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Diagnostic accuracy of community health worker blood pressure measurements against 24-hour ambulatory blood pressure monitoring: Validating task-shifting for hypertension screening in urban slums of central India

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Abstract

Background & objectives:

Hypertension is one of the leading causes of cardiovascular disease in India, yet the screening cascade under the National Programme for Non-Communicable Diseases (NP-NCD) suffers from substantial attrition at each referral step. Task-shifting blood pressure (BP) measurement directly to Accredited Social Health Activists (ASHAs) could bypass this attrition, but evidence validating ASHA-measured BP against ambulatory blood pressure monitoring (ABPM)—the gold standard—is lacking. This study evaluated the diagnostic accuracy of ASHA-measured BP against 24-hour ABPM for hypertension detection in urban slums.

Methods

In this cross-sectional diagnostic accuracy study, 111 adults (≥ 30 year) from urban slums of Bhopal underwent BP measurement by trained ASHAs using validated digital devices (Omron HEM-7120) following a two-visit protocol, followed by 24-h ABPM (Schiller BR-102 plus). Diagnostic accuracy and agreement (Bland-Altman, Cohen's kappa, intraclass correlation) were computed against ABPM.

Results

ABPM-defined hypertension prevalence was 25.2 per cent (28/111). The two-visit ASHA protocol showed sensitivity 85.7 per cent (95% CI: 68.5–94.3), specificity 90.4 per cent (82.1–95.0), positive predictive value 75.0 per cent, negative predictive value 94.9 per cent and Cohen's kappa 0.73 (substantial agreement). Single readings had significantly more false positives (McNemar P = 0.025). Bland-Altman analysis showed mean systolic BP bias of + 3.1 mmHg (limits of agreement: −18.7 to + 24.8) against 24-h ABPM. White-coat hypertension was 7.2 per cent and masked hypertension 3.6 per cent on two-visit ASHA protocol compared to 24-h ABPM.

Interpretation & conclusions:

ASHA-measured BP using a two-visit protocol demonstrates good diagnostic accuracy and substantial agreement with ABPM. These findings provide robust evidence that ASHAs can measure blood pressure as reliably as any industry-standard measurement, supporting task-shifting of BP measurement to ASHAs to achieve realistic screening with higher yield and better follow-up of persons with hypertension in the community. Single readings should be avoided due to higher false-positive rates.

Background

Hypertension is one of the leading causes of cardiovascular disease globally and in India, affecting an estimated 1.3 billion adults worldwide and responsible for significant morbidity and mortality[1,2]. In India, the National Family Health Survey-5 (NFHS-5, 2019-21) estimated hypertension prevalence at 21–24 per cent among adults, but the critical issue is that hypertension follows the rule of halves — half the actual patients are unaware of their disease status, half of those aware are not on treatment, and half of those on treatment do not have controlled blood pressure[3,4]. Over half of hypertensive individuals are newly diagnosed at the time of survey, pointing to massive undetected disease in the community[5].

To address this, the Population Based Screening (PBS) programme under the National Programme for Prevention and Control of Non-Communicable Diseases (NP-NCD) deploys ASHAs to administer the Community Based Assessment Checklist (CBAC) to adults aged 30 years and above[6,7]. Those with higher scores are referred to Auxiliary Nurse Midwives (ANMs) for BP measurement, and those found elevated are further referred to Medical Officers (MOs) for confirmation. This three-step referral process looks good on paper, but what has been observed is that people do not go for blood pressure measurement at the first referral point. This multi-step cascade leads to significant attrition at each stage, with district-level screening coverage documented as low as 2–62 per cent[8]. However, if someone is screened at home and told that their blood pressure is raised, there is a higher likelihood of them following up for confirmation — because there is a cue to action.

