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Original article

Comparison of Auscultatory and Oscillometric Blood Pressure Measurements among School Children in Nigeria

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ABSTRACT

Objective: The aims of this study was to compare the blood pressure (BP) measurements using mercury sphygmomanometer and oscillometric device among Nigerian school children and examine the extent of their differences, if any. **Patients and methods:** A total of 1745 Nigerian school children were systematically recruited, each had two serial BP measurements done with mercury sphygmomanometer using 'fourth report' guideline which were followed by two BP measurements using validated oscillometric device (Omron 705 IT®). **Results:** The oscillometric mean systolic BP, was significantly higher than the auscultatory (mercury) mean systolic BP (103.8 ± 11.0 mmHg vs. 98.7 ± 11.1 mmHg, **p<0.001**)**.** The oscillometric mean diastolic BP was significantly higher than that of auscultatory (mercury) mean diastolic BP (61.3 ± 8.4 mmHg vs. 58.7 ± 9.0 mmHg, **p<0.001**). The differences in the mean BP measured by the two methods (oscillometric minus auscultatory) were 5.11 mmHg (95% CI, 4.61 to 5.61; **p =<0.001**), and 2.60 mmHg (95% CI, 2.11 to 3.10; **p=<0.001**) for systolic and diastolic BP respectively. **Conclusion:** The BP measured by the two methods are different, as the oscillometric method was significantly higher systolic and diastolic BPs compared with auscultatory method.

KEYWORDS: Auscultatory (Mercury) BP measurements; Nigerian school children, Oscillometric BP measurements;

INTRODUCTION

The gold standard for the measurement of blood pressure (BP) is mercury sphygmomanometers which are being replaced by other devices for non-invasive blood pressure measurements (aneroid sphygmomanometers, hybrid sphygmomanometers and oscillometric devices)[1].The oscillometric method seems to have wider popularity among clinicians because of its convenience, avoidance of observer bias, and it is preferred in younger children [2].

Despite its popularity, most studies on comparison of BP measurements between the oscillometric devices with mercury sphygmomanometer were carried out predominantly among adult Caucasians with few documented studies among children[3,4]. On a comparative note, there are few studies that have compared blood pressure values recorded with oscillometric devices and auscultatory methods in children besides the regular validation studies.

This is not unexpected, considering the fact that validation studies differ from comparative studies. While the validation studies tend to follow a specific protocols and grading of outcome as either pass or fail, a comparative studies of blood pressure measurements tend to compare their findings without following the specific guidelines in the validation protocols [5]. Furthermore, validation studies usually involved a small sample size (European Society of Hypertension International Protocol [ESP-IP] 2, an update to earlier version requires a sample size of 33) which tends to raise issue of statistical bias in the analysis [5]. In contrast, a comparative study tends to involve large sample size. Also, specific ranges of BP (ESH-IP 2 required BP range of 90–180 mmHg for systolic BP and 40–130 mmHg for diastolic BP) are required to assess the performance of devices at various BP values while in comparative studies, references are not made to specific ranges of BPs during the recruitments of subjects [5].

Rather, the focus is the performance of the test device when compared to the standard regardless of individual blood pressure. These main reasons could account for the observation that the devices that pass clinical validation tend to perform differently at the community level as documented by Park *et al*[6] and Lewis *et al*,[7]which were carried out in children and adults respectively. Thus, this study aimed to measure the blood pressure using the auscultatory and oscillometric methods, and compared the findings among the primary school children in North-central Nigeria.

MATERIALS AND METHODS

This was a cross sectional, descriptive school based study carried out over a six month period (December 2014 to May 2015) among primary school pupils aged 6-12 years in Ilorin, Kwara State, North-Central part of Nigeria. Ilorin had an estimated population of 1,049,168 in 2013 [8]. The minimum sample for the study was estimated by Yamane's formula ($\mathbf{n} = N / 1+Ne^2$)[9].Where **n** is the desired sample size and N is the size of the study population (109,492),*e* is the level of precision and a precision level of 2.5% was used for the sample size determination. For this study, therefore $\mathbf{n}= 109{,}492/1+ (109{,}492 \times 0.025^2) =109{,}492/69.43 = 1577$. Adjusting for 10% non-response, which was 158. Thus, **n**= 1735. However, a total of 1745 pupils from both public and private primary schools were finally recruited for the study.

