ORIGINAL RESEARCH ARTICLE

Accuracy of Aneroid Versus Digital Sphygmomanometer in Community-Based Screening for Hypertension in Hubballi, Karnataka, India - A Cross-Sectional Study

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ABSTRACT

Background: Hypertension is a significant global health issue, responsible for approximately 7.5 million deaths annually. Even a modest increase of 5 mm Hg in systolic blood pressure (BP) can elevate the risk of fatal stroke and infarction by about 25%. Hence this study aimed to assess the accuracy of aneroid and digital sphygmomanometers relative to the mercury sphygmomanometer.

Methodology: This community-based cross-sectional study was conducted in the urban slums of old Hubballi among 270 participants aged 30 years and above. Participants were selected using Probability Proportion to Size from 3 wards. Blood pressures were measured with all three sphygmomanometers and Bland Altman plot analysis was done.

Results: The results revealed that the mean difference in systolic blood pressure compared to mercury was -0.57 mmHg for the aneroid and -4.63 mmHg for the digital ($p < 0.05$). For diastolic blood pressure, the mean difference was -0.39 mmHg for the aneroid and -3.43 mmHg for the digital ($p < 0.05$). Bland-Altman analysis showed agreement limits of 66.3% for systolic and 75.2% for diastolic blood pressure with the aneroid sphygmomanometer.

Conclusion: The aneroid sphygmomanometer provides more reliable BP readings compared to the digital sphygmomanometer for both systolic and diastolic measurements.

Keywords: Aneroid sphygmomanometer, Digital sphygmomanometer, Bland-Altman plot, Blood pressure

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INTRODUCTION

Blood pressure (BP) measurement is fundamental to the diagnosis and management of hypertension (HTN). Literature suggests that interventions aimed at reducing BP below 140/90 mm Hg significantly lower the risk of cardiovascular events. Hypertension is a global health crisis, contributing to 7.5 million deaths annually, accounting for 12.8% of all deaths worldwide.[1] In Asia, hypertension is responsible for approximately 4.5 million deaths, with 3.2 million occurring in India alone each year due to hypertension and its complications.[2]

Controlling blood pressure is critical, as even a 5 mm Hg increase in systolic BP can elevate the risk of fatal stroke and infarction by approximately 25%.[3] Similarly, overestimating true BP by this margin could result in inappropriate antihypertensive treatment for nearly 30 million Americans.[4] To mitigate the risks of overestimation and underestimation, and to enhance early detection, it is essential to conduct hypertension screening in community health settings. Mercury sphygmomanometers have long been considered the gold standard for accurate BP measurement in non-invasive settings.[5]

However, concerns about mercury toxicity and environmental hazards associated with mercury disposal have led to a global decline in the use of mercury-based instruments.[6] The United Nations Environment Program (UNEP) and the World Health Organization (WHO) have highlighted mercury pollution as a significant global environmental and public health issue.[7]

Despite the mercury sphygmomanometer's status as the gold standard, the search for safer alternatives has led to the development of aneroid and, more recently, digital sphygmomanometers.[8] Yet, the Seventh Report of the Joint National Commission on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure raised concerns about the accuracy of these replacement devices.[9] In response, organizations like the US Association for the Advancement of Medical Instrumentation (AAMI) and the British Hypertension Society (BHS) have established validation protocols for BP devices.[10]

Despite these efforts, uncertainties surrounding the accuracy of alternative BP devices have made healthcare providers hesitant to replace mercury sphygmomanometers with more environmentally friendly options.[11] Given the large population, widespread poverty, and limited access to institutional healthcare, there is an evident need for more feasible and affordable BP measurement instruments.[12]

Hence this study was planned to provide evidence-based guidance on the viability of aneroid and digital sphygmomanometers as accurate alternatives to mercury devices, ultimately supporting better hypertension screening and management in diverse healthcare settings.

The objectives of the study were to measure and compare blood pressure readings obtained from aneroid and digital sphygmomanometers and to evaluate the accuracy of aneroid and digital manometers compared to mercury sphygmomanometers.

