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Comparison of blood pressure measurements obtained in the home setting: analysis of the Health Measures at Home Study

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Abstract

Background—Automated blood pressure (BP) devices have been used in the home for self-management purposes and are increasingly being used in population-based research. Although these devices are convenient and affordable and may be used by inexperienced lay personnel, the potential impact of an examiner's skill level on the results needs to be evaluated quantitatively. The aim of this study was to compare BP measurements obtained in a home setting by personnel with healthcare experience with those obtained by personnel without healthcare experience. In addition, the percent agreement in high blood pressure (HBP) classification between the home BP measurement by the field interviewer (FI) and measurements obtained in a standardized environment was examined.

Methods—The Health Measures at Home Study was a pilot study carried out among 128 adult participants recruited from the National Health and Nutrition Examination Survey. The Health Measures at Home Study provided the opportunity to compare the BP values obtained with an automated device in a home setting by both experienced health technicians (HTs) with those obtained by FIs who had no healthcare experience. Differences between measurements obtained by the HT and measurements obtained by the FI were assessed using paired *t*-tests, Pearson's correlations, and Bland–Altman plots. Percent agreement and κ-statistics were used to assess agreement in HBP classification between examiners in the home. Measurements obtained by the FI were also compared with those obtained in the National Health and Nutrition Examination Survey mobile exam center (MEC) by a physician using percent agreement and κ-statistics.

Results—There was a high correlation in both systolic blood pressure (SBP; $r = 0.903$) and diastolic blood pressure (DBP; $r = 0.894$) between measurements obtained by HTs and those obtained by FIs. The mean SBP and DBP obtained by the FIs (SBP, 119.0 ± 14.4 mmHg; DBP,71.9 ± 9.8 mmHg) were significantly higher than the HT measurements (SBP, 117.0 ± 12.7

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Conflicts of interest

There are no conflicts of interest.

mmHg; DBP,69.9.9 ± 9.2 mmHg). In the home, the FI classified 11.7% as having HBP, whereas the HT classified 7.0%. The percent of individuals classified as having HBP by the physician in the MEC was 10.2% of the participants.

Conclusion—Operationally, FIs could take BP measurements in the home; however, there were some differences between measurements obtained by the FI and HT. The absolute difference between measurements obtained by the FI and those obtained by the HT in the home showed that measurements obtained by the FI tended to be higher than the HT, but the magnitude of these differences was less than 5 mmHg. The HT classified 7.0% of HBP whereas the FI classified 11.7% of HBP. Similarly, the FI and the MEC physician classified a different percent of individuals with HBP. Further investigation is warranted to determine the cause of these small but significant absolute differences between measurements obtained by the FI and HT.

Keywords

blood pressure; health technician; home measurements; National Health; Nutrition Examination Survey

Introduction

In September 2011, the Department of Health and Human Services launched the ‘Million Hearts’ initiative, aimed at preventing one million heart attacks and strokes over the next 5 years [1]. This initiative requires tracking of blood pressure (BP) in a timely manner at both national and subnational levels. The National Health and Nutrition Examination Survey (NHANES) is the only national survey that combines household survey questionnaires with a physical examination performed at a mobile examination center (MEC). However, the NHANES findings have limited applicability at the state and local levels. Although there are a few state-level community surveys, they are not reproduced on a regular basis because of human resource limitations and financial burden [2]. One possible way to enhance surveillance capabilities at the subnational level would be to add physical examinations and biospecimen collection to an existing national household health survey that can produce state-level estimates. Inclusion of physical measures on a large household survey, such as the National Health Interview Survey (NHIS), could provide detailed state-level and reliable subgroup information that would be useful in assessing and targeting intervention needs. In addition, the annual release of estimates from the NHIS would allow for more frequent reporting of these measures as NHANES data are released only at the completion of each 2-year cycle. However, the existing NHIS workforce, while highly trained as interviewers, do not have training in performing physical measurements.

International studies have examined whether nonhealth workers could measure BP in resource-limited environments and have indicated that BP measurement could be performed by nonclinical staff; however, these studies were not carried out in a home environment [3]. Further information is still required to assess whether nonclinical staff can obtain accurate BP measurements in a participant’s home.

The National Center for Health Statistics carried out a pilot study in 2012, the Health Measures at Home Study (HMHS), to examine the ability of field interviewers (FI) to collect

physical measurements including BP, anthropometry, and dried blood spots in the homes of participants. The study was designed to address operational and methodological questions about the addition of a physical examination component to the NHIS for use by FI in the home.

In this paper, we present the results of the HMHS BP examination. This paper seeks to provide some analytical basis for evaluating the variance introduced by nonclinical personnel using an automated BP device in a home setting. The aim was to assess the validity and reliability of measurements obtained by FIs in the home. We compared the measures obtained by the FI with those obtained by the health technician (HT) in the home, and also compared the percent of individuals classified as having high blood pressure (HBP) between the FI and the HT in the home as well as between the FI in the home and the physician in the standardized environment of the NHANES mobile exam center (MEC).

