Comparison of Automated versus Manual Blood Pressure Measurement among Hospitalized Medical Patients: A Crossover Trial

Keven Joy C. Batan, MD,[1] Karla Rhea R. Posadas, MD,[2] Annie Urmaza-Olarte, MD[2]

Abstract

Background. Blood pressure is an important vital sign measured not only in hypertension but also among hospitalized patients for clinical evaluation of the actual hemodynamic status. In the digital era, mercury and aneroid sphygmomanometers are being replaced by automated monitors despite lacking validation and recommendations for their use, especially in acute illness.

Objective. To compare automated and manual blood pressure measurement among hospitalized medical patients with acute illness.

Methods. A crossover design was used in a single tertiary hospital. Blood pressure was recorded from 216 participants, with 432 observations from an automated monitor (Omron HBP1120) and a mercury sphygmomanometer. Automated and manual BP recordings were done twice following the same arm sequential method. The average of the two recordings was used for comparison.

Results. Most participants were female, elderly, obese, and had cardiac complaints. Comparing automated and manual methods, the mean difference for systolic was 1.47 ± 12.12 ($p = 0.08$) and 1.82 ± 10.99 ($p=0.02$) for diastolic. Subgroup analysis revealed that males had higher manual systolic BP than females (pairwise p-value= *0.017*). Overweight and obese participants had higher automated systolic and diastolic BP ($p=0.04$). Overweight and obese participants had significantly higher systolic and diastolic BP regardless of the method. Significantly higher diastolic BP for different age groups and areas of admission ($p=0.02$) were observed from the automated method.

Conclusion. Automated BP monitoring showed a significant difference in diastolic BP recordings. Automated BP monitors should be used with caution, especially in interpreting diastolic BP among hospitalized patients.

Keywords. Automated blood pressure, manual blood pressure, Omron® HBP 1120

Introduction

Blood pressure (BP) measurement has a crucial role in the management of hypertension and other conditions like dehydration, infection, vascular disease, and stroke. It is a common medical procedure that gives the hemodynamic profile of a person. Accurate measurement is, therefore, imperative in the clinical setting for appropriate management. Mercury sphygmomanometer was the reference standard for several decades in BP measurement. Its simple design eliminates the need for calibration as the mercury gauge is always set to zero, avoiding inaccurate blood pressure recordings.[1] Trends in BP monitoring shifted from mercury sphygmomanometers in recent years due to environmental and toxicity risks. Aneroid sphygmomanometers are safer but are associated with examiner-related reading inaccuracies and need gauge calibration. In addition, observers should know the Korotkoff phases for proper systolic and diastolic BP reporting using an aneroid BP monitor.

[1] Resident-in-training, Department of Internal Medicine, Notre Dame De Chartres Hospital
[2] Research Consultant, Department of Internal Medicine, Section of Cardiology, Notre Dame De Chartres Hospital
Corresponding Author: Keven Joy Batan, MD Email: kevenjoybatan@gmail.com

Automated BP devices have addressed these issues and are currently employed in clinics and hospitals, providing efficient and promising results. Recent Canadian and American guidelines have approved the accuracy of using validated automated BP devices in the office or outpatient clinic setting. However, limited data supports their use in patients with acute illness and the hospital setting.[2] Further, the consequences of using a non-validated blood pressure device in the clinical setting can result in misinterpretation and mistreatment of an inaccurate reading.[3]

Differences in blood pressure results are further explained by the different techniques in BP measurement, namely the auscultatory or oscillometric technique. The auscultatory technique (mercury or aneroid sphygmomanometer) listens to Korotkoff sounds produced by the blood flow against the compressed artery. The first sound is classified as the systolic BP, while the complete disappearance of all sounds is considered as the diastolic BP.[4] The oscillometric technique (automated device) does not follow the phases of Korotkoff but instead incorporates oscillometric waves for BP measurement. This technique's maximal oscillation amplitude is equivalent to the mean arterial pressure (MAP). The MAP derives the systolic and diastolic BP based on a manufacturer's algorithm.[2] Therefore, different oscillometric devices are not interchangeable even if they are from the same manufacturer and should be independently validated using an established protocol as recommended by the American Heart Association (AHA) and European Society of Hypertension (ESH). [2, 5]

In today's digital era, there are different kinds of automated blood pressure devices marketed to the public and are being utilized without proper education on their accuracy. It remains a health concern due to insufficient validation or inaccuracy in special populations.[6] Literature review shows conflicting BP measurements using automated and manual monitors in elderly patients with atrial fibrillation, neurologic diseases, emergency conditions, and critical care.[7-9] This questions the device's validity since it becomes inaccurate in a hospital setting.