A multi-stage stratified random sampling technique was used in the selection of pupils from each of the three local governments (LGAs) that make up Ilorin. In Ilorin West LGA, 89 pupils were recruited from each of the nine selected schools to give a total 801. Similarly, 84 pupils were recruited from each of the selected six schools in Ilorin South to give a total of 504 pupils. In Ilorin East, 88 pupils were recruited from each of the five selected schools to give a total of 440 pupils. In each school, the total number to be recruited was divided by the six. At each class, pupils' names was then listed in alphabetical order (for surnames) and stratified into males and females. Equal number of males and females were selected from each class except primary six in Ilorin West LGA. For the primary six in Ilorin West, five schools had 10 males and nine females while the remaining four schools had nine males and 10 females. The sampling interval was determined separately for males and females. In a situation where the selected pupil is absent, the next pupil on the class list was selected as a replacement.

All primary school pupils of the selected schools who were apparently healthy, aged 6-12 years were eligible to participate in the study. However, the following children were excluded from the study : Children whose parents/guardians decline consent; Children with known cardiovascular problems such as Congenital or Acquired Heart Diseases; Children with known endocrine disorder such as diabetes, thyroid diseases; Children with suspected genetic syndrome such as Down syndrome or dysmorphic features; Children that were unavailable on the study day.

Mercury sphygmomanometer (*Accoson*® England) was used for the auscultatory BP measurement while a previously validated oscillometric device among children and adolescents (Omron 705 IT®) was used for the oscillometric BP measurement [10]. Omron 705 IT® measures BP at a range between 0-229mmHg, pulse rate between 40-180 beats/min, and powered by four Alkaline batteries (1.5V X 4= 6V). The device has an accuracy of ±3 mmHg, memory up to 28 BP measurements and a PC-link capacity. Both mercury sphygmomanometer and Omron 705 IT® were provided with different sizes of cuffs based on fourth report recommendations [11]. A Littmann Classic II Paediatric stethoscope (*3M Health Care*®, USA) with a bell and diaphragm was used for auscultation of Korotkoff sounds.

Blood pressure were measured in a quiet room between 9 am to 2 pm [12]. The procedure were explained to each of the subjects prior to measurements. Minor discomfort that may be experienced during cuff inflation were also explained to the subjects. The blood pressure was measured on the right arm after the child had sat quietly for at least five minutes. The subjects' back were supported, leg uncrossed, feet resting on firm surface, right arm supported and at the level of heart (mid-sternum). The mercury sphygmomanometer was positioned at the observer's eye level. Subjects who had just eaten or had physical activity had their blood pressure measured at least 30 minutes after the meal or physical activity.

The appropriate cuff size, which was defined as bladder width of at least 40% of arm circumference and length of 80–100% of arm circumference was determined by measuring the mid-upper arm circumference [11]. The cuff was applied to a bare right arm, with the lower border approximately 2 cm above elbow crease and the midline of the bladder over the brachial artery. It was fitted snugly to allow two fingers to slide under the cuff. The radial artery was palpated and counted for 30 second and repeated for a second reading, with at least a minute interval. The cuff was rapidly inflated to about 30 mmHg above the point at which the pulse disappeared; the cuff was then slowly deflated at rate of 2 mmHg per second and the point of reappearance of the pulse was noted. This observed pressure gave approximate systolic pressure by palpatory method.

The bell of the stethoscope was subsequently placed with sufficient pressure over the brachial artery (to provide good sound transmission without over-compressing the artery). The cuff was rapidly inflated to 30 mmHg above the approximate systolic pressure and subsequently deflated at 2 mmHg per second while listening for Korotkoff sounds. Systolic blood pressure was determined by the onset of the "tapping" Korotkoff sounds (phase 1/K1) while disappearance of Korotkoff sound (phase V) determined the diastolic blood pressure. With the disappearance of Korotkoff sounds, the cuff was deflated rapidly and completely to prevent venous congestion of the arm before the measurements is repeated. Two measurement were taken to nearest 2 mmHg with at least one minute interval and the mean of the two reading was used for analysis [13].

The above procedure was observed for oscillometric method using Omron 705 IT® with omission of palpatory method and auscultation. The mean of two readings taken after at least a minute interval was used for analysis.

For both auscultatory and oscillometric methods, children who cried or appeared frightful during the procedure were excused and allowed additional 30 minutes to rest before the blood pressure measurements were taken. However, where a pupil remained uncooperative by crying or appeared frightful after resting for the 30 minutes period, such a pupil was excluded from the study and replaced by next pupil on the class list. In addition, the oscillometric device occasional gave errors readings especially when the children moved during the BP measurements; for such pupils, the BP was repeated after the pupils had rested for five minutes.The observed values were recorded immediately into the study proforma for each measurement (both auscultatory and oscillometric methods).