Methods

Sample

Participants for the HMHS were recruited from the NHANES sample – a cross-sectional survey of the non-institutionalized USA civilian population. NHANES collects extensive health information through home interviews and physical measurements. Further details on the NHANES sample design and data collection methods can be found elsewhere [4].

HMHS participants were a convenience sample recruited during a 4-month period in the NHANES 2011–2012 survey cycle. Participants were enrolled only after they completed the following examinations required at the MEC: anthropometry, BP, and phlebotomy. Interested participants signed an informed consent electronically. Home visits were scheduled in the first available time slot after the MEC visit (normally 1–3 weeks later) as close to the same time of day as the MEC exam as possible. However, flexibility was allowed in scheduling home exams if needed to avoid refusals. Pregnant women and nonfluent English speakers were excluded from participation in the study. A total of 130 participants aged 18 years and older participated in the HMHS. Further details of the HMHS study are provided elsewhere [5]. BP was not measured for two participants because of equipment malfunction in the home, resulting in a final analytic sample of 128 participants.

The National Center for Health Statistics Research Ethics Review Board reviewed and approved the HMHS study design and all participants provided written consent.

Examiners and measurements

BP measurement in the home

In this study, home BP measurement refers to a single assessment at a particular point in time obtained in the home by a trained examiner, rather than self-monitoring when measurements are obtained (by the participant him/herself) multiple times within a given day for several days.

The FI and the HT performed the home exam on the same visit. HTs had, at minimum, an Associate's degree in Health Science, cardiopulmonary resuscitation certification, and at least 1-year experience working in the healthcare field. FIs had, at minimum, a high school diploma or equivalent but no previous healthcare experience or training.

In the home, data collection included dried blood spots, height, weight, and BP. The approximate duration to complete one exam sequence was 30 min. Details of the study design and descriptions of all three components can be found elsewhere [5]. A brief description of the BP component is presented here.

Participants were not told which examiner was the FI or the HT. Similarly, home examiners were instructed not to volunteer their skill level. Examiners were not allowed to observe each other perform the exam sequence; thus, the home examiners were not aware of each other's BP readings. The second examiner started his or her exam only after the first examiner completed his or her exam and packed up his or her equipment. In addition, the order of the examiners was randomized to control for any order effect [6].

Two weeks before the start of the HMHS, four FIs and two HTs were trained on the NHANES BP protocol [7] using the same device. The BP measurements were three successive readings on the same arm, with the participants seated with their backs supported, both feet flat on the floor, and forearms supported on a stable surface at the heart level [8]. An initial 5-min wait period was observed before the start of each BP exam, with 30-second rest intervals between each of the BP readings. The BP results were manually keyed in by the examiners as the BP devices do not have data-transfer capability. The examiners keyed in their BP results twice to reduce data entry error. All of the participants had six replicate BP readings in the home (three by the HT and three by the FI).

A subset of participants ($n = 82$) had an extra set of BP measurements obtained over a sleeved arm by the FI. The rationale for recording BP over the sleeve is explained in the series report [5]. BP differences between bare arm and sleeved arm are beyond the scope of this study and are not explored in this paper.

The OMRON HEM-907XL Intellisense digital BP monitor (Omron Healthcare, Bannockburn, Illinois, USA) was used to obtain BP. The Omron device was chosen for the study because it had been validated in a previous NHANES methodology study [9]. It has a 'hide' feature that was used during the home BP measurements to block visibility of the measurements from the participant. Cuff size in the home was determined by estimating the mid-arm circumference (mid-AC) using a sex-specific regression equation published by Ostchega *et al.* [10] to minimize physical contact with a participant. This equation used the height and weight measurements obtained in the anthropometry section of the home exam to calculate mid-AC. Mid-AC was then used to select the appropriate cuff size. The Omron machine had four available cuff sizes fitting the following arm circumferences: small (17.0–22.0 cm), adult (>22.0–32.0 cm), large adult (>32.0–42.0 cm), and extra-large adult (>42.0–50.0 cm).

Calibration and quality assurance/quality control procedure for home BP device

The FI performed monthly calibrations on all the Omron machines using the Netech Digimano 2000 pressure vacuum (Netech Corp., Farmingdale, New York, USA). The calibration technique involved connecting the Omron device and the pressure vacuum gauge through a T-connector [8,9]. Pressure points were compared between the two devices and comparative readings were required to fall within ± 3 mmHg [8,9]. Before the start of the HMHS, all BP machines passed calibration testing. This responsibility for calibration was intentionally given to the least experienced examiner to determine whether equipment maintenance could be performed by FIs.

BP measurement at the mobile examination center

As the HMHS participants were drawn from the NHANES sample, all HMHS participants had BP measurements taken in the MEC as part of their routine physical examination by a trained physician using the auscultation method using a standard wall-mounted mercury sphygmomanometer and a Littman Cardiology III stethoscope (3M Health Care, St. Paul, Minnesota, USA). The physician followed the standard NHANES protocol described on the NHANES website [7] to obtain three replicate BP measurements. The appropriate cuff size was based on a direct measurement of mid-AC [11]. There were four available cuff sizes for the mercury sphygmomanometer fitting the following arm circumferences: small (17–21.9 cm), adult (22–29.9 cm), large adult (30–37.9 cm), and extra-large (38–47.9 cm). The physician keyed in all BP values by hand. BP equipment in the MEC are inspected on a regular basis.