METHODOLOGY

A community-based cross-sectional study was conducted for the duration of one month from February 2022 to March 2022 among adults aged 30 years and above, residing in urban field practice area of a medical college in north Karnataka. It has 3 wards 54,59 and 60 with an adult population of 8195, 15703 and 10705 respectively.

Sample size calculation was based on an assumed correlation coefficient (r) of 0.97 between two variables, aiming to reject the null hypothesis and assuming no difference between the two measurement methods with a power of 0.8 and a 95% confidence interval. The minimum sample size required was 261 subjects, rounded off to 270. Based on Probability Proportion to Size (PPS) 64, 123 and 83 patients were selected using simple random sampling from ward numbers 54, 59 and 60 respectively.

Ethical approval: Approval was given by the institutional ethics committee of Karnataka Institute of Medical Sciences, Hubballi. (Ref no: KIMS/IEC/2021-22/033 dated 15/09/2021)

After obtaining informed consent from participants, followed by an explanation of the procedure. A self-administered questionnaire was used to collect socio-demographic details, including the participants' name, age, sex, education, occupation, socio-economic status, and marital status. The participant's weight was measured using a GVC large surface iron analog weighing scale. The GVC Iron Weighing Balance (analog) provides measurements with an accuracy to the nearest 100 grams. Height was measured in centimetres using a measuring tape, with a precision to the nearest millimetre. Diamond Mercurial BP apparatus (mercury sphygmomanometer), Rossmax GD102 palm-type aneroid sphygmomanometer (cuff size: 24-32 cm), Dr Morepen BP-11 model digital sphygmomanometer (cuff size: 22-30 cm) and MICRO-TONE MSI stethoscope were used to measure blood pressure of the participants.

BP Measurement- Guidelines of the British and Irish Hypertension Society (BIHS) were followed [13]

The patient was made to sit in a chair with a backrest and feet on the floor for at least 5 minutes. The right arm was supported at the level of the heart by resting on the table. It was ensured that no tight clothing constricted the arm.

The cuff was placed 2cm above the elbow joint aligning the brachial artery mark. The bladder should encircle at least 80% of the arm but not more than

100%. We used the cuff size recommended by the manufacturer of the devices which were for Mercury manometer 24-32cm; for Aneroid manometer 24-32cm, and for Digital manometer 22-30cm.

After placing the cuff; in **mercury and aneroid sphygmomanometer,** estimated the systolic pressure beforehand using the palpatory method. Then continued with the auscultatory method by inflating to 30mm of Hg above the estimated systolic level to occlude the pulse. The stethoscope diaphragm was placed over the brachial artery and deflate at the rate of 2-3mm oh Hg/s until a tapping sound (Korotkoff sounds) was heard. Appearance of 1st sound was recorded as systolic and the disappearance of the 5th sound as diastolic pressure,

After placing the cuff in **Digital sphygmomanometer, t**he device automatically inflates (and re-inflates to the next setting if required) and deflates. Measurements were recorded as displayed.

Frequency of BP measurement: two readings were recorded from each sphygmomanometer

Statistical analysis: Data was entered in Microsoft Excel and analysed using SPSS version 21. Categorical variables were presented by numbers and percentages. Continuous variables were expressed as mean and standard deviation. To compare the measurements of blood pressure using aneroid and digital sphygmomanometers with Mercury sphygmomanometer, the correlation was done and Pearson's correlation coefficient was estimated. To evaluate the accuracy of aneroid and digital sphygmomanometers in comparison with the Mercury sphygmomanometer, Bland Altman plot analysis was done. A P-value of <0.05 was considered significant.

RESULTS

The Mean age was 50.78±12.03years and 49.6 ±11.94years for males and females respectively. The blood pressure measured by each non-mercury device was compared with the measurements done by the mercury instrument (gold standard). The sociodemographic characteristics and comorbidities details are expressed in Table 1.