All measurements including the blood pressure were done in the school clinic where available. The schools without clinic or sick bay, provided a separate room for the study. The school break times (both short and long break time) were used in order to minimize the disruption of school academic activity. All the measurements were carried out by the principal investigator and either of the two trained research assistants who were medical doctor (post-internship).

Quality assurance

The principal investigator trained two research assistants (medical doctors who had completed internship) in the technique of BP measurement using the American Heart Association (2005) guideline [13]. This was done via didactic lectures and the use of video demonstration. The inter-observer bias was minimized by ensuring that the investigator and one research assistant measures each of the subjects' BP (auscultatory methods) separately and their results were compared. Where inter-observer differences was greater than 5 mmHg, (which was checked at the end of each batch of 10 pupils), the principal investigator repeated the measurement and the average of his reading and the closest of the previous reading was used for the study.

The mercury sphygmomanometer was also checked daily to ensure accuracy of measurements. The oscilloscope was calibrated by the manufacturer prior to its use for blood pressure measurements. Also, the manufacturer's instruction for maintenance of the Omron 705IT® was observed during the study including new batteries replacement after every 300 readings

Ethical approval was obtained from University of Ilorin Teaching Hospital Ethical Review Committee while a written permission was obtained from Kwara State Ministry of Education. In addition, verbal permission was also obtained from the school head teacher and class teacher during the field works. Furthermore, a written informed consent was obtained from the parents or guardians of the subjects. For subjects 10 years and above, assent was also sought for the study.

Data analysis

The information obtained with pretested semi-structured questionnaire, were numerically coded and entered into excel spread sheet. This was then exported and analysed with SPSS® Version 20. The data from two the methods had their means, standard deviations (SD), and range calculated. The mean differences between systolic and diastolic BPs obtained from the methods were compared using paired student *t* tests to determine if they were different from zero. For the comparison between the two methods, Pearson correlation coefficients for systolic BP and diastolic BP measurements from the two methods (oscillometric and mercury sphygmomanometer) were calculated. The degree of agreement between the two methods was analysed using the Bland-Atlman (BA) plots.The*p* value of less than 0.05 was considered statistically significant.

RESULTS

A total of 1745 primary school aged children were studied. There were 873 males and 872 females giving the male to female ratio (M: F) of 1:1 **(Table 1)**. The mean age of the males was 8.76 ± 2.0 years, which was not significantly different from that of the females (8.78 ± 1.9 years), *p*=0.838 as shown in **Table 1.**

Table 1: The mean age and gender distribution of the study population.

Variable	Male	Female	*t*	*p*
Age (Years)				
Mean ± SD	8.76 ± 1.99	8.78 ± 1.94	0.205	0.838
Total (1745)	873	872		
Range (years)	6–-12	6-12		

The oscillometric mean systolic BP (103.8 ± 11.0 mmHg), was significantly higher than the auscultatory (mercury) mean systolic BP (98.7 ± 11.1 mmHg), ***p*<0.001 (Table 2)**. Similarly, the oscillometric mean diastolic BP (61.3 ± 8.4 mmHg) was significantly higher than that of auscultatory (mercury) mean diastolic BP (58.7 ± 9.0 mmHg), ***p*<0.001** **(Table 2)**. **Table 2** also showed the differences in the mean systolic BP measured by the two methods (oscillometric minus auscultatory) was 5.11 mmHg (95% CI, 4.61 to 5.61; ***p* =<0.001**), while the mean differences for diastolic BP was 2.60 mmHg (95% CI, 2.11 to 3.10; ***p*=<0.001**). The mean systolic BP measured with oscillometric method was significantly higher across the age groups when compared with the mean systolic BP measured via auscultatorymethod (**Table 3).**

Table 2: Comparison of mean blood pressure of oscillometric and auscultatory methods [mmHg]

	Oscillometric Mean ± SD n (1745)	Auscultatory Mean ±SD n (1745)	Mean difference ± SD	*95 % CI of mean differences*	*t*	*p*
Systolic BP [mmHg]	**103.8 ± 11.0**	**98.7 ± 11.1**	**5.11 ± 10.7**	**4.61- 5.61**	**13.633**	**<0.001**
Diastolic BP [mmHg]	**61.3 ± 8.4**	**58.7 ± 9.0**	**2.60 ± 10.5**	**2.11 - 3.10**	**8.822**	**<0.001**

Table 3: The mean differences between the auscultatory and oscillometric systolic BP [mmHg] based on the age group

