study. One should note, however, that correction factors are population-specific, and therefore, authors should test the applicability of our equations for other age groups and populations.

When categorical variables are used, in order to define hypertension or pre-hypertension, the agreement between the instruments should be checked again. In our sample, because hypertension was very rare, we were not able to explore this issue further. However, for pre-hypertension, we show that the digital device has a specificity close to 90%, and sensitivity close to 80%. These values are acceptable for research purposes. Obviously, in clinical settings, these values are not acceptable, and therefore, the use of aneroid monitors is recommended.

The growing use of digital manometers for measuring blood pressure is positive in terms of public health. It can likely make blood pressure monitoring more accessible to the population. It can also be an excellent tool for epidemiological studies, particularly in low and middle-income settings, where most research is carried out at the household level.

Authors' contributions

Ana M. B. Menezes had the original idea and was in charge of the writing of the manuscript. Samuel C. Dumith carried out most of the analyses, with the supervision of Pedro C. Hallal. Ricardo B. Noal was responsible for training the technicians on the blood pressure measurement and was responsible for planning the study design. Ana Paula Nunes, Fernanda Mendonça, Marta A. Duval and Paulo E. Caruso performed the fieldwork and data entry. Cora L. Araujo, Ana M. B. Menezes and Pedro C. Hallal are coordinating the 1993 Pelotas (Brazil) Birth Cohort Study. All authors contributed to the early drafts of this manuscript and approved its final version.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any post-graduation program.

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