Measurement of blood pressure (both systolic and diastolic) was done with all three types of sphygmomanometers and were compared. The values of digital sphygmomanometer and aneroid sphygmomanometers were compared and correlated with the blood pressure measured with the mercury sphygmomanometer. (Table 2 and Table 3) The scatter plot shows the relationship between the blood pressure measurements with different types of sphygmomanometers. (Figure 1, figure 2, figure 3, figure 4). A statistically significant positive correlation existed between the blood pressures measured using an aneroid, digital sphygmomanometer, and Mercury sphygmomanometer. (Table 3)

Table 1: Sociodemographic characteristics of the participants

Variable	Participants (%)
Age	
30-45	113 (41.9)
46-60	100 (37)
61-75	56 (20.7)
>75	1 (0.4)
Gender	
Male	131 (48.5)
Female	139 (51.5)
Illiterate	65 (24.1)
Primary	52 (19.3)
Middle school	42 (15.6)
High school	64 (23.7)
Education	
Intermediate	34 (12.6)
Graduate	12 (4.4)
Professional degree	1 (0.4)
Socioeconomic status	
Class III	111 (41.1)
Class IV	142 (52.6)
Class V	17 (6.3)
Tobacco use	
Yes	42 (15.6)
No	228 (84.4)
Family history of hypertension	
Yes	43 (15.9)
No	227 (84.1)
Known case of Hypertension	
Yes	39 (14.4)
No	231 (85.6)

Table 2: Comparison of the blood pressure measured using aneroid and digital sphygmomanometers with mercury sphygmomanometer

Blood pressure & Instrument	Cases	Mean ± SD (mm of Hg)	P value
Systolic			
Pair 1			
Mercury	270	133.97 ± 14.33	0.282
Aneroid	270	134.54 ± 14.93	
Pair 2			
Mercury	270	133.97 ± 14.33	<0.005
Digital	270	138.6 ± 18.29	
Diastolic			
Pair 1			
Mercury	270	83.1 ± 7.9	0.294
Aneroid	270	83.49 ± 7.79	
Pair 2			
Mercury	270	133.97 ± 14.33	<0.005
Digital	270	138.6 ± 18.29	

Bland-Altman analysis was used to compare aneroid and digital sphygmomanometers with Mercury sphygmomanometer and quantify their agreement. Bland -Altman plots comparing the difference in systolic blood pressure (SBP) measurements obtained with: (A) mercury v/s aneroid (mean difference = -0.6) and (B) mercury v/s digital (mean difference -4.6) sphygmomanometer: Most of the differences are within 2.0 SDs but the differences were substantially located in the limits of agreements +16.6 and -17.7 for mercury v/s aneroid and +16.5 and -25.7 for mercury v/s digital while the standard limits of agreement lie between +5 and -5.

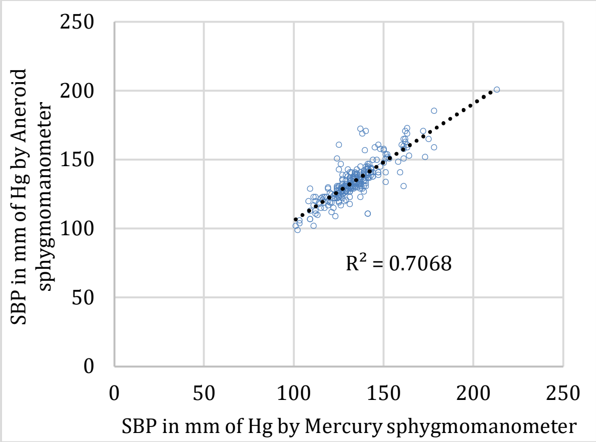

Figure 1: Correlation of the Systolic blood pressure measured using aneroid sphygmomanometers with a mercury sphygmomanometer

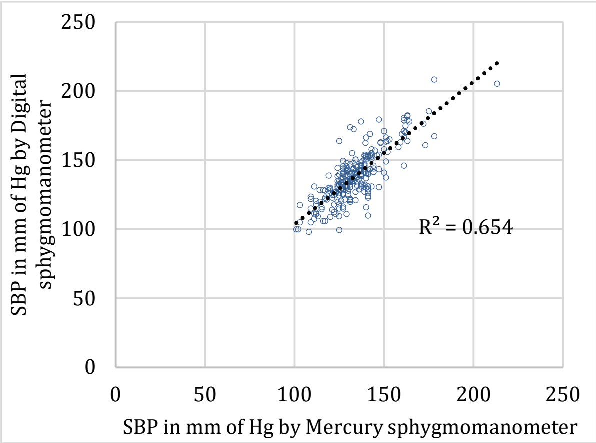

Figure 2: Correlation of the Systolic blood pressure measured using digital sphygmomanometers with a mercury sphygmomanometer