Age (years)	n	Auscultatory Mean ± SD [mmHg]	Oscillometric Mean ± SD [mmHg]	Mean Difference ± SD [mmHg]	*t*	*P*
6	**297**	**97.2 ± 11.3**	**102.8 ± 11.1**	**-5.59 ± 10.3**	**-6.093**	**<0.001**
7	**259**	**97.2 ± 10.0**	**103.9 ± 9.9**	**-6.72 ± 10.9**	**-7.663**	**<0.001**
8	**237**	**97. 8 ± 10.9**	**103.5 ± 10.7**	**-5.70 ± 11.7**	**-5.745**	**<0.001**
9	**299**	**98.7 ± 10.7**	**102.2 ± 10.6**	**-3.51 ± 10.3**	**-4.018**	**<0.001**
10	**282**	**99.7 ± 11.6**	**105.0 ± 10.9**	**-5.30 ± 10.0**	**-5.591**	**<0.001**
11	**152**	**100.4 ± 11.2**	**104.7 ± 11.5**	**-4. 29 ± 10.4**	**-3.302**	**0.001**
12	**219**	**101.4 ± 11.1**	**105.9 ± 12.1**	**-4.42 ± 11.3**	**-4.056**	**<0.001**

The diastolic BP measured with oscillometric method was significantly higher across the age groups except at age 11 and 12, compared to the diastolic BP measured via auscultatory method (**Table 4).** For systolic BP, the Pearson correlation coefficient (*r*) was = 0. 53, ***p*<0.0001 (Table 5).** Similarly, for diastolic BP the (*r)* was = 0.30,***p*<0.0001 (Table 5).**The Bland-Altman (BA) plots the differences between each paired measurements for each of the subjects against the mean of the two measurements. For the systolic BP measurements, 86.4% (1508/1745) of the differences between the pair readings of the two methods fall within the 95% confidence interval of the mean differences (**Table 6).** However, there was a wide limit of agreement (41.98 mmHg) with a lower limit of -15.88 mmHg (95% CI, -16.74--15.02) and upper limit of 26.10 mmHg (95% CI, 25.24-26.96) of the mean difference. For the diastolic BP measurements, 92.2% (1609/1745) of the differences between the pair readings of the two methods fell within the 95% confidence interval of the mean differences (**Table 6**). However, there was a wide limit of agreement (41.08 mmHg), with a lower limit of -17.94 (95% CI, -18.78--17.10) and a upper limit of 23.14 mmHg (95% CI, 22.30-23.98).

Table 4: The mean differences between the auscultatory and oscillometric diastolic BP based on the age group [mmHg].

Age (years)	n	Auscultatory Mean ± SD [mmHg]	Oscillometric Mean ± SD [mmHg]	Mean difference ± SD [mmHg]	*t*	*p*
6	297	58.1 ± 9.0	61.5 ± 8.6	-3.50 ± 11.2	-4.707	**<0.001**
7	259	57.7 ± 8.1	61.5 ± 8.5	-3.83 ± 9.7	-5.209	**<0.001**
8	237	57.7 ± 8.3	61.2 ± 7.9	-3.62 ± 10.2	-4.702	**<0.001**
9	299	58.5 ± 9.2	60.3 ± 8.0	-1.82 ± 10.5	-2.553	**0.011**
10	282	58.5 ± 9.1	62.1 ± 8.2	-3.68 ± 10.4	-4.935	**<0.001**
11	152	59.3 ± 9.9	61.3 ± 8.8	-1.98 ± 10.0	-1.918	0.056
12	219	61.8 ± 9.0	60.8 ± 9.1	1.02 ± 10.3	0.963	0.336

Table 5: The relationship between the auscultatory and oscillometric BP measurements

	r	α	*β*	95% CI of *β*	*p*
Systolic BP [mmHg]	0.53	43.42	0.53	0.49-0.57	**<0.0001**
Diastolic BP [mmHg]	0.30	40.43	0.30	0.25-0.35	**<0.0001**

r-Pearson correlation coefficient; ***β***-Beta coefficient; α- Constant (auscultatory BP); Dependent variable (Oscillometric BP) and Independent variable (Auscultatory BP)

Table 6: The Bland-Atlman Plots of agreement between the Oscillometric and auscultatory methods

Blood pressure (Oscillometric-Auscultatory) BP	Mean differences [mmHg]	Numbers of measurement within 95% CI of mean difference	Upper limit of Mean difference (+1.96 SD), 95% CI [mmHg]	Lower limit of mean difference (-1.96 SD), 95% CI [mmHg]	Width of limit agreement (LoA) [mmHg]
Systolic BP	5.10	1508/1745 (86.4%)	26.10 (25.24-26.96)	-15.88 (-16.74--15.02)	41.98
Diastolic BP	2.60	1609/1745 (92.2%)	23.14 (22.30-23.98)	-17.94 (-8.78--17.10)	41.08