Currently, no studies are listed in the HERDIN Plus data registry and ASEAN Citation Index comparing automated and manual BP measurement among hospitalized patients in the Philippines. This study compares systolic and diastolic blood pressure measurements using automated versus manual methods in patients with acute illness admitted under internal medicine. Specifically, it aims to compare automated versus manual BP measurement (1) in varied hospital areas (intensive care unit, general ward, and emergency department); (2) in patients with varied clinic-epidemiologic profiles (age, gender, and body mass index); and (3) in patients with varied disease states.

Methodology

Research Design. This study employed a crossover design to compare automated and manual blood pressure recording among hospitalized patients in a single-center tertiary hospital in Baguio City, Philippines (*Figure 1*). The study was approved by a designated ethics review committee. A total of 216 participants have enrolled voluntarily in the study. The recruitment period started in July 2023 and went until October 2023. The same participant underwent manual and automated blood pressure monitoring, totaling 432 observations.

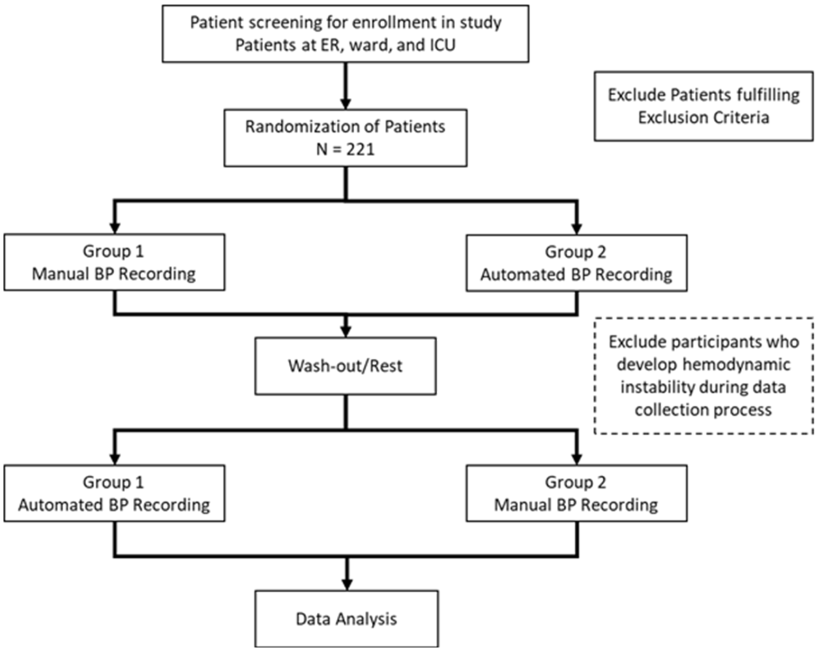

Figure 1. Study Flowchart

Participants. The study included patients aged 19 and above admitted at Notre Dame De Chartres Hospital under the Department of Internal Medicine and cared for in the ward, emergency department, or intensive care unit. The age, gender, and BMI of the participants, as well as the reason for admission, were recorded. Participants were excluded if they had recent smoking, extreme physical activity, or caffeine intake. Pregnant patients and those with decreased GCS of 12 and below were also excluded. Critical patients who were hemodynamically unstable, complaining of chest pain, and intubated were excluded. Also, patients receiving inotropes, vasopressors, nicardipine, or

Table I. Arm circumference and cuff size

Cuff Size	Arm Circumference (cm)	Cuff Dimensions
Small Adult	22-26	12 x 22
Adult	27-34	16 x 30
Large Adult	35-44	16 x 36
Extra Large Adult	45-52	16x 42

nitroglycerine infusions, which could rapidly affect BP results, were excluded.

The sample size was computed from the total population of Baguio City, which was 366,358, and the institution's admission rate was 17.35%. Using the Open-epi online sample size calculator, with a 95% confidence level, the computed sample was 221. Participants were recruited using convenience sampling to be enrolled in the study. The sample size of 221 was divided into three groups: 35% from wards, 35% from the emergency department, and 30% from the intensive care unit. A random sample was drawn from each group following the formula of f=n/N; hence, every 3rd patient admitted in each subgroup was enrolled. Two patients developed hemodynamic instability among the initially computed sample size where data gathering was not completed. Three participants did not give consent. A total of 216 patients were observed in the study.

Data Collection. The patient record was screened before contact with the patient to identify those who met the inclusion and exclusion criteria. Participants were seated comfortably with back support and allowed to rest during data gathering. The examiner explained the procedure and secured the consent form, and questions or clarifications were addressed. Participants were assigned a code, and no individual names were recorded. Age, BMI, gender, and disease were ensured to be correctly documented, and initial missing data were completed. Arm circumference was measured at the midpoint of the acromion and olecranon. The appropriate cuff was selected based on the patient's arm circumference, which was adapted from AHA recommendations.