Statistical analyses

In the first set of analyses, the examiners in the home were compared. Mean differences were calculated and compared with national standards. Differences in BP classification were also compared. The second set of analyses compared results from the FI with the MEC physician. For each examiner, averages were calculated for the three sets of replicate systolic blood pressure (SBP) and diastolic blood pressure (DBP) measures. These averages were used throughout the subsequent analyses. Overall mean BP values were computed and compared by the home examiner. The magnitude of the BP difference was assessed between the home examiners, overall, by sex, and by the age of the participants. Inter-rater reliability between the FI and HT was assessed by Pearson’s correlation coefficients.

To provide another familiar metric for the evaluation of differences between the two examiners, the mean and absolute differences by home examiner were compared with criteria for accuracy developed by the Association for the Advancement of Medical Instrumentation (AAMI) and the revised British Hypertension Society (BHS). It should be noted that the validation approach used to compare the examiners in the home are traditionally used to evaluate devices rather than individuals. The AAMI guidelines indicate that the mean difference between values measured by the two different types of examiners should be no greater than ± 5 mmHg, with a maximum SD of 8 mmHg [12,13]. The revised BHS guidelines use a grading system from A to D to evaluate accuracy from best to worse. We calculated the percentage of absolute differences between the examiners that fell within

5, 10, and 15 mmHg [14]. Bland–Altman graphs and scatter plots were used to visually show agreement between the home examiners.

We classified individuals into the following categories: elevated systolic blood pressure (ESBP), elevated diastolic blood pressure (EDBP), and HBP. ESBP was defined as SBP of 140 mmHg or more, EDBP was defined as DBP of 90 mmHg or more, and HBP was defined as both ESBP and EDBP. To assess the level of agreement of HBP classification between the two home examiners, κ-statistics and percent agreement were calculated.

In a second set of analyses, we examined the classification agreement of HBP between the FI and the MEC physician by also using the κ-statistic and percent agreement.

All tests were evaluated for statistical significance using a P value of less than 0.05. All analyses were carried out using the SAS software (version 9.3; SAS Institute, Cary, North Carolina, USA). No adjustment was made for multiple comparisons.

Results

The mean age of the participants was 44 ± 18.7 SD years; 55% of the sample were men and 30% were 60 years and older. Participant characteristics are shown in Table 1.

Before each home BP exam, participants were asked whether they ate, smoked, or ingested alcohol or caffeine in the 30 min before the BP examination as these are factors known to affect BP. Almost 22% of participants stated that they had eaten or smoked, 15% of participants drank coffee, and 2% had consumed alcohol in the 30 min before the home exam [5].

The use of a regression equation to estimate the mid-arm circumference measurement and determine the appropriate BP cuff used on participants in the home resulted in the same cuff size selection by both the FI and HT for all participants: 42% had an adult-sized cuff, 53% had a large adult-sized cuff, and 5% had an extra-large adult sized cuff. The mean time to complete the exam was13.2 min for the FI and 13.7 min for the HT [5].

Comparison of home blood pressure measurements (HT vs. FI)

The overall BP mean ± SD measured by HTs (SBP, 117.0 ± 12.7 mmHg; DBP, 69.9 ± 9.2 mmHg) was lower than the overall BP mean measured by FIs (SPB, 119.0 ± 14.4 mmHg; DBP, 71.9 ± 9.8 mmHg) (Table 2).

The mean difference was 2.0 ± 6.2 mmHg ($P < 0.001$) for SBP and 2.0 ± 4.4 mmHg ($P < 0.001$) for DBP (Table 3). The FI had higher BP readings compared with the HT for both sexes and for one age group (18–39 years of age) (Table 3).

The mean BP measurements between the home examiners were highly correlated ($r = 0.903$ for SBP and $r = 0.894$ for DBP) (Fig. 1).

The Bland–Altman graphs provide a visual comparison of the average differences in SBP and DBP measures (HT vs. FI) against the corresponding average BP measurement of the

examiners (Fig. 2). All figures showed some extreme values beyond two SD. The Bland–Altman plots show good agreement for both SBP and DBP with no clear linear pattern, indicating, on average, that the difference in BP readings between the HT and FI was close to the zero line along the entire continuum of BP values.

Also, in Table 3, the comparison between the FI and HT measurements fulfilled the AAMI criteria, with the exception of the SBP measurements in the 60 years and older age group (n = 39), in which the SD for the difference between the HT and FI measurements was8.5 mmHg.

The percentages of BP differences within 5, 10, and 15 mmHg were 64, 91, and 97%, respectively, for SBP and 71, 97, and 99%, respectively, for DBP (Table 3).