The ASHA cadre was introduced in 2004 with primary roles in reproductive and child health and nutrition. With the emerging non-communicable disease landscape, ASHAs have also been delegated responsibilities for community screening using CBAC. Task-shifting in the present context means shifting the responsibility of BP measurement to ASHAs instead of relying on the three-step cascade. A systematic review of 63 studies by Anand *et al.*[9] demonstrated that task-sharing with non-physician health workers reduced systolic BP by 4.85 mmHg. BP measurement by ASHAs at the community setting itself would not only decrease screening attrition but may also reduce detection of white-coat hypertension, since measurement happens in the familiar home environment.

Previous studies have reported that even non-health workers can measure BP reliably using electronic devices. Reidpath *et al.*[10] demonstrated this in Malaysia, and Hesse *et al.*[11] showed that community health workers (CHWs) with mHealth support achieved physician-equivalent diagnostic accuracy in Guatemala. However, the main gap is that these studies compared CHW BP measurements with physician measurements, which are themselves prone to observer bias and the phenomenon of white-coat hypertension[12]. Blood pressure measurement has traditionally been considered a task done by doctors involving skill, but automated BP monitors have demonstrated that readings can be obtained quite accurately at home as well. Twenty-four-hour ambulatory blood pressure monitoring (ABPM) is the recognized gold standard, eliminating white-coat effects and providing superior cardiovascular risk prediction[13,14]. Comparing ASHA-measured BP against this gold standard and demonstrating agreement would resolve queries about measurement accuracy by non-physician health workers, so that when task-

shifting is considered there should be no doubt about the validity of the work done by ASHAs. To our knowledge, no study has validated ASHA-measured BP against ABPM in an Indian community setting.

Methods

Aim

The aim of this study was to evaluate the diagnostic accuracy of ASHA-measured BP — using both a single-visit and a two-visit protocol — against 24-hour ABPM for hypertension detection in an urban slum community of Bhopal, Madhya Pradesh.

Design and setting

This cross-sectional diagnostic accuracy study was conducted in communities of urban slums served by eight Urban Primary Health Centres (UPHCs) in Bhopal district, Madhya Pradesh, from August 2020 to April 2021, within the PBS programme framework. The study is reported per STARD guidelines[15].

Participants

The study included adults aged 30 years and above, recruited by ASHAs from selected urban slum communities based on their willingness to undergo 24-hour ABPM monitoring. Pregnant women, people having arrhythmias and those who could not tolerate ABPM were excluded. A total of 111 participants were finally recruited in the study.

Index test—ASHA BP measurement

ASHAs measured blood pressure using validated digital oscillometric devices (Omron HEM-7120). Two readings were taken at one-minute intervals, and a third was obtained if the difference exceeded 5 mmHg in either systolic or diastolic readings; the lowest reading was then recorded. If on the first visit BP was ≥ 140/90 mmHg, a second visit to measure blood pressure was made after a gap of 7–10 days. Hypertension by the two-visit protocol was classified if the reading was ≥ 140/90 mmHg on both visits. Classification was also done based on the first visit reading alone (single-visit protocol). Though the single-reading protocol is easier and less time-intensive, it is associated with white-coat hypertension and measurement bias. The two-visit protocol, by allowing a wash-off period, bypasses these biases and gives a more stable estimate.

Reference standard—24-h ABPM

A Schiller BR-102 plus device was applied by the study investigator for 24 hours. Recordings were taken at 30-minute intervals during daytime (06:00–22:00 h) and at 60-minute intervals during nighttime

(22:00–06:00 h). To be valid, a minimum of 20 readings were required. Hypertension by ABPM was classified using American Heart Association criteria: 24-hour average ≥ 130/80 mmHg, daytime average ≥ 135/85 mmHg, or nighttime average ≥ 120/70 mmHg[16].

Statistical analysis

For accuracy of ASHA BP measurement, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios and diagnostic odds ratio were calculated with 95 per cent confidence intervals. Agreement between ASHA recordings and 24-hour ABPM was assessed using Bland-Altman analysis[17], intraclass correlation coefficients (ICC) and Cohen's kappa[18]. McNemar's test was used to compare hypertension detection rates between the single-visit and two-visit protocols. White-coat hypertension was defined as elevated ASHA-measured BP with normal ABPM; masked hypertension as normal ASHA BP with elevated ABPM.