The participant's arm was supported without clothing in between the cuff. The cuff was placed on the patient's upper arm at the level of the right atrium (midpoint of the sternum). The participants were randomly assigned to the intervention group to which they belonged. Group 1 had BP taken by the manual method first, followed by a washout/rest period, and then the automated method was employed. Group 2 had BP taken by the automated method, washout, and manual method. Blood pressure was taken on a single arm and repeated with 1-2 minute intervals. The average of two manual BP readings will be the final plotted manual BP used for data analysis, and the same will be used for the automated method. A washout period or rest for 10-15 minutes was allotted prior to the next observation to eliminate possible effects of the first observation method.

For the manual method, phase I of Korotkoff was plotted as systolic BP, and phase V was plotted as diastolic blood pressure. A reading of hypotension or hypertension was informed to the team attending to the patient. Patient safety was observed. Participants who developed hemodynamic instability and chest pain during data collection were attended to immediately and excluded from the study. Participants who wished to withdraw during the data collection process were also acknowledged. There were no data-gathering injuries reported.

Variable Consideration. Considering several factors leading to inaccurate BP recordings, a single mercury sphygmomanometer was used throughout the data-gathering process as the reference BP recording device per AAMI/ESH/ISO collaboration statement recommendations.[1] Participants were informed of the procedure and advised to limit movements while recording is taken to prevent inaccuracies. A proper cuff was utilized to avoid overestimating and underestimating the blood pressure. The same arm sequential method of blood pressure measurement was preferred to exclude the possibility of inter-arm BP variability.[1] Although a single trained observer took the manual blood pressure to limit inter-observer variation in measurement, this research still considers the possibility of an intra-observer bias where the two BP results were known to the observer.

A single calibrated automated oscillometric sphygmomanometer was used in this study, particularly the Omron HBP1120. The device is FDA-approved and was newly acquired upon study approval by the ethics research committee. Likewise, this model has similar equivalence to a previously validated model passing the American Association of Medical Instrumentation protocol and Revised International Protocol of the ESH 2010 for clinical use.[10] Participants with cardiovascular disease were included as they would benefit from the result. Intake of oral antihypertensive medications was not excluded, considering the longer duration of oral medication to take into effect versus the intravenous route and the minimal amount of time required for data gathering. The specific timing of antihypertensive medication intake and data gathering was not considered and is a variable in this study. However, data gathering was randomly done during the usual vital sign monitoring hours of 8 am, 12 noon, and 4 pm in hopes of addressing this variable.

Statistical Analysis. Descriptive statistics using frequency and percentage were used to determine the demographic distribution of the research participants. Each variable being defined in relation to the blood pressure recorded was computed independently. The mean and standard deviation were used to summarize the data gathered. A scatter plot illustrated the relationship among data. Inferential statistics were analyzed using a binomial test and chi-square among the variables for the participant characteristics. Continuous

Table II. Demographic data of the enrolled participants

Total = N (216)		Frequency	Percentage
Gender	*Male*	91	42.13%
	Female	125	57.87%
Area	*ER*	76	35.18%
	ICU	64	29.63%
	Ward	76	35.18%
Age	*< 60 y*	96	44.44%
	≥ 60 y	120	55.56%
BMI	*Normal*	70	32.41%
	Overweight	53	24.54%
	Obese	93	43.06%
Disease	*Cardiology*	53	24.54%
	Endocrine	3	1.39%
	Gastroenterology	29	13.43%
	Infectious	23	10.65%
	Nephrology	14	6.48%
	Neurology	46	21.30%
	Pulmonology	25	11.57%
	Rheumatology	9	4.17%
	Oncology	14	6.48%

Table III. Descriptive Statistics of Automated versus Manual Blood Pressure Results

Method		N	Min	Max	Mean	SD
Systolic BP	Auto	216	73.00	266.00	134.88	26.56
	Manual	216	80.00	255.00	133.41	26.07
Diastolic BP	Auto	216	35.00	125.00	79.66	14.82
	Manual	216	40.00	110.00	77.83	13.50

Table IV. Paired t-test of Automated and Manual Systolic BP

Paired differences	N	Mean	Standard Deviation	P Value
Systolic BP Auto - Manual	216	1.47	12.12	0.08
Diastolic BP Auto - Manual	216	1.82	10.99	0.02*

Note: * denotes ≤ 0.05 level of significance

Table V. Difference between BP measurement based on variables using ANOVA

Variable	Source	Degrees of Freedom	F	P value
Gender	Systolic BP	1, 214	5.26	0.02*
	Diastolic BP	1, 215	5.94	0.02*
Age	Systolic BP	1, 214	3.41	0.07
	Diastolic BP	1, 214	5.41	0.02*
BMI	Systolic BP	1, 213	4.19	0.04*
	Diastolic BP	1, 213	4.32	0.04*
Area	Systolic BP	1, 213	2.82	0.91
	Diastolic BP	1, 213	5.48	0.02*
Disease	Systolic BP	1, 207	2.01	0.16
	Diastolic BP	1, 207	2.36	0.13

Note: * denotes ≤ 0.05 level of significance

variables were rounded off to one decimal place and recorded.