Table 4 presents the percentages of participants who were classified as having elevated SBP (ESBP ≥ 140 mmHg), elevated DBP (EDBP ≥ 90 mmHg), and HBP (SBP/DBP ≥ 140/90 mmHg) by examiner type. In the home, the FI classified 8.6% of participants as having ESBP, whereas the HT classified 6.3%. The FI identified 5.5% as having EDBP, whereas the HT identified 0.8%. The FI classified 11.7% of participants as having HBP, whereas the HT classified 7.0% of the participants as having HBP. The FI consistently identified more cases than the HT in all categories.

The percent agreement between the HT and FI in the determination of ESBP was 95%, with a κ-statistics of 0.60 [95% confidence interval (CI) = 0.30–0.87], suggesting moderate agreement. Similarly, the percent agreement for HBP was 92%, with a moderate κ-statistics [κ = 0.54, 95% CI = 0.30–0.79]. However, the percent agreement for EDBP was 95%, with a lower κ-statistics [κ = 0.24, 95% CI = − 0.15 to 0.63], indicating fair agreement. A κ-statistics value between 0.21 and 0.40 represents fair agreement, a value between 0.41 and 0.60 represents moderate agreement, and a value between0.61 and 0.80 represents considerable agreement [15] (Table 5).

κ-Statistic are usually used to assess observer agreement, but can be constrained by low prevalence.

Agreement on high blood pressure classification between home and MEC (FI vs. MEC physician)

The mean SBP (119.6 ± 15.4 mmHg) and the mean DBP (72.7 ± 9.3 mmHg) values from the MEC were higher than those reported in the home, irrespective of the home examiner.

In the MEC, the physician classified 10.2% of participants as having ESBP, 3.1% as having EDBP, and 10.2% as having HBP (Table 4), whereas the FI classified 8.6% of participants as having ESBP, 5.5% as having EDBP, and 11.7% of participants as having HBP.

The percent agreement across two categories (ESBP and HBP) between the FI and physician was 92 and 91%, respectively, with the following moderate κ-statistics (κ = 0.54, 95% CI = 0.29–0.79 and 0.57, 95% CI = 0.35–0.80, respectively). The percent agreement for EDBP between the physician and FI was 91%, but the κ-statistic was low (κ = 0.34, 95% CI = − 0.03 to 0.71) (Table 5).

Discussion

Although a number of states and special population studies include BP measurements as part of their home exam, to date, little information is available on the quality of the measurements in a home setting. Although the SBP and DBP measurements obtained by the FI were higher than those obtained by the HT (reaching significance overall and in certain demographic subgroups), the absolute values of these differences were all less than 5 mmHg. The overall BP measurements in the home between the FIs and HTs were highly correlated and fulfilled the AAMI and the revised BHS criteria for SBP and DBP. The estimated percent of participants with elevated BP was higher in measurements obtained by the FI than the HT. Our study findings suggest that using an FI alone to measure BP in the home could result in an overestimated national estimate of individuals with HBP. The agreement between the FI and the physician for the different classifications varied from low to fair. These results could potentially be influenced by the low prevalence of the outcomes of interest.

Although some of our findings corroborate international findings that nonhealth workers are able to accurately measure BP [3,16], there were small but significant differences in SBP and DBP measurements when comparing examiners with no healthcare experience with examiners who had healthcare experience. One factor that could account for this difference is the examiner–participant interaction that may have been different for the two types of examiners, yielding systematically different measurements. For example, all the participants in the home had their fingers pricked to obtain dried blood spots before the BP exam. Participants may have had a physiological response to the dried blood spots component, which could have affected BP readings. If this response was more intense for the FI than the HT, this could have accounted for some of the differences in BP measurement. Pierin *et al.* [17] showed that BP readings are affected by the presence of an observer or a stranger, although this effect could not be assessed in this study. Gindi *et al.* [5] noted that the FI took longer to complete the dried blood spot portion of the exam and did not use hand-warming techniques as often as the HT. In the HMHS, one or both examiners reported some external factor (i.e. other adult, children, animal, and telephone) that could have introduced variability in measurements in over 70% of the homes. Gindi *et al.* [5] noted that 35% of the participants had some sort of disruption in the home during their BP examination, which may have affected BP results. However, it should be noted that there is no evidence to support that the disruptions occurred more frequently for the FI.

Even though the HMHS participants were recruited from the NHANES and had completed a set of BP measurements by a physician using a mercury sphygmomanometer, the study design enabled only a limited comparison of the measurements obtained in the MEC with those obtained in the home. Primarily, this was because of the ~1–3-week lag time between the MEC appointment and the home visit. No effort was made to standardize the time between MEC and home visits, and visit-to-visit variability in BP has been documented [18]. Our findings also do not take into account possible lifestyle modification behaviors or newly prescribed medications that could have occurred between the MEC and home visits. A variety of changes in both the environments and protocols between the MEC and home measurements make it difficult to determine the impact of each of the changes

independently. The MEC is a controlled environment with low noise and interference, whereas the home environment was subject to disruptions. Protocol and equipment differences included the selection of cuff size by a direct measure in the MEC versus regression equation in the home as well as the type of BP instrument used. It is well established that BP obtained by auscultation with the mercury sphygmomanometer is subject to observer bias and end digit preference. Furthermore, BP is recognized as a hemodynamic phenomenon, which can be influenced by both external and internal factors [19]. Accurate BP measurement is dependent on a number of factors, which include but are not limited to body positioning, consumption of alcohol and caffeine, room temperature, and background noise [20].