Results

A total of 111 adult participants were recruited, of whom 72 were females (64.9%) and 39 males (35.1%). Median age was 44 years (Interquartile Range-IQR: 38–53; range: 31–77). Mean ASHA-measured systolic/diastolic BP was 124.0 ± 16.5/83.1 ± 10.3 mmHg on the first visit and 123.4 ± 16.7/82.8 ± 10.5 mmHg on the second visit, compared with 24-hour ABPM of 120.6 ± 14.3/74.6 ± 10.1 mmHg and daytime ABPM of 124.3 ± 14.7/78.1 ± 10.2 mmHg.

Hypertension as per ABPM criteria was detected in 28 participants (25.2%), which is similar to the hypertension prevalence reported in NFHS-5 data. The two-visit ASHA protocol classified 32 participants (28.8%) and the single-visit protocol 37 participants (33.3%) as hypertensive. ABPM-defined hypertension increased with age: 13.2 per cent in the 30–39 years group, 27.3 per cent in 40–49 years, 31.8 per cent in 50–59 years and 38.9 per cent in those 60 years and above. Nocturnal non-dipping was present in 55.9 per cent of participants.

Table 1
Cross-classification of hypertension by ASHA protocol and ABPM (N = 111)

Two-visit		**ABPM HTN+**	**ABPM HTN−**	**Total**
	ASHA HTN+	**24**	**8**	**32**
protocol	ASHA HTN−	4	75	79
Single-reading	ASHA HTN+	24	13	37
protocol	ASHA HTN−	4	70	74

HTN, hypertension; ABPM, ambulatory blood pressure monitoring; ASHA, Accredited Social Health Activist

Table 2
Diagnostic properties of ASHA BP measurements against ABPM

Parameter	Two-visit protocol (95% CI)	Single reading (95% CI)
Sensitivity (%)	85.7 (68.5–94.3)	85.7 (68.5–94.3)
Specificity (%)	90.4 (82.1–95.0)	84.3 (75.0-90.6)
PPV (%)	75.0 (57.9–86.8)	64.9 (48.8–78.2)
NPV (%)	94.9 (87.7–98.0)	94.6 (86.9–97.9)
LR+	8.89 (6.87–11.52)	5.47 (4.64–6.45)
LR−	0.16 (0.10–0.26)	0.17 (0.10–0.28)
DOR	56.3 (15.6-203.4)	32.3 (9.6-108.6)
Cohen's κ	0.73 (0.50–0.96)	0.63 (0.41–0.85)
Diagnostic accuracy (%)	89.2 (82.1–93.7)	84.7 (76.8–90.2)

PPV, positive predictive value; NPV, negative predictive value; LR, likelihood ratio; DOR, diagnostic odds ratio. McNemar's test for difference between protocols: P = 0.025

The two-visit ASHA protocol detected hypertension with sensitivity of 85.7 per cent (95% CI: 68.5–94.3), specificity of 90.4 per cent (82.1–95.0), PPV of 75.0 per cent and NPV of 94.9 per cent. Cohen's kappa was 0.73, indicating substantial agreement between ASHA detection and 24-hour ABPM. When only a single reading was used, specificity dropped to 84.3 per cent, PPV fell to 64.9 per cent, and the diagnostic odds ratio decreased — indicating detection of more false positives (McNemar P = 0.025). This means the single reading would lead to overclassification of people as hypertensives when they are actually normotensives.