Paired t-test was used to determine the general difference between the two BP methods for the same participant. A mixed analysis of variance (ANOVA) was used to determine the effect of patient characteristics (age, gender, BMI, disease, and area of admission) and within-subject effects (automated versus manual BP device). Specifically, the Sphericity Assumed test was done, and further correction tests such as Greenhouse-Geisser, Huynh-Feldt, and Lower bound were also employed in the ANOVA. All statistical tests were conducted at a 0.05 level of significance. All of the data were analyzed using Jamovi and SPSS version 26.

*Ethical Considerations***.** Recruitment of participants was done by chart review and then direct person-to-person contact with prospective participants who meet the inclusion criteria. The clinical stability of the prospective participant was ensured during data collection. Approval from the Research Ethics Committee was secured prior to recruitment and data collection. Informed and written consent was secured from the participants, and their confidentiality was maintained. Voluntary participation was respected, and hospital services did not differ based on participant decisions. The participant's identity was kept confidential. The name is not a part of the participant information form. All data collected were kept in a secured envelope and locker.

Results

A total of 216 hospitalized patients at Notre Dame De Chartres Hospital were included in the study, with 432 recorded observations (216 automated and 216 manual BP). Systolic and diastolic blood pressures were analyzed separately. All of the 216 participants have complete data for variables of interest. Table 2 describes the data gathered, which offers a comprehensive demographic snapshot of patients within a medical context, covering essential attributes such as gender, hospital areas, age, BMI, and primary disease category.

Comparing Automated and Manual Blood Pressure. The descriptive statistics provide a summary of systolic BP measurements, differentiating between the automated blood pressure (ABP) and manual blood pressure (MBP) measurement methods, as shown in Table 3. Mean ABP is 134.88/79.66 mmHg, while mean MBP is 133.41/77.83 mmHg. Manual diastolic BP has a lower degree of variability, as indicated by its standard deviation of 13.50 mmHg. These findings emphasize that ABP diastolic measurements have a higher mean value than their manual counterparts and that manual diastolic BP measurements demonstrate lower variability in the dataset.

Inferential statistics analyzed paired differences on 432 observations, providing insights comparing automated versus manual methods. The mean difference between paired systolic measurements is approximately 1.47 mm Hg and SD of 12.12 mmHg. The standard error of the mean is estimated at 0.8, with a 95% confidence interval

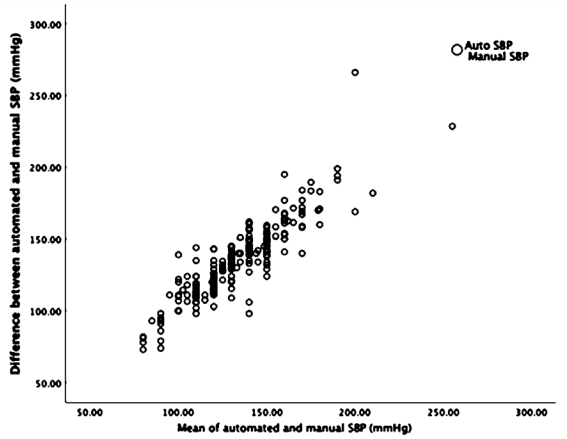

Figure 2. Bland-Altman Plot of Automated and Manual Systolic BP Measurements

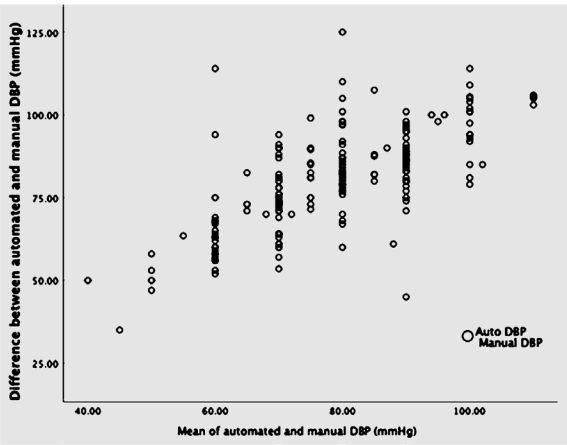

Figure 3. Bland-Altman Plot of Automated and Manual Diastolic BP Measurements

of the difference span from -0.16 mm Hg to 3.09 mmHg. The statistical analysis for systolic BP difference yielded a two-tailed significance level of 0.08, which is not statistically significant. On the other hand, the statistical output indicates a significant difference between automated and manual diastolic BP measurements. The direction of this difference reveals that diastolic BP readings obtained through the automated method are higher than those acquired through the manual method.

Furthermore, a Bland-Altman plot was used to portray the relationship between the two blood pressure measurement methods. As seen in *Figure 2*, the results of systolic BP gathered have a linear association with a positive correlation. Results also show more clustering towards the normal blood pressure range, with two outliers noted. The Bland-Altman plot for diastolic BP results (*Figure 3*) shows a more dispersed pattern with less association correlated with the statistically significant p-value of 0.02 for the diastolic BP measurements.