Table 3: Correlation between the blood pressures measured with aneroid and digital sphygmomanometers with Mercury sphygmomanometer

Blood pressure & Sphygmomanometer	Pearson's co-efficient	p-value
Systolic		
Aneroid	0.821	<0.005
Digital	0.809	<0.005
Diastolic		
Aneroid	0.703	<0.001
Digital	0.611	<0.001

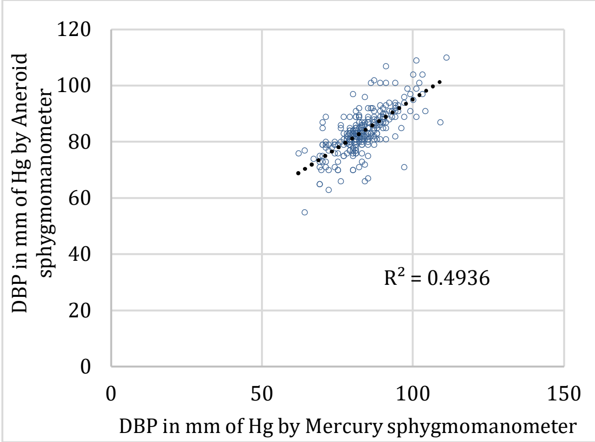

Figure 3: Correlation of the Diastolic blood pressure measured using aneroid sphygmomanometers with a mercury sphygmomanometer

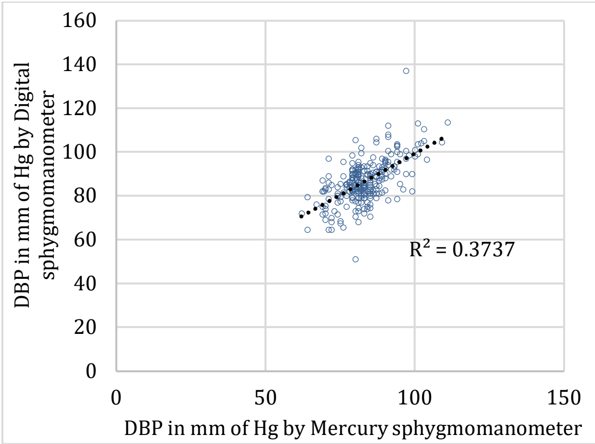

Figure 4: Correlation of the Diastolic blood pressure measured using digital sphygmomanometers with a mercury sphygmomanometer

Bland -Altman plots comparing the difference in diastolic blood pressure (DBP) measurements obtained with (A) mercury v/s aneroid (mean difference = -0.4) and (B) mercury v/s digital (mean difference -3.4) sphygmomanometer: Most of the differences are within 2.0 SDs but the differences were substantially located in the limits of agreements +11.5 and -12.2 for mercury v/s aneroid and +12.2and -19.0 for mercury v/s digital while the standard limits of agreement lie between +5 and -5 for both. (Table IV, figure 5 and figure 6)

Table 4: Results of Bland-Altman analysis

Parameter	Aneroid		Digital	
	Values	95 % CI	Values	95 % CI
Sensitivity (%)	81.52	72.07 to 88.85	82.61	73.30 to 89.72
Specificity (%)	87.64	81.89 to 92.09	61.24	53.66 to 68.43
Positive Predictive Value (%)	77.32	67.70 to 85.21	52.41	43.96 to 60.76
Negative Predictive Value (%)	90.17	84.73 to 94.17	87.2	80.05 to 92.50
Disease prevalence (%)	34.07%	28.44 to 40.06	34.07	28.44 to 40.06
Positive Likelihood Ratio	6.6	4.41 to 9.87	2.13	1.73 to 2.62
Negative Likelihood Ratio	0.21	0.14 to 0.33	0.28	0.18 to 0.45
AUC	0.85	0.80 to 0.89	0.72	0.66 to 0.77