Bland-Altman analysis (Fig. 1) showed a small but significant systolic bias of + 3.1 mmHg (P = 0.005) against 24-hour ABPM, with limits of agreement of − 18.7 to + 24.8 mmHg. Against daytime ABPM, this bias became negligible (− 0.6 mmHg, P = 0.59). ASHA readings were more discordant for diastolic BP: the bias was + 8.4 mmHg (P < 0.001) against 24-hour ABPM and + 4.9 mmHg (P < 0.001) against daytime ABPM. More agreement was present between daytime values compared to 24-hour values, which is expected because nighttime dipping changes the scenario and puts the ASHA versus 24-hour readings more off than the daytime comparisons. Pearson's r ranged from 0.67 to 0.77 and ICC from 0.50 to 0.77. White-coat hypertension was present in eight participants (7.2%) and masked hypertension in four (3.6%).

Discussion

This study demonstrates that ASHA-measured BP using a two-visit protocol has high diagnostic accuracy and substantial agreement with 24-hour ABPM, the gold standard. The sensitivity of 85.7 per

cent, specificity of 90.4 per cent and kappa of 0.73 together indicate that hypertension detection by ASHAs is highly reliable. This implies that hypertension screening can be task-shifted to ASHAs with confidence. To our knowledge, this is among the first studies validating CHW BP measurements against ABPM rather than physician BP in an Indian community setting, providing more robust evidence for task-shifting than was previously available.

Other studies have reported that even non-health workers and CHWs equipped with electronic devices can record BP values very close to physicians. Reidpath *et al.*[10] demonstrated in Malaysia that non-health workers using electronic devices measured BP as reliably as qualified health workers, with differences of only 5–7 mmHg for diastolic BP. Hesse *et al.*[11] showed that CHWs with mHealth support achieved physician-equivalent diagnostic accuracy in Guatemala. However, both these studies used physician measurements as their reference standard and not 24-hour ABPM, which is the gold standard. Physician office BP itself suffers from white-coat effects and measurement variability that can misclassify 15–30 per cent of patients[12,13]. By using ABPM as the reference, our study eliminates this limitation. The NPV of 94.9 per cent means that fewer than five per cent of individuals screened negative by ASHAs are truly hypertensive, confirming that ASHA-led screening is fit for purpose in a population programme.

Two visits perform better than a single reading mainly because they are able to balance physiological fluctuations and reduce measurement bias. The white-coat effect also decreases as people become more relaxed with repeat visits by ASHAs, offsetting the anxiety felt on the first visit. This has been documented by Jose *et al.*[19] and in NFHS-4 data, which showed that single readings lead to higher hypertension prevalence mostly due to measurement bias. In our data, the significant deterioration in specificity (90.4 to 84.3%) and PPV (75.0 to 64.9%) with single readings resulted in five additional false positives per 111 screened, or approximately 4.5 per cent unnecessary referrals — a substantial burden when scaled to millions of screenings nationally. Despite this evidence, many ASHAs measure BP only once due to workload pressures, and programme managers need to ensure adherence to the two-visit protocol.

When we looked at the Bland-Altman plots, the near-zero systolic bias against daytime ABPM (− 0.6 mmHg) is reassuring — the nighttime dipping is what changes the scenario and makes ASHA versus 24-hour readings appear more off than the daytime comparisons. However, looking at the traditional analysis — the number of points beyond the limits of agreement lines — the concordance between ASHA-measured and ABPM blood pressure does not seem to be a major problem. The nighttime dip is a physiological phenomenon which can never be captured in daytime office readings. The larger diastolic bias (+ 4.9 to + 8.4 mmHg) can be explained by the combination of white-coat effect and absence of nocturnal dipping in office BP — ambulatory BP catches the nocturnal dip which happens more for diastolic BP, so the average diastolic falls more in ambulatory recordings[13,21]. The wide limits of agreement (~ ± 20 mmHg for systolic BP) are typical in BP method comparison studies and reinforce the programme's design of using ASHA screening with facility-level confirmation rather than stand-alone

diagnosis. The low white-coat hypertension rate (7.2%) likely reflects that measurement happened in participants' homes, suggesting that ASHA-led screening may inherently reduce white-coat effects — an additional advantage of task-shifting. The high nocturnal non-dipping prevalence (55.9%) highlights the diagnostic value that ABPM adds beyond office measurements[22].