Limitations in the present study include a small sample size as well as few individuals with HBP included in our study. In particular, κ-statistics values and agreement statistics can be constrained when the prevalence of the outcome of interest is low. There were not enough cases of elevated BP to detect a meaningful difference; a larger sample size would be needed to detect a difference. Participants were not asked to abstain from caffeine, smoking, or intake of medication before or between exams, which is a potential drawback as these factors could influence BP measurements. In addition, a heart rate measurement was not determined in the home visit, which could have helped to assess participant reaction to the home examiners. Furthermore, there was no effort to identify individuals with arrhythmias, which is a condition that can influence the accuracy of an automatic BP device. Despite the fact that the examiners were trained, there is still a possibility of the deterioration of protocol adherence that may have occurred during the study. Although these findings are applicable to other household surveys considering collection of BP in the home, the findings are not intended to estimate national BP prevalence.

Conclusion

Overall, the average BP measurements obtained by FIs with no healthcare experience were close to those obtained by HTs. Although FIs recorded higher measured BP values than the HTs, the results were nevertheless comparable with each other on the basis of the AAMI and BHS criteria. However, the HT and the FI in the home classified different percentages of HBP. Similar results in the classification of HBP were observed between the FI and the MEC physician. Currently, there is a lack of objectively measured data on cardiovascular disease at the subnational level. The inclusion of BP measurements as part of a nationally representative population survey such as NHIS could help to provide these estimates. At this time, it is difficult to tease out the most important contributing factors for the differences between the home examiners, and with a small sample of hypertensive adults, our comparisons are limited.

References

1. Million Hearts Initiative. Available at: http://millionhearts.hhs.gov/index.html. [Accessed 3 June 2013].
2. Zohoori N, Pulley L, Jones C, Senner J, Shoob H, Merritt RK. Conducting a statewide health examination survey: the Arkansas Cardiovascular Health Examination Survey (ARCHES). Prev Chronic Dis 2011; 8:A67 Available at: http://www.cdc.gov/pcd/issues/2011/may/10_0134.htm. [Accessed 3 June 2013]. [PubMed: 21477507]

3. Reidpath DD, Ling ML, Yasin S, Rajagobal K, Allotey P. Community-based blood pressure measurement by non-health workers using electronic devices: a validation study. Glob Health Action 2012; 5:14876. [PubMed: 22761601]
4. Zipf G, Chiappa M, Porter KS, Ostchega Y, Lewis B, Dostal J. National health and nutrition examination survey: plan and operation 1999–2010. Vital Health Stat 1 2013; (56):1–37.
5. Gindi R, Zipf G, Galinsky A, Miller I, Nwankwo T, Terry A. Comparison of in-home collection of physical measurements and bio specimens with collection in a standardized setting: the Health Measures at Home Study. Vital Health Stat 2 2014; (164):1–16.
6. Grossardt BR, Graves JW, Gullerud RE, Bailey KR, Feldstein J. The occurrence of the alerting response is independent of the method of blood pressure measurement in hypertensive patients. Blood Press Monit 2006; 11:321–327. [PubMed: 17106316]
7. National Health and Nutrition Examination Survey (NHANES). Physician examination procedures manual. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/Physician_Exam_Manual.pdf. [Accessed 17 May 2013].
8. Ostchega Y, Zhang G, Sorlie P, Reed-Gillette D, Nwankwo T, Yoon S. Blood pressure randomized methodology study comparing automatic oscillometric and mercury sphygmomanometer devices: National Health and Nutrition Examination Survey, 2009–2010. Natl Health Stat Report 2012; :1–15.
9. Ostchega Y, Nwankwo T, Sorlie PD, Wolz M, Zipf G. Assessing the validity of the Omron HEM-907XL oscillometric blood pressure measurement device in a National Survey environment. J Clin Hypertens (Greenwich) 2010; 12:22–28. [PubMed: 20047626]
10. Ostchega Y, Prineas RJ, Dillon C, McDowell M, Carroll M. Estimating equations and tables for adult mid-arm circumference based on measured height and weight: data from the third National Health and Nutrition Examination Survey (NHANES III) and NHANES 1999–2000. Blood Press Monit 2004; 9:123–131. [PubMed: 15199305]
11. National Health and Nutrition Examination Survey (NHANES). Anthropometry procedures manual. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/Anthropometry_Procedures_Manual.pdf. [Accessed 11 June 2013].
12. ANSI/AAMI SP10–2002 Protocol: Association for the Advancement of Medical Instrumentation, 2003 American National Standard. Electronic or automated sphygmomanometer ANSI/AAMI SP10–2002, 3330 Washington Boulevard, Suite 400, Arlington, VA 22201–4598, AAMI, USA.
13. Accuracy Criteria for the Evaluation of Blood Pressure devices. Available at: http://www.dableducational.org/accuracy_criteria.html. [Accessed 3 June 2013].
14. Khawaja RA, Qureshi R, Mansure AH, Yahya ME. Validation of Datascope Accutorr Plus using British Hypertension Society (BHS) and Association for the Advancement of Medical Instrumentation (AAMI) protocol guidelines. J Saudi Heart Assoc 2010; 22:1–5. [PubMed: 24936124]
15. Viera AJ, Garrett JM. Understanding interobserver agreement: the kappa statistic. Fam Med 2005; 37:360–363. [PubMed: 15883903]
16. Amarchand R, Sharma H, Krishnan A. Community health workers can be trained to measure blood pressure: experience from India. Regional Health Forum 2013; 17:1.
17. Pierin AM, Ignez EC, Jacob Filho W, Barbato AJ, Mion D. Blood pressure measurements taken by patients are similar to home and ambulatory blood pressure measurements. Clinics (Sao Paulo) 2008; 63:43–50. [PubMed: 18297206]
18. Mancia G, Ferrari A, Gregorini L, Parati G, Pomidossi G, Bertinieri G, et al. Blood pressure and heart rate variabilities in normotensive and hypertensive human beings. Circ Res 1983; 53:96–104. [PubMed: 6861300]
19. Wang W, Xie JX, Liu L, Ai XH, Zhang J, Sun JY, et al. Agreement comparison between home and clinic blood pressure measurements in 200 Chinese participants. Blood Press Monit 2011; 16:277–281. [PubMed: 22045018]
20. Beevers G, Lip GY, O'Brien E. ABC of hypertension. Blood pressure measurement. Part I-sphygmomanometry: factors common to all techniques. BMJ 2001; 322:981–985. [PubMed: 11312235]