Determining the effects of patient characteristics on the BP method. Mixed Analysis of Variance (ANOVA) was used, where we have between-subject effects (patient characteristics) and within-subject effects (MBP vs. ABP). When considering the interaction between blood pressure and gender, sensitivity analysis using a sphericity assumed test shows statistically significant differences in systolic and diastolic BP. Significant interaction is F (1, 214) = 5.26, *p=0.023* for the systolic and F (1, 215) = 5.96, *p=0.02* for the diastolic BP. With these data, it becomes evident that gender plays a significant role in influencing the observed differences. Specifically, male patients showed significantly higher mean systolic manual BP (135.01 mmHg) readings than their mean systolic automated BP readings (134.28 mmHg).

On the other hand, female patients display an opposite trend, demonstrating higher mean systolic ABP (134.28 mmHg) compared to their mean systolic MBP (132.25 mmHg). For the diastolic BP, males and females had higher recordings with the automated method. The mean automated diastolic BP in males is 81.10 mmHg and 78.60 mmHg for females. The mean manual diastolic BP in males is 79.31 mmHg and 76.76 mmHg for females. Further subgroup analysis of gender showed a significant difference between blood pressure for males and females using pairwise comparisons (p-value = 0.017), where males had higher diastolic BP than females.

There is no statistically significant difference between automated and manual measurement in systolic BP when it comes to age. However, the two methods have a significant difference in measuring diastolic BP, with an interaction at F (1, 214) = 5.41, *p=0.021*. Participants < 60 years old had a diastolic ABP mean of 82.36 mmHg and a mean MBP of 81.25 mmHg. Participants who were $\geq$ 60 years old had a diastolic ABP mean of 77.49 mmHg and MBP mean of 75.10 mmHg. Automated blood pressure recorded higher measurements for both age groups. Further, those under 60 also had higher diastolic blood pressure results (Pairwise comparison, *p=0.021*).

BMI and blood pressure comparison also showed a significant difference for systolic and diastolic measurements, with a p-value of 0.042 for systolic and 0.04 for diastolic. BMI was classified into normal, overweight, and obese BMI, following the Asian BMI classification. Both systolic and diastolic BP mean recorded from the automated method was consistently higher among the three BMI groups. A pairwise comparison was used among subgroups and the weight and blood pressure interaction. It showed a mean difference of -4.65 mmHg and a Pairwise p-value of 0.049, signifying a statistically significant difference in comparing normal and overweight individuals. This suggests that individuals with normal weight have lower diastolic BP compared to their overweight counterparts. In comparing normal and obese diastolic BP, the mean difference is -5.43 mmHg with a pairwise *p=0.008*, which is also statistically significant. In summary, the statistical findings suggest that the average diastolic BP of overweight and obese individuals is significantly higher than participants with normal BMI.

Comparing BP monitoring among ward, ER, and ICU participants, there is no significant difference between the two methods of measuring systolic BP. In contrast, diastolic BP measurement was statistically significant among these areas, with a p-value of 0.02. The automated method yielded consistently higher diastolic BP in all three clinical areas. Mean automated diastolic in the ER, ward, and ICU were 82.07 mmHg, 79.89 mmHg, and 76.52 mmHg, respectively. Mean manual diastolic BP was lower in the ER, ward, and ICU, with results of 80.24 mmHg, 77.05 mmHg, and 75.91 mmHg, respectively.

Comprehensive data subset from the participants encompassed varied disease categories, including cardiology, endocrine, gastroenterology, infectious disease, nephrology, neurology, pulmonology, rheumatology, and oncology. Frequencies per disease are listed in Table 3. Comparing these variables and their effect on blood pressure measurement, mixed ANOVA revealed no significant difference between disease conditions when measured using automated and manual methods.

Discussion

Automated versus manual blood pressure monitoring. Blood pressure measurement is a common procedure among hospitalized patients. Its role in acute illness and clinical practice is of utmost importance. Multiple automated devices have been produced for technological advancement and improvement, making mercury sphygmomanometers almost obsolete. European Society of Hypertension recommends that if automated BP monitors are used in the hospital, they should be previously validated to adhere to standards and programmed to take multiple BP with a wide memory capacity.5 In the Philippines, a resource-limited country, previously validated BP monitors are scarce, and the application of these devices is becoming a challenge.

In this study, although both systolic and diastolic BP were higher with the automated method, only the diastolic blood pressure was statistically significant, yielding an overestimation of the recordings. Automated devices base the systolic and diastolic recordings on waveforms and pulse signals, which does not necessarily equate to the contemporary Korotkoff sound detected by the auscultatory manual method.[11,12] Another clinical study by Chio et al. evaluated the waveforms recorded by automated BP devices and compared to each phase of the Korotkoff sound. They noted a significant difference in blood pressure measurement in phases 1, 4, and 5.[13]. Inaccurate diastolic BP might result in a false understanding of the actual vascular relaxation of the patient and lead to undue treatment. Further analysis and understanding of the differences between these automated waveforms from the auscultatory Korotkoff sound need ongoing investigation to improve automated BP devices.