The main limitation is that recruiting people for ABPM is quite difficult — these were participants in the catchment area of our urban field practice centres, and considering the time available, we could not go beyond 111 participants. This moderate sample size limits the precision of our estimates. Convenience sampling based on willingness to undergo 24-hour ABPM may have introduced selection bias, as participants who agreed may differ systematically from those who declined; however, since both the index test and reference standard were applied to the same participants, internal validity of the diagnostic accuracy comparison is preserved. The study was limited to urban slums of a single city, so results need to be generalised with caution. ASHAs' awareness that their measurements would be compared with ABPM may have improved their measurement quality (Hawthorne effect). The strengths of the study include use of ABPM rather than physician BP as the reference standard, the operational context of the NP-NCD programme, and the comprehensive analytical approach including Bland-Altman, ICC and kappa statistics.

These findings have direct implications for India's NP-NCD programme. Our study provides an evidence base for a policy shift — that BP measurement can be task-shifted to ASHAs, since their readings have been validated against the gold standard and not just against physicians. If along with CBAC administration, BP measurement is also done by ASHAs, then the second step of confirmation could happen at the ANM level, and therapy initiation at the Medical Officer or the newly introduced Community Health Officer level at the sub-centre. This gives a manifold edge considering the dropouts between the current screening levels. Currently the ASHA's follow-up responsibility involves only informing patients for continued visits, but if she is empowered to measure blood pressure, she can also take stock of their control status and give precise advice — and patients will have cues to act. The current cascade documents screening coverage as low as 2–62 per cent across districts[8]. With approximately one million ASHAs nationally[23], equipping them with digital devices and standardised protocols could substantially improve coverage at modest cost. Programme managers should prioritise training and operational support to ensure two-visit protocol adherence.

Conclusion

In conclusion, this study provides robust evidence that ASHAs can measure blood pressure as reliably as any industry-standard measurement. We need to delegate this responsibility to ASHAs so that we have realistic screening with a higher yield and also better follow-up of persons with hypertension in the community. The two-visit protocol should be the standard; single readings should be avoided due to higher false-positive rates.

Abbreviations

National Programme for Non-Communicable Diseases	NP-NCD
Blood Pressure	BP
Accredited Social Health Activists	ASHAs
Ambulatory Blood Pressure Monitoring	ABPM
National Family Health Survey-5	NFHS-5
Population Based Screening	PBS
Community Based Assessment Checklist	CBAC
Auxiliary Nurse Midwives	ANMs
Medical Officers	MOs
Community Health Workers	CHWs
Urban Primary Health Centres	UPHCs
All India Institute of Medical Sciences	AIIMS
Positive Predictive Value	PPV
Negative Predictive Value	NPV
Intraclass Correlation Coefficients	ICC
Interquartile Range	IQR

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Human Ethics Committee, All India Institute of Medical Sciences (AIIMS), Bhopal (IHECPGRPHD066, dated June 23, 2020). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AL, AP, RJ and AJ were involved in the conception and design of the work. AL, NS and RC were also involved in data acquisition. AL, PP, AP and AJ cleaned the data and conducted the data analysis. AL, PP, AP and AJ also performed the data interpretation. AL and PP drafted the work, with all authors substantially revising the draft. All authors read and approved the final manuscript.