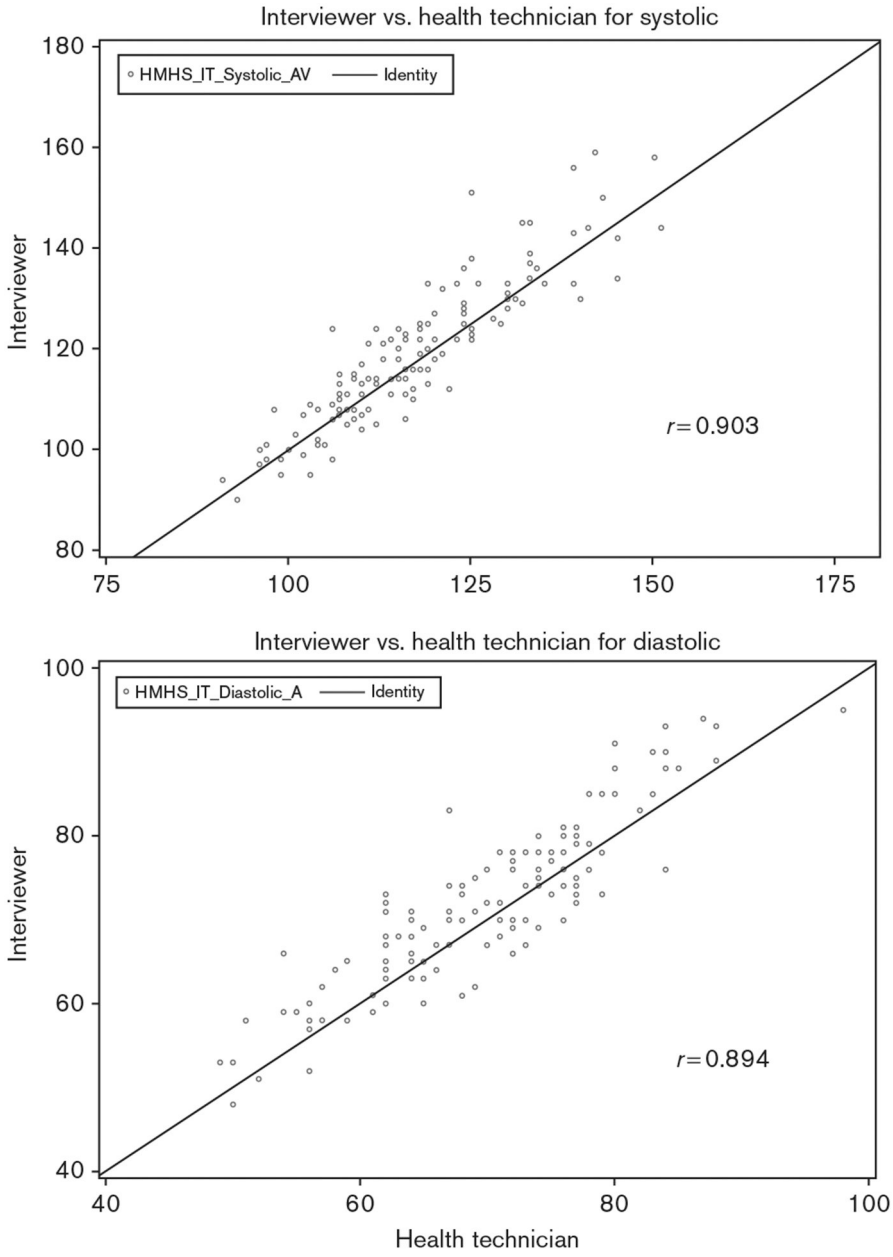

Fig. 1.