Automated and manual BP measurement in hospital setting. American and Canadian guidelines recommend automated BP devices for use in primary care.[2] However, studies show that automated BP devices have significantly different measurements in the hospital setting. Miradmadi & Etebari noted a 15 mmHg difference between automated and manual BP monitoring in the ICU and was higher in the systolic BP.[8] Another clinical trial done in the Emergency room supported this finding with a statistically significant difference in the systolic automated and manual results, having a mean difference of 8.54 ± 9.38 mmHg.[9] In this study, there was no significant difference between the two methods when measuring systolic BP, but noted a significant difference in the diastolic BP recorded from the ward, ER, and ICU ($p=0.02$) with higher readings from the automated method.

Method of measurement and body mass index. Known risk factors for hypertension include diabetes, lipid disorder, overweight, obesity, smoking, age more than 65 years old, and male gender.5 Excessive weight gain induces hypertension by affecting normal kidney function. Increased body weight causes physical compression of the kidneys, activating the renal-angiotensin-aldosterone system and subsequently increasing sympathetic nervous system activity.[14] There is also a significantly increased arterial stiffness index in obese patients, an independent risk factor that increases systolic and diastolic pressure.[15]

Hussain et al. reported a difference in automated and manual BP readings among patients with increased body mass index, yielding 4.5% higher diastolic BP than the manual recordings.[16] This finding was supported by another randomized control trial by Padwal & Majudmar, where two automated devices showed significant differences in BP results among severely obese patients.[17] The findings of our study are consistent, revealing a significant difference between automated and manual methods in both systolic and diastolic ($p=0.04$). The automated method revealed higher results. Interestingly, in this study, within-subject effects revealed that a higher BMI showed significantly higher diastolic BP results for overweight (pairwise $p=0.049$) and obese (pairwise $p=0.01$) compared to normal BMI participants. Despite adjusting cuff sizes with increasing BMI in this study, there was a significant difference between the two methods, which could be in part due to the known increased arterial wall stiffness. Therefore, further investigation is warranted in this subset of patients for accurate blood pressure monitoring in patients with increased body mass index. Due to these discrepancies, automated BP monitors should be avoided in patients with increased BMI.

Method of measurement in relation to age and gender. Godai et al. previously documented no difference in blood pressure measurements between automated and manual methods in the elderly population.[18] However, the study had a limited sample size, with only 35 participants. A larger observational study, the northern Sweden MONICA study, which included 1729 participants, negated this. They reported a difference in BP results between the two methods when used in different age groups and gender, with higher diastolic BP

from the automated method. The later study suggested using a numerical adjustment to balance BP measurements' differences.[19] In this study, the automated method's diastolic blood pressure results were also significantly higher (*p=0.021*). Moreover, the results of both systolic (*p=0.023*) and diastolic BP (*p=0.02*) were significantly different between the two methods when analyzed with different genders. Males had higher manual systolic BP, while females had higher automated systolic and diastolic BP. Whether calculations or device adjustments are needed for less difference in BP recordings among the elderly population and different genders, manufacturers should take note of this difference for calibration.

Method of measurement and disease. Different disease states affect blood pressure, as in the case of acute stroke and various cardiovascular diseases. Various studies have documented different BP measurements from the automated method in admitted patients with atrial fibrillation, chronic kidney disease, and neurosurgical problems.[7,8,20] In this study, however, mixed ANOVA revealed no significant difference between ABP and MBP. This could be due to the varied number of diseases included, resulting in a decreased frequency and significance per disease.

Conclusion

Calibration of automated devices is recommended to address different readings, particularly diastolic blood pressure. Professionals should be cautious when using automated blood pressure monitoring devices, especially in hospitals. Suspicious automated BP results should always be manually checked. Continuous validation is encouraged to test the accuracy of new devices, especially in a special subset of diseases and admitted patients. A validated BP monitor should be given priority over availability in resource-limited countries. A list of validated automated BP monitors should be readily available and made known to the public for proper blood pressure management. A collaborative effort from healthcare professionals, medical institutions, professional societies, medical manufacturers, and the social media industry is needed to ensure correct automated BP monitor use in the digital era.

Limitations and Recommendations

Diurnal blood pressure change is known to cause varied recordings and is a limitation of the study. The study only validated recordings from an automated oscillometric device and did not consider monitoring the diurnal changes. However, the data gathering in this study was done during the daytime to limit this variation. Consideration of the timing of data gathering and intake of antihypertensive medication is also a recommendation for future studies. The researchers acknowledge that the study was not limited to a particular disease of interest. Studies focusing on a special population of patients with a specific disease condition are recommended to have a clearer picture of ABP accuracy in varied illnesses. Further studies are needed to understand possible associations or causes of why there is a significant difference in ABP when used among admitted patients.