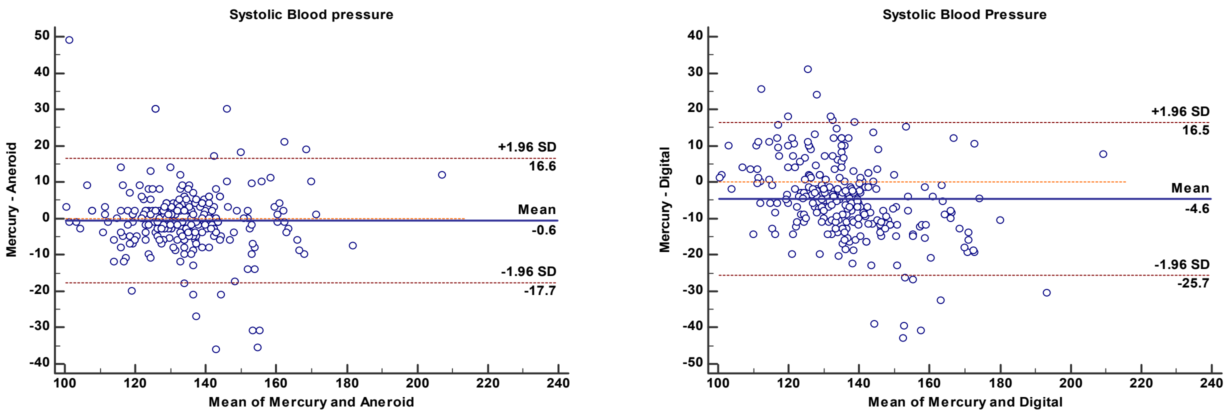

Figure 5: Bland-Altman plot for systolic blood pressure

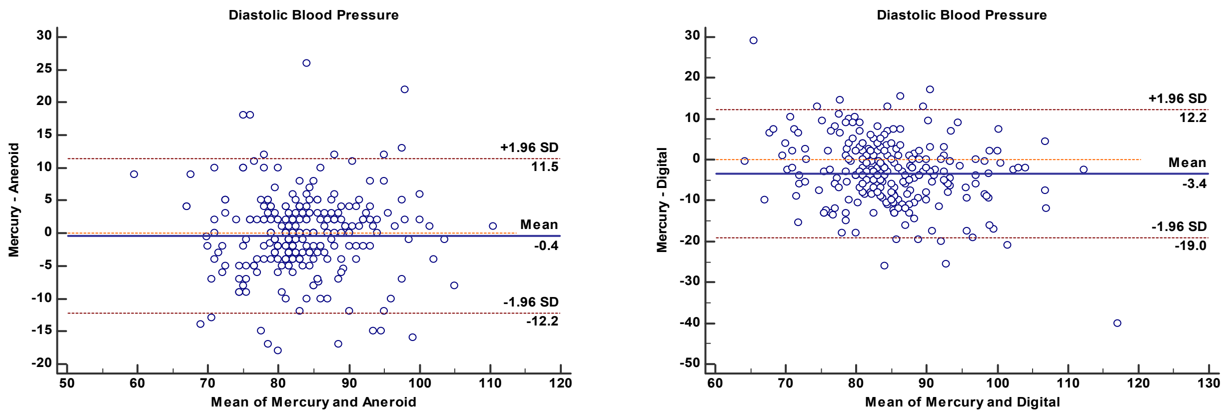

Figure 6: Bland-Altman plot for diastolic blood pressure

On comparison of mercury and aneroid sphygmomanometers, 66.30% of readings were in the clinically accepted range for systolic and 75.2% for diastolic readings. On comparison of mercury and digital sphygmomanometers, 34.4% and 49.3% for systolic and diastolic blood pressure readings respectively were in an acceptable range. (Table V)

Table 5: Difference in the measurement of blood pressure using aneroid and digital sphygmomanometer

Blood pressure	Difference in measurement n (%)	
	≤5 mm Hg	> 5 mm Hg
Systolic		
Mercury – Aneroid	179 (66.30)	91 (33.70)
Mercury – Digital	93 (34.40)	177 (65.60)
Diastolic		
Mercury – Aneroid	203 (75.2)	67 (24.8)
Mercury – Digital	133 (49.3)	137 (50.7)