Scatter plot of systolic and diastolic blood pressure readings obtained by the health technician and the interviewer.

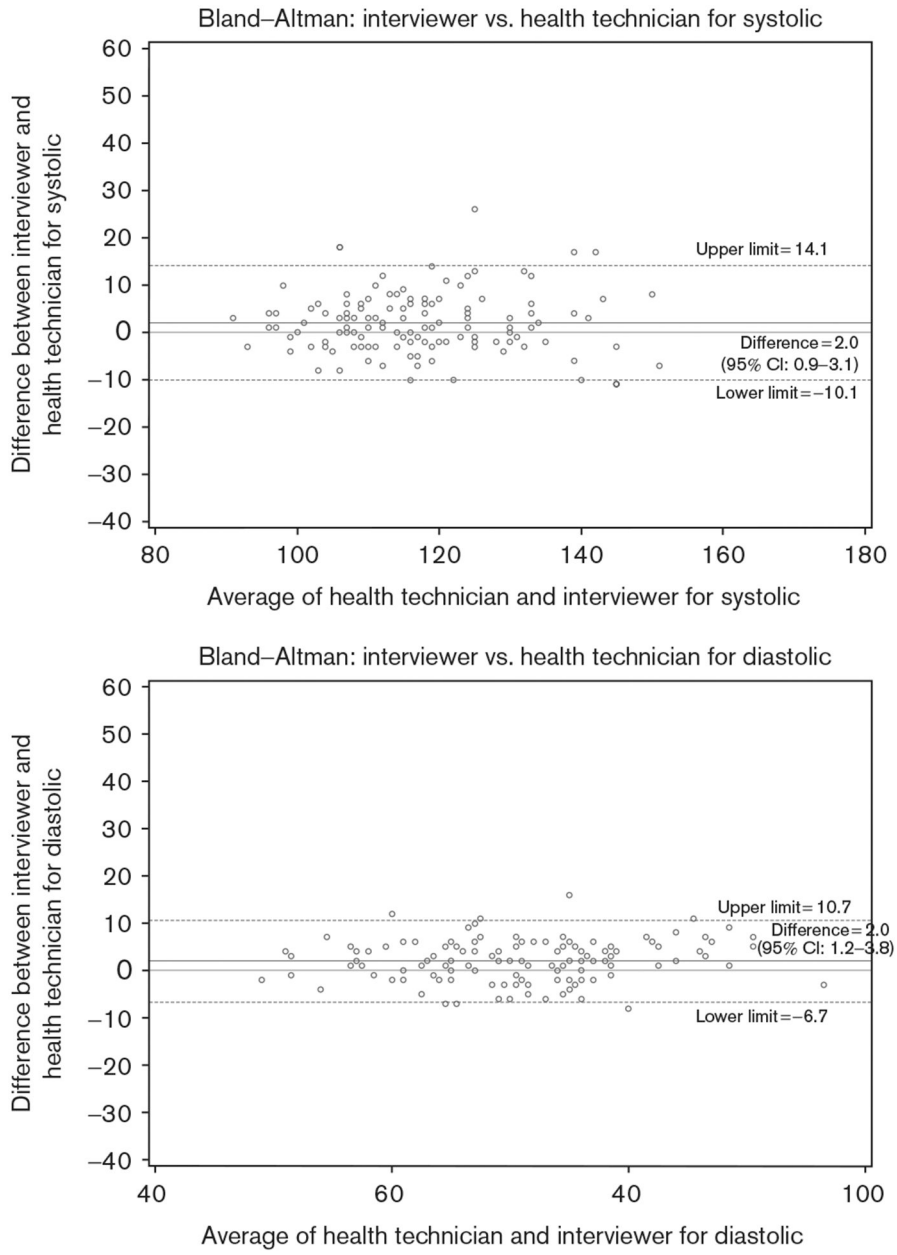

Fig. 2.

The Bland–Altman graphs provide a visual comparison in the average differences in SBP and DBP measures (HT vs. FI) against the corresponding average BP measurement of the examiners. BP, blood pressure; CI, confidence interval; DBP, diastolic blood pressure; FI, field interviewer; HT, health technician; SBP, systolic blood pressure.