Due to the study's findings, the researchers also recommend properly validating automated blood pressure monitors. The accuracy of monitors should be made known to healthcare professionals, hospitals, and the public. An approval seal or a list of validated monitors from professional societies available locally is recommended to ensure validation. The study was also limited to comparing automated and manual BP monitors. Further studies are recommended to determine healthcare professionals' and hospitals' knowledge and practices regarding accurate blood pressure monitoring, especially in resource-limited countries where securing a validated monitor might be a challenge.

Conflict of Interest. The authors have no conflict of interest to declare. This research was not sponsored by any third party or agency. The authors personally funded all the equipment and materials used in the study, including the statistical analysis fee.

References

1. Stergiou GS, Alpert B, Mieke S, Asmar R, Atkins N, Eckert S, Frick G, Friedman B, Graßl T, Ichikawa T, Ioannidis JP, Lacy P, McManus R, Murray A, Myers M, Palatini P, Parati G, Quinn D, Sarkis J, Shennan A, Usuda T, Wang J, Wu CO, O'Brien E. A universal standard for the validation of blood pressure measuring devices: Association for the Advancement of Medical Instrumentation/European Society of Hypertension/International Organization for Standardization (AAMI/ESH/ISO) Collaboration Statement. J Hypertens. 2018 Mar;36(3):472-478. doi: 10.1097/HJH.0000000000001634. PMID: 29384983; PMCID: PMC5796427.
2. Muntner P, Shimbo D, Carey RM, Charleston JB, Gaillard T, Misra S, Myers MG, Ogedegbe G, Schwartz JE, Townsend RR, Urbina EM, Viera AJ, White WB, Wright JT Jr. Measurement of Blood Pressure in Humans: A Scientific Statement From the American Heart Association. Hypertension. 2019 May;73(5):e35-e66. doi: 10.1161/HYP.0000000000000087. PMID: 30827125.
3. Whelton PK, Picone DS, Padwal R, Campbell NR, Drawz P, Rakotz MK, et al. Global proliferation and clinical consequences of non-validated automated BP devices. Journal of Human Hypertension. 2022;37(2):115–9. doi:10.1038/s41371-022-00667-z
4. Campbell M, Pillarisetty L, Shumway K, Sultan A. Physiology, Korotkoff Sound - StatPearls - NCBI Bookshelf [Internet]. 2022 [cited 2023 Oct 14]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK539778/
5. Mancia G, Kreutz R, Brunström M, Burnier M, Grassi G, Januszewicz A, Muiesan ML, Tsioufis K, Agabiti-Rosei E, Algharably EAE, Azizi M, Benetos A, Borghi C, Hitij JB, Cifkova R, Coca A, Cornelissen V, Cruickshank JK, Cunha PG, Danser AHJ, Pinho RM, Delles C, Dominiczak AF, Dorobantu M, Doumas M, Fernández-Alfonso MS, Halimi JM, Járai Z, Jelaković B, Jordan J, Kuznetsova T, Laurent S, Lovic D, Lurbe E, Mahfoud F, Manolis A, Miglinas M, Narkiewicz K, Niiranen T, Palatini P, Parati G, Pathak A, Persu A, Polonia J, Redon J, Sarafidis P, Schmieder R, Spronck B, Stabouli S, Stergiou G, Taddei S, Thomopoulos C, Tomaszewski M, Van de Borne P, Wanner C, Weber T, Williams B, Zhang ZY, Kjeldsen SE. 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the