DISCUSSION

The current study, which included 270 participants with a mean age of 50.78 years for males (SD = 12.03) and 49.6 years for females (SD = 11.94), assessed the accuracy of aneroid and digital sphygmomanometers compared to mercury. We found that the mean difference in systolic blood pressure between mercury and aneroid sphygmomanometers was -0.57 mm Hg, while it was -4.63 mm Hg between mercury and digital devices. The difference between mercury and digital devices was statistically significant (p <0.005), but the difference with aneroid devices was not significant (p = 0.282). For diastolic blood pressure, the mean difference was -0.39 mm Hg between mercury and aneroid and -3.43 mm Hg between mercury and digital, with only the mercury vs. digital comparison showing statistical significance (p < 0.005).

These results align with a study conducted by Bhaskar Shah Babu et al. in Kolkata, which involved 218 participants with a mean age of 54.9 years. This study also found that the aneroid device had high agreement with mercury, reinforcing the accuracy of aneroid devices.[12]

A larger study involving over 8,000 participants, which evaluated 604 sphygmomanometers, reported that 78% of aneroid models and 88% of digital devices provided measurements within a 3 mm Hg acceptance error, supporting the notion that while digital devices are widely used, their precision might not match that of aneroid devices.[7]

Our study revealed that the aneroid device demonstrated superior sensitivity and specificity compared to the digital device, reducing the likelihood of hypertensive misclassification. This finding is consistent with another study that reported sensitivity and specificity rates of 86.7% and 98.7%, respectively, for aneroid devices, while digital devices had lower sensitivity (80%) and specificity (67.7%).[14]

Another study reported that all 283 aneroid devices evaluated were accurate within the range recommended by the Association for the Advancement of Medical Instrumentation (AAMI), demonstrating their reliability in clinical settings. This aligns with our findings, where the aneroid device showed better agreement with mercury compared to digital devices.[15]

A study found that the mean aneroid sphygmomanometer readings showed good agreement with the mercury device, as demonstrated by the kappa value ($\kappa = 0.81$), sensitivity (81%), and specificity (98%).[16] This suggests that the aneroid device is a reliable alternative for blood pressure measurements, similar to our findings.

In Ahmedabad, research using the Bland-Altman test showed clinically non-significant bias for systolic and diastolic blood pressure readings between the aneroid and mercury devices, which aligns with our results, suggesting that the aneroid device's accuracy is comparable to mercury.[17]

In contrast, a study conducted in Deoghar found a strong correlation between automated (digital) and mercury sphygmomanometers, with Spearman's rank correlation coefficient of 0.933 and a p-value < 0.0001, indicating a strong agreement between the two devices.[18] However, this differs from our study, where the correlation between digital and mercury devices was weaker.

Another study by Behera et al. reported no significant difference in average blood pressure measurements between digital, mercury, and aneroid sphygmomanometers (p = 0.71 for digital vs. mercury, p = 0.46 for digital vs. aneroid, and p = 0.71 for aneroid vs. mercury).[19] This finding contrasts with our study, where the digital sphygmomanometer showed a statistically significant difference compared to mercury.

Amy Shah et al. found no significant difference in systolic blood pressure readings between mercury and aneroid devices, but there was a slight difference in diastolic readings (-1.53 ± 5.06 mm Hg), which is consistent with our observation that the aneroid sphygmomanometer closely matches mercury measurements.[20]

Putripratama's study found a significant difference between digital and mercury sphygmomanometers (p = 0.0001), highlighting potential inaccuracies with digital devices, which is in line with our findings.[21]

Pooja Bhatt et al. conducted a comparison study that found a good agreement between mercury and aneroid sphygmomanometers but poor agreement with digital sphygmomanometers, reinforcing the conclusion that aneroid devices are more reliable.[22]

Another study observed no statistically significant difference in systolic blood pressure (SBP) readings between the aneroid and mercury devices (P > 0.05) but found a small, yet significantly lower (0.8 mm Hg) difference in diastolic blood pressure (DBP).[23] This is consistent with our findings that aneroid devices are fairly accurate.