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Figures

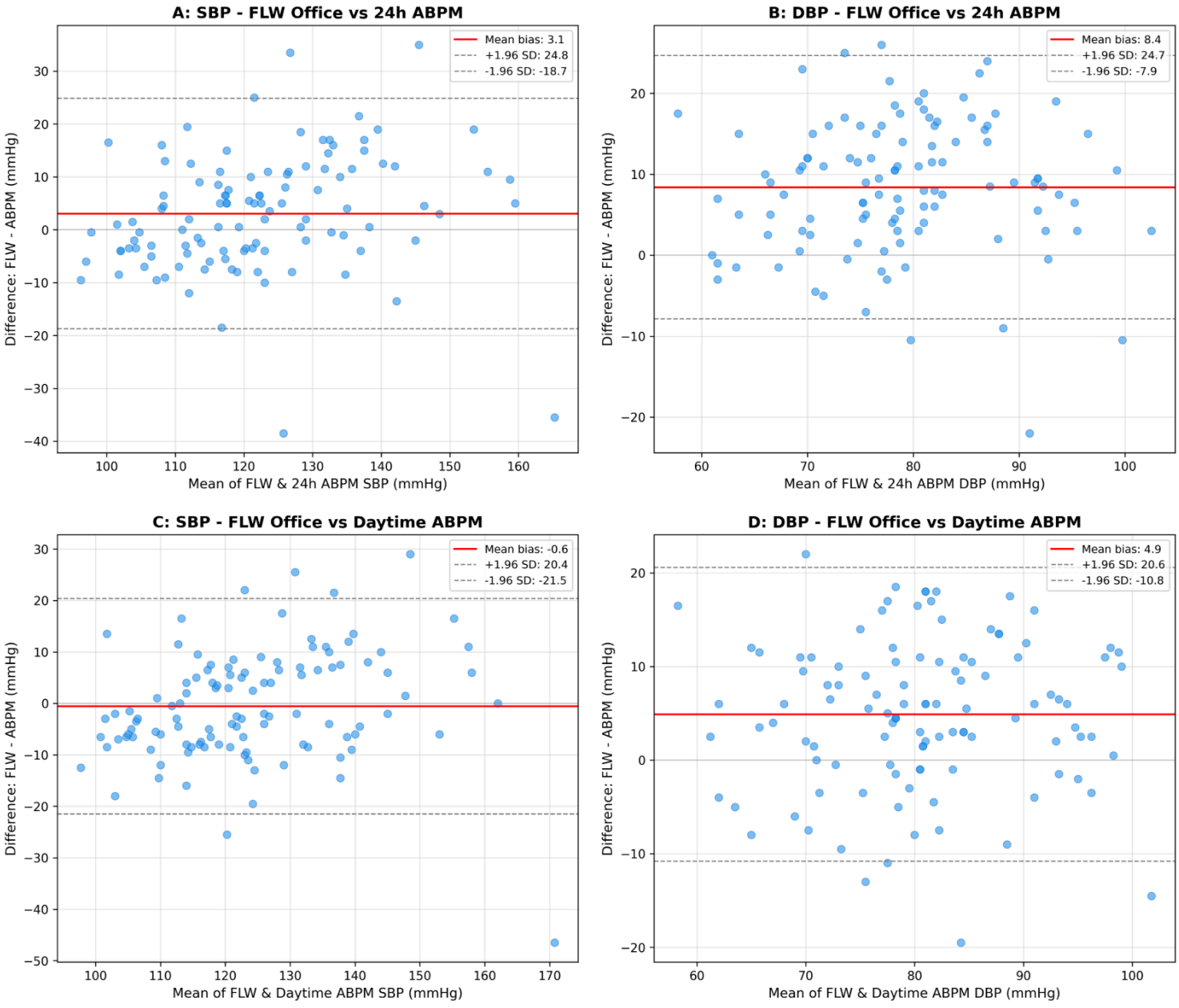


Figure 1

Bland-Altman plots showing agreement between ASHA office blood pressure and ambulatory blood pressure monitoring (ABPM)

Panel A: Systolic BP vs 24-h ABPM; Panel B: Diastolic BP vs 24-h ABPM; Panel C: Systolic BP vs daytime ABPM; Panel D: Diastolic BP vs daytime ABPM. Red horizontal lines indicate mean bias; dashed grey lines indicate 95 per cent limits of agreement.