Table 1

Health Measures at Home Study sample characteristics

Characteristics	***n*** **(%)**
Total	128 (100)
Sex	
Male	71 (55)
Female	59 (45)
Age group	
18–39	59 (45)
40–59	32 (25)
60+	39 (30)
Race/ethnicity	
Non-Hispanic White, single race	67 (52)
Non-Hispanic Black, single race	43 (33)
Hispanic and/or other races	20 (15)

Table 2

Overall mean and SD of systolic blood pressure and diastolic blood pressure by home examiners and mobile examination center physician

		SBP (mmHg) [mean (SD)]			DBP (mmHg) [mean (SD)]		
Examiners	***N***	**MEC**	**HT**	**FI**	**MEC**	**HT**	**FI**
Overall	128	119.6 ± 15.4	117.0 ± 12.7	119.0 ± 14.4	72.7 ± 9.3	69.9 ± 9.2	71.9 ± 9.8
Age group (years)							
18–39	58	113.5 ± 10.4	112.6 ± 10.0	115.0 ± 12.0	71.6 ± 8.4	69.1 ± 9.5	71.1 ± 9.4
40–59	31	120.4 ± 15.5	116.4 ± 12.2	116.9 ± 12.3	75.1 ± 10.2	72.8 ± 8.5	75.2 ± 8.8
60 +	39	127.8 ± 17.2	124.0 ± 13.6	126.5 ± 16.4	72.3 ± 9.5	68.8 ± 9.0	70.5 ± 10.7
Sex							
Male	70	122.3 ± 14.0	120.3 ± 12.3	122.6 ± 12.9	74.4 ± 8.5	69.9 ± 9.7	72.8 ± 10.3
Female	58	116.3 ± 16.4	113.0 ± 12.0	114.6 ± 14.9	70.6 ± 9.8	70.0 ± 8.6	70.9 ± 9.2

DBP, diastolic blood pressure; FI, field interviewer; HT, health technician; MEC, mobile examination center physician; SBP, systolic blood pressure.

Table 3

Mean difference and percent of absolute difference between readings for systolic and diastolic blood pressure taken by field interviewer and health technician

	Systolic blood pressure (mmHg)						Diastolic blood pressure (mmHg)					
				Percent of absolute differences between average readings (mmHg) (%)						Percent of absolute differences between average readings (mmHg) (%)		
Examiners	**Mean (SD)**	**AAMI**	**Correlation**	**≤ 5**	**≤ 10**	**≤ 15**	**Mean (SD)**	**AAMI**	**Correlation**	**≤ 5**	**≤ 10**	**≤ 15**
Overall FI-HT	2.0 ± 6.2 *	Pass	0.903	64	91	97	2.0 ± 4.4 *	Pass	0.894	71	97	99
Male FI-HT	2.3 ± 6.4 *	Pass	0.870	60	90	97	2.9 ± 4.3 *	Pass	0.908	69	96	99
Female FI-HT	1.6 ± 5.9 *	Pass	0.927	69	91	97	0.9 ± 4.3	Pass	0.885	74	98	100
18–39 FI-HT	2.5 ± 4.8 *	Pass	0.919	69	93	100	2.0 ± 4.2 *	Pass	0.903	74	98	100
40–59 FI-HT	0.5 ± 4.9	Pass	0.920	68	100	100	2.4 ± 4.1 *	Pass	0.890	68	100	100
60+ FI-HT	2.5 ± 8.5 [a]	Fail	0.856	54	79	90	1.7 ± 5.1 *	Pass	0.881	69	92	97

AAMI, Association for the Advancement of Medical Instrumentation; FI, field interviewer; HT, health technician.

[a] SD did not meet AAMI standards, exceeding the recommended threshold of ± 8 mmHg.

* $P < 0.05$.

Table 4

Count and percent of elevated blood pressure by examiner

Examiner types	Count of elevated BP	Count of normotensive	Percent of elevated BP (%)	Percent of normotensive (%)
Elevated systolic blood pressure (≥140mmHg)				
MEC physician	13	115	10.2	89.8
Health technician	8	120	6.3	93.7
Field interviewer	11	117	8.6	91.4
Elevated diastolic blood pressure (≥90 mmHg)				
MEC physician	4	124	3.1	96.9
Health technician	1	127	0.8	99.2
Field interviewer	7	121	5.5	94.5
HBP (systolic/diastolic BP) (≥140/90mmHg)				
MEC physician	13	115	10.2	89.8
Health technician	9	119	7.0	93.0
Field interviewer	15	113	11.7	88.3

BP, blood pressure; HBP, high blood pressure; MEC, mobile examination center physician.

Table 5

κ-Statistic and percent agreement of high blood pressure classification by paired examiners

Paired examiners	Percent agreement (%)	κ-Statistic
Elevated systolic blood pressure (≥140mmHg)		
Health technician/field interviewer	95	0.60 (0.34–0.87)
MEC physician/field interviewer	92	0.54 (0.29–0.79)
Elevated diastolic blood pressure (≥90 mmHg)		
Health technician/field interviewer	95	0.24 (−0.15 to 0.63)
MEC physician/field interviewer	91	0.34 (−0.03 to 0.71)
HBP (systolic/diastolic BP) (≥140/90mmHg)		
Health technician/field interviewer	92	0.54 (0.30–0.79)
MEC physician/field interviewer	91	0.57 (0.35–0.80)

HBP, high blood pressure; MEC, mobile examination center physician.