Madhan Srinivasan Kumar et al. reported significant variations in blood pressure readings when using aneroid and digital monitors compared to mercury, suggesting that these alternatives should be used cautiously in clinical settings.[24]

A systematic review and meta-analysis on similar objective reported that the digital blood pressure monitoring has a moderate level of accuracy and the device can correctly distinguish hypertension with a pooled estimate sensitivity of 65.7% and specificity of 95.9%. it also suggested that suggests that the digital blood pressure monitor had moderate accuracy with a mercury sphygmomanometer.[25]

Our study's results confirm that aneroid sphygmomanometers have a closer agreement with mercury devices than digital devices, aligning with most of the referenced studies. Therefore, the use of aneroid sphygmomanometers, with regular calibration, appears to be a reliable alternative to mercury devices in screening for hypertension in the community. However further research is needed to evaluate the efficacy of the devices and their cost-effectiveness in using them for community-based screening of hypertension, considering the potential hazards due to the use of mercury sphygmomanometers.

Conclusion

The current research highlights that aneroid sphygmomanometers offer greater accuracy and reliability in blood pressure measurement than digital devices when using mercury sphygmomanometers as the reference standard. The aneroid device demonstrated better sensitivity, specificity, and correlation with mercury, reducing the risk of hypertensive misclassification. Despite the growing use of digital devices, this study emphasizes the continued clinical relevance of aneroid sphygmomanometers, especially for more accurate and consistent blood pressure assessments.

Availability of the data

The data that support the findings of this study are available from the corresponding author on request.

Non-Use of GENERATIVE AI

No generative AI tools were used to prepare this manuscript.

References

1. World Health Organization. (2011). Global status report on noncommunicable diseases 2010. World Health Organization. Available from https://iris.who.int/handle/10665/44579

2. Gupta R, Xavier D. Hypertension: The most important non communicable disease risk factor in India. Indian Heart J. 2018 Jul-Aug;70(4):565-572. DOI: https://doi.org/10.1016/j.ihj.20 18 .02.003

3. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet. 2002;360(9349):1903–13. https://doi.org/10.1016/s0140-6736(02)11911-8

4. Jones DW, Appel LJ, Sheps SG, Roccella EJ, Lenfant C. Measuring blood pressure accurately: new and persistent challenges. JAMA. 2003;289(8):1027–30. https://doi.org/10.1001/jama. 289.8.1027

5. Muntner P, Shimbo D, Carey RM, Charleston JB, Gaillard T, Misra S, et al. Measurement of blood pressure in humans: A scientific statement from the American Heart Association. Hypertension.2019;73(5):e35-e66. DOI: https://doi.org/10.1161 /HYP.0000000000000087

6. Directive 2007/51/EC of the European Parliament and of the Council of 25 September 2007 amending Council Directive 76/769/EEC relating to restrictions on the marketing of certain measuring devices containing mercury (Text with EEA relevance) [Internet]. 2007. Available from: http://eur-lex. europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0051.

7. United Nations Environmental Programme. Global Mercury Assessment. UNEP Chemicals, Geneva; December 2002.

8. A'Court C, Stevens R, Sanders S, Ward A, McManus R, Heneghan C. Type and accuracy of sphygmomanometers in primary care: a cross-sectional observational study. Br J Gen Pract. 2011;61(590)–603.

9. National Heart, Blood and Lung Institute. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure. US Dept of Health and Human Services; August 2004. Available from: www.nhlbi.nih.gov/guidelines/hypertension/jnc7full.pdf.

10. O'Brien E, Waeber B, Parati G, Staessen J, Myers MG. Blood pressure measuring devices: recommendations of the European Society of Hypertension. BMJ. 2001;322:531–6.

11. Buchanan S, Orris P, Karliner J. Alternatives to the mercury sphygmomanometer. J Public Health Policy. 2011;32(1):107–20.

12. Shahbabu B, Dasgupta A, Sarkar K, Sahoo SK. Which is more accurate in measuring the blood pressure? A digital or an aneroid sphygmomanometer. J Clin Diagn Res. 2016;10(3). DOI: https://doi.org/10.7860/jcdr/2016/14351.7458.