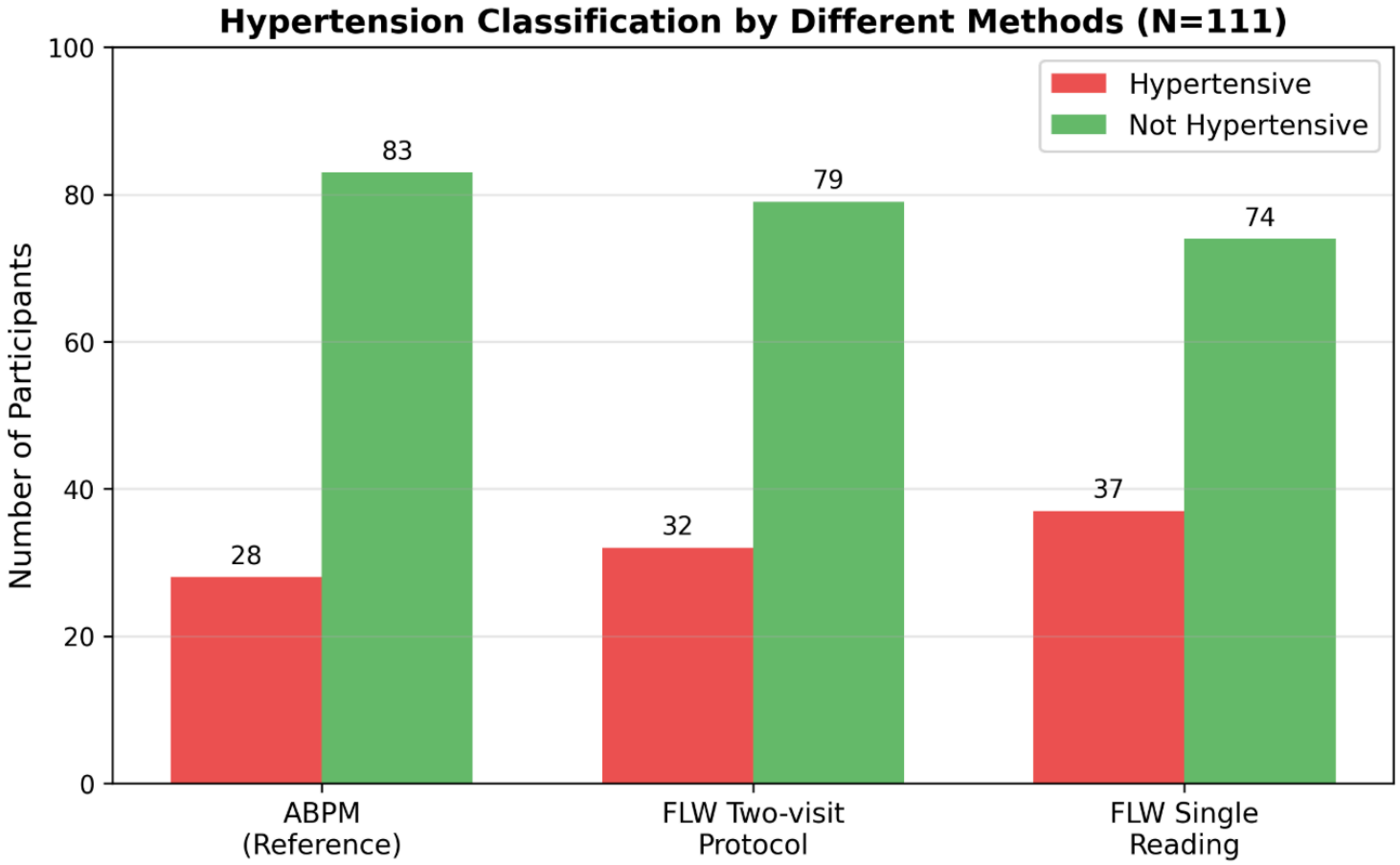


Figure 2

Hypertension classification by different measurement method (N=111).

ABPM-defined hypertension was present in 28 participants (25.2%). The two-visit ASHA protocol classified 32 (28.8%) and the single-reading protocol 37 (33.3%) as hypertensive.