DISCUSSION

The comparison of recorded mean BPs of the two methods from the current study showed that oscillometric method overestimated both mean systolic BP and diastolic BP by 5.1 mmHg and 2.6 mmHg respectively, which are comparable to the reports of other researchers [6,14,15]. Flynn *et al*[14] in US found that oscillometric device (SpaceLabs Healthcare®) overestimated systolic and diastolic BP by 9 mmHg and 6 mmHg respectively. The possible explanations for the higher values found in the US study may be the different algorithms of the devices. Also, the US study recruited children and adolescents with chronic kidney disease, who tend to have vascular alteration as part of the disease complications. In addition, oscillometric devices have been found to be inaccurate in abnormal vascular tone. The San Antonio Triethnic Children's Blood Pressure Study in Texas[6] found that oscillometric (Dinamap model 8100®) systolic and diastolic were overestimated by 10.2 mmHg and 4.7 mmHg respectively.

These values were also higher than the values obtained from this current study which could also be attributed to differences in devices used. In South Korea,[15] higher oscillometric (DinamapProCare 200®) values (1.85 mmHg and 4.41 mmHg for systolic and diastolic BP respectively) compared to auscultatory BP were recorded. However, the oscillometric values from South Korea were lower for systolic BP and higher for diastolic when compared to the values from the current study. The differences could be due to the fact that South Korea study involved a small sample size (45) as well as hospital based carried out among children with minor urological abnormalities. It is noteworthy that studies have shown that the performance of oscillometric device at the hospital or clinical settings tends to differ from that of community[6,7].

In contrast to oscillometric overestimation of BPs found in the current study, Kamath *et al*[16] in India reported that both oscillometric (Datascope Duo) systolic and diastolic BP were underestimated by 11.6 mmHg and 10.3 mmHg respectively. On the other hand, the Arsakion[10] study in Greece that used the same device as the current study found that systolic BP was overestimated by 4 mmHg while diastolic BP was underestimated by 2.1 mmHg. The variation in methodology and devices could account for the differences with respect to the India study. While the Indian study involved large number of school children, purposive sampling technique was used in subjects recruited which could have caused a bias in the results. The difference with respect to the Arsakion school study could be accounted by the relative small sample size of the recruited subjects.

The present study showed moderate correlation between auscultatory and oscillometric systolic BP measurements, while a weak correlation were found between the two methods for the diastolic BPs. This is similar to findings in Iceland[17] where the two methods showed moderate and weak correlation for systolic and diastolic BPs respectively. The clinical import of the correlation between the two methods of BP measurements found in this study was confirmed by significant linear regression equations for predicting the corresponding auscultatory values from oscillometric methods. The regression equation provided "correction factor" for converting the oscillometric BP to expected value with auscultatory method **(Table 5).** For instance, multiplying the oscillometric mean systolic BP by 0.53 and adding 43.4 will give the corresponding value for auscultatory BP. Similarly, multiplying the oscillometric mean diastolic BP by 0.30 and adding 40.43 will give the corresponding auscultatory BP.

In the current study, the Bland-Altman plots which was used to assess the agreements in the measured BPs values by the two methods showed wide limit of agreements (difference between the upper and lower limits of the mean differences at 95% CI) of 42 mmHg and 41 mmHg for systolic and diastolic BPs respectively. This is not an unexpected finding considering the weak to moderate correlation found in the relationship between the two methods. The observed wide limit of agreement (LoA) from this study is in consistent with the findings of previous workers [6,15,18].Park *et al*[6] in US found LoA of 28 mmHg and 37 mmHg for systolic and diastolic BP measurements respectively.

A similar study in UK[18] documented wide LoA of 41 mmHg and 51mmHg for systolic and diastolic respectively. In contrast to the findings of this present work, a study in South Korea[15] found narrow LoA of 9.4 mmHg for systolic BPs measurements and 16.5 mmHg for diastolic BP measurements. The possible reason why the South Korea study LoA differ from the current work could be attributed to a small sample size (45), differences in devices used and study settings.The clinical import of the wide LoA agreement is the fact the two methods may have wide variation in measurements and thus, interchanging their values may be wrong.

In conclusions, there was a significant difference between the two methods as the blood pressure measured with the oscillometric method was higher than that of auscultatory method by 5.1 mmHg and 2.5 mmHg for systolic and diastolic BPs respectively. Thus, the blood pressure measurements are not the same for the two methods, and as such, they should not be interchanged and preferably, where a high BP is gotten from oscillometric, this should be noted as such and denote oscillometric device reading.

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