13. How to measure Blood Pressure. Available from How to measure Blood Pressure - British and Irish Hypertension Society | Registered UK Charity No. 287635 (bihsoc.org)

14. Martin J. Hypertension guidelines: revisiting the JNC 7 recommendations. J Lanc Gen Hosp. 2008;3(3):91–7.

15. Canzanello VJ, Jensen PL, Schwartz GL. Are aneroid sphygmomanometers accurate in hospital and clinic settings? Arch Intern Med. 2001;161(5):729–31. DOI: 10.1001/archinte. 161.5.685

16. Ostchega Y, Prineas RJ, Nwankwo T, Zipf G. Assessing blood pressure accuracy of an aneroid sphygmomanometer in a national survey environment. Am J Hypertens. 2011 Mar;24(3):322-7. DOI: https://doi.org/10.1038/ajh.2010.232. Epub 2010 Dec 16. PMID: 21164495.

17. Kakkad KM, Damor P, Parmar B, Patel S, Prajapati V, Dhivar N. Comparative Study of Blood Pressure Measurement by Aneroid and Digital Manual Sphygmomanometer. Natl J Community Med [Internet]. 2016 Aug. 31;7(08):700-2. Available from: https://www.njcmindia.com/index.php/file/article/view/103 4

18. Heemanshu Shekhar Gogoi. A Comparative Study on Blood Pressure Measurement by Automated versus Manual Mercury Sphygmomanometer in the Urban Population of Deoghar, Jharkhand. Indian Journal of Basic and Applied Medical Research; 2020: 9(4):229-240 DOI: 10.36848/IJBAMR/2020/ 18215.56055

19. Hamied, Lola Ilona Abdul; Sofiatin, Yulia; Rakhmilla, Lulu Eva; Putripratama, Ayu Anisa; Roesli, Rully M.A.. Comparison of Mercury, Aneroid and Digital Sphygmomanometer in Community Setting. Journal of Hypertension 2015; 33: e33-e34. DOI: 10.1097/01.hjh.0000469843.06908.c3

20. Shah AS, Dolan LM, D'Agostino RB Jr, Standiford D, Davis C, Testaverde L, Pihoker C, Daniels SR, Urbina EM; SEARCH for Diabetes in Youth Study Group. Comparison of mercury and aneroid blood pressure measurements in youth. Pediatrics. 2012 May;129(5):e1205-10. doi: 10.1542/peds.2011-3087. Epub 2012 Apr 16. PMID: 22508914; PMCID: PMC3340597.

21. Putripratama, Ayu Anisa; Rahayuningsih, Sri Endah; Hamied, Lola Ilona Fuad Abdul; Sofiatin, Yulia; Roesli, Rully M.A.. Mean Differences between Digital and Mercury Sphygmomanometer in Community-Based Setting. Journal of Hypertension 33():p e34, June 2015. | DOI: 10.1097/01.hjh.0000469844.01070.05

22. Bhatt Pooja & Arora, Smriti & Tamang, EKL. (2016). Comparison of Measurement Accuracy of Aneroid, Digital, and Mercury Sphygmomanometer. Journal of nursing science and practice. 6. 28-32.

23. Yong Ma, Marinella Temprosa, Sarah Fowler, Ronald J. Prineas, Maria G. Montez, Janet Brown-Friday, Mary L. Carrion-Petersen, Tracy Whittington, for The Diabetes Prevention Program Research Group, Evaluating the Accuracy of an Aneroid Sphygmomanometer in a Clinical Trial Setting, *American Journal of Hypertension*, Volume 22, Issue 3, March 2009, Pages 263–266, https://doi.org/10.1038/ajh.2008.338

24. Kumar, Madhan Srinivasan & Kumar, K. & Ilango, Saraswathi & Raaju, A. & Rao, B.. (2018). Are Automated Blood Pressure Apparatus Reliable? Automated Versus Manual Measurement of Blood Pressure. Journal of Clinical and Diagnostic Research. 12. CC09-CC12. 10.7860/JCDR/2018/34993.11868.

25. Muniyandi, M., Sellappan, S., Chellaswamy, V. *et al.* Diagnostic accuracy of mercurial versus digital blood pressure measurement devices: a systematic review and meta-analysis. *Sci Rep* 12, 3363 (2022). Doi: 10.1038/s41598-022-07315-z