European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). J Hypertens. 2023 Dec 1;41(12):1874-2071. doi: 10.1097/HJH.0000000000003480. Epub 2023 Sep 26. PMID: 37345492.
6. Sharman JE, O'Brien E, Alpert B, Schutte AE, Delles C, Hecht Olsen M, Asmar R, Atkins N, Barbosa E, Calhoun D, Campbell NRC, Chalmers J, Benjamin I, Jennings G, Laurent S, Boutouyrie P, Lopez-Jaramillo P, McManus RJ, Mihailidou AS, Ordunez P, Padwal R, Palatini P, Parati G, Poulter N, Rakotz MK, Rosendorff C, Saladini F, Scuteri A, Sebba Barroso W, Cho MC, Sung KC, Townsend RR, Wang JG, Willum Hansen T, Wozniak G, Stergiou G; Lancet Commission on Hypertension Group. Lancet Commission on Hypertension group position statement on the global improvement of accuracy standards for devices that measure blood pressure. J Hypertens. 2020 Jan;38(1):21-29. doi: 10.1097/HJH.0000000000002246. PMID: 31790375; PMCID: PMC6919228.
7. Park S-H, Choi Y-K. Measurement reliability of automated oscillometric blood pressure monitor in the elderly with atrial fibrillation: A systematic review and meta-analysis. Blood Pressure Monitoring. 2020;25(1):2–12. doi:10.1097/mbp.0000000000000414
8. Mirdamadi A, Etebari M. Comparison of manual versus automated blood pressure measurement in intensive care unit, coronary care unit, and emergency room. ARYA Atheroscler. 2017 Jan;13(1):29-34. PMID: 28761452; PMCID: PMC5515188.
9. Mansoor K, Shahnawaz S, Rasool M, Chaudhry H, Ahuja G, Shahnawaz S. Automated Versus Manual Blood Pressure Measurement: A Randomized Crossover Trial in the Emergency Department of a Tertiary Care Hospital in Karachi, Pakistan: Are Third World Countries Ready for the Change? Open Access Maced J Med Sci. 2016 Sep 15;4(3):404-409. doi: 10.3889/oamjms.2016.076. Epub 2016 Jul 27. PMID: 27703563; PMCID: PMC5042623.
10. Dabl Educational Trust. Declaration of Blood Pressure Measuring Device Equivalence [Internet]. 2019 [cited 2023 Jun 3]. Available from: http://www.dableducational.org/sphygmomanometers/devices_1_clinical.html#ClinTable
11. Amoore JN, Lemesre Y, Murray IC, Mieke S, King ST, Smith FE, Murray A. Automatic blood pressure measurement: the oscillometric waveform shape is a potential contributor to differences between oscillometric and auscultatory pressure measurements. J Hypertens. 2008 Jan;26(1):35-43. doi: 10.1097/HJH.0b013e3282f06ec7. PMID: 18090538.
12. Benmira A, Perez-Martin A, Schuster I, Aichoun I, Coudray S, Bereksi-Reguig F, Dauzat M. From Korotkoff and Marey to automatic non-invasive oscillometric blood pressure measurement: does easiness come with reliability? Expert Rev Med Devices. 2016;13(2):179-89. doi: 10.1586/17434440.2016.1128821. Epub 2016 Jan 8. PMID: 26641026.
13. Chio SS, Urbina EM, Lapointe J, Tsai J, Berenson GS. Korotkoff sound versus oscillometric cuff sphygmomanometers: comparison between auscultatory and DynaPulse blood pressure measurements. J Am Soc Hypertens. 2011 Jan-Feb;5(1):12-20. doi: 10.1016/j.jash.2010.10.005. Epub 2011 Jan 26. PMID: 21269907.
14. Hall JE, do Carmo JM, da Silva AA, Wang Z, Hall ME. Obesity-induced hypertension: interaction of neurohumoral and renal mechanisms. Circ Res. 2015 Mar 13;116(6):991-1006. doi: 10.1161/CIRCRESAHA.116.305697. PMID: 25767285; PMCID: PMC4363087.
15. Efe FK, Tek M. Increased ambulatory arterial stiffness index and blood pressure load in normotensive obese patients. Afr Health Sci. 2021 Sep;21(3):1185-1190. doi: 10.4314/ahs.v21i3.27. PMID: 35222581; PMCID: PMC8843281.
16. Hussain MM, Solomon IE, Pazdernik V, Bandarpalle S, Navarro I, Shneyder T, LeBeau L. Relationship Between Elevated Automatic Blood Pressure Readings and Manual Blood Pressure Readings in Adult Patients With Normal and High Body Mass Index. J Am Osteopath Assoc. 2019 Jun 1;119(6):364-370. doi: 10.7556/jaoa.2019.065. PMID: 31135864.
17. Padwal RS, Majumdar SR. Comparability of two commonly used automated office blood pressure devices in the severely obese. Blood Press Monit. 2016 Oct;21(5):313-5. doi: 10.1097/MBP.0000000000000196. PMID: 27100401.
18. Godai K, Kabayama M, Saito K, Asayama K, Yamamoto K, Sugimoto K, et al. Validation of an automated home blood pressure measurement device in oldest-old populations. Hypertension Research. 2019;43(1):30–5. doi:10.1038/s41440-019-0330-7
19. Eriksson M, Carlberg B, Jansson JH. Comparison of blood pressure measurements between an automated oscillometric device and a Hawksley random-zero sphygmomanometer in the northern Sweden MONICA study. Blood Press Monit. 2012 Aug;17(4):164-70. doi: 10.1097/MBP.0b013e328356ef58. PMID: 22781634.
20. Stergiou GS, Menti A, Asayama K, De La Sierra A, Wang J, Kinoshita H, Sawanoi Y, Yamashita S, Kollias A, Wu CO, Ichikawa T, Alpert B. Accuracy of automated cuff blood pressure monitors in special populations: International Organization for Standardization (ISO) Task Group report and call for research. J Hypertens. 2023 May 1;41(5):811-818. doi: 10.1097/HJH.0000000000003403. Epub 2023 Mar 2. PMID: 36883464.