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Comparison of Home Blood Pressure Monitoring with and without Training: Does Adherence to the Recommended Instructions Overlook Hypertension?

ABSTRACT

Background: Home blood pressure monitoring (HBPM) is commonly used to diagnose hypertension (HT), with a diagnostic threshold of ≥135/85 mm Hg, the same as daytime ambulatory BP monitoring (ABPM). This study hypothesizes that training and adherence to HBPM guidelines will yield more accurate BP readings compared to ABPM.

Methods: The study involved 129 patients with elevated office BP but no prior HT diagnosis. After a two-week observation period with lifestyle advice, HBPM was conducted over a week before and after structured measurement training, with ABPM performed in each period. Adherence to instructions post-training was also assessed.

Results: Post-training, mean systolic and diastolic home BP values significantly decreased (from 128 ± 13.1/84.9 ± 8.2 to 122.6 ± 12.7/81.8 ± 7.8; $P < 0.001$ for both), while daytime ABPM values remained unchanged (131.7 ± 11.1/86.7 ± 9.3 before vs. 130.7 ± 11.7/85.9 ± 8.6 after; $P = 0.185$). Although HBPM values were consistently lower than ABPM values, the discrepancy grew post-training. The number of patients reaching the HT threshold via HBPM decreased significantly post-training [71 (55%) to 54 (41.9%); $P = 0.006$], whereas the number via daytime ABPM remained similar [82 (64.3%) vs. 84 (65.1%); $P = 1.000$].

Conclusion: Training and adherence to HBPM guidelines led to lower BP readings and fewer HT diagnoses. Contrary to the hypothesis, this method under "ideal conditions" underestimated HT prevalence when compared to daytime ABPM. Further studies with clinical endpoints are needed to refine HBPM methods and establish new BP thresholds for more accurate HT detection.

Keywords: Hypertension, home blood pressure monitoring, patient education, ambulatory blood pressure monitoring

INTRODUCTION

Arterial hypertension is the most important risk factor affecting cardiovascular, cerebrovascular, and renal disease-related morbidity and mortality.[1,2] The prevalence of hypertension was estimated to be 1.13 billion in 2015, and the number of patients is expected to increase by 15-20% to approach 1.5 billion by 2025. The overall prevalence of hypertension in adults is around 30-45%.[3-5]

Hypertension is mostly asymptomatic, and BP measurement scans show that more than half of the patients are unaware of their high BP.[4] The inadequacy of office blood pressure measurements (OBPMs) in diagnosing hypertension has increased the need for out-of-office blood pressure monitoring.[1] Such as home blood pressure monitoring (HBPM) and ambulatory blood pressure monitoring (ABPM), which are more closely associated with the risk of organ damage and cardiovascular events caused by hypertension than in-office measurements. It also has advantages such as detecting white coat and masked hypertension.[1,2,6]

Home blood Pressure monitoring is much less expensive than ABPM and can demonstrate day-to-day BP variability, which has prognostic value because multiple measurements are taken over several days.[7]

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Home BP measurements are required for the diagnosis of hypertension due to the limited availability of ABPM devices, high cost, patient density, and non-compliance with ABPM. It has been shown that HBPMs are often inaccurate and unreliable due to improper preparation, suboptimal environments, inappropriate devices, and insufficient patient information about the measurement techniques.[8] Because the threshold for HT diagnosis is the same with HBPM and the daytime values of ABPM (135/85 mmHg), we hypothesize that training and adherence to the recommended home BPM method will reflect hypertensive patients more accurately when daytime ABPM results are taken as reference.

This study was designed to evaluate the effect of training on and adherence to the recommended methods of HBPM and to compare the results with and without structured training.

METHODS

This study was conducted in the Cardiology Outpatient Clinics of Gülhane Training and Research Hospital between January 1, 2021, and June 30, 2021.

Patients admitted to the outpatient clinic who were older than 18 years of age had no previous diagnosis of hypertension, had an OBPM between systolic 140 and 180 mm Hg and/or diastolic 90 and 110 mm Hg, and were recommended HBPM by a physician were included in the study. Patients with a previous diagnosis of hypertension, who had been started on antihypertensive treatment in the past and had systolic blood pressure (SBP) >180 mm Hg and diastolic blood pressure (DBP) >110 mm Hg were excluded.

Calibrated Omron M7 Intelligent BP monitors were used for office and home measurements, and Mobil-O-Graph brand ambulatory BP monitors were used for ambulatory measurements. OBPM, HBPM, and ABPM measurements of the patients were performed with the same devices when the measurements were repeated.

After enrollment in the first visit, the patients were given a brochure on lifestyle changes prepared according to World Health Organization "Healthy living" recommendations and 2 weeks to implement these recommendations without measuring their BP unless needed. We prepared an educational brochure entitled "How to measure blood pressure at home?" and a questionnaire entitled "Test for Accurate Blood Pressure Measurement at Home" according to the guidelines.[1,2,9] The questionnaire consisted of 26 yes/no questions to understand how the patient measured BP correctly in accordance with the recommendations. One point for correct answers and zero points for false answers were given. The patients took the test twice, once after they measured their BP at home before training (pre-test) and once after training (post-test).

Training on accurate BP measurement at home was explained to the patients one by one in detail. It was recommended to measure BP in the morning after waking up and in the evening before going to bed. We explained the measurement style in 3 stages as follows: preparation, position, and measurement.

Preparation

- Avoid caffeine, smoking, and exercise for 30 minutes before measuring your BP.
- Wait at least 30 minutes after a meal.
- Keep taking your medicine regularly.
- If you are on BP medication, measure your BP before you take your medication.
- Empty your bladder beforehand.
- Find a quiet space where you can sit comfortably without distractions.

Position

- Put the cuff on bare arm, above the elbow at mid-arm.
- Position the arm so cuff is at heart level.
- Keep the arm supported, palm up, with muscles relaxed.
- Sit with legs uncrossed.
- Keep feet flat on the floor.
- Keep your back supported.

Measure

- Rest for 5 minutes while in position before starting.
- Take 2 or 3 measurements, 1 minute apart, twice daily for 7 days.
- Keep your body relaxed and in position during measurements.
- Sit quietly with no distractions during measurements (avoid conversations, TV, phones, and other devices).
- Record your measurements when finished.

The actions in each step according to the study protocol were as follows (Figure 1):

- Visit 1: Office BP was measured. Afterward, lifestyle changes were explained according to the World Health Organization "Healthy living recommendations" brochure.[10] Patients were asked to implement these changes for 2 weeks.
- Visit 2: The patients were asked to measure and record their BP in the morning and evening at home for 1 week with the provided automated BP monitoring device.
- Visit 3: The records in the device memory were verified by comparing them with the records written by the patient. Then the patients were requested to have an ABPM device fitted for 24 hours.
- Visit 4: ABPM results were uploaded to the system. Then the *pretest* was applied. Afterward, training on correct BP measurement at home was given with a brochure. The

HIGHLIGHTS

- Out-of-office blood pressure (BP) monitoring, including home BP measurements, is widely used in the diagnosis of hypertension.
- There are guideline-based instructions on home blood measurement, but training on these instructions was not systematically applied.
- Training on and adherence strictly to the instructions may cause lower BP measurements compared to home measurements without training and daytime ambulatory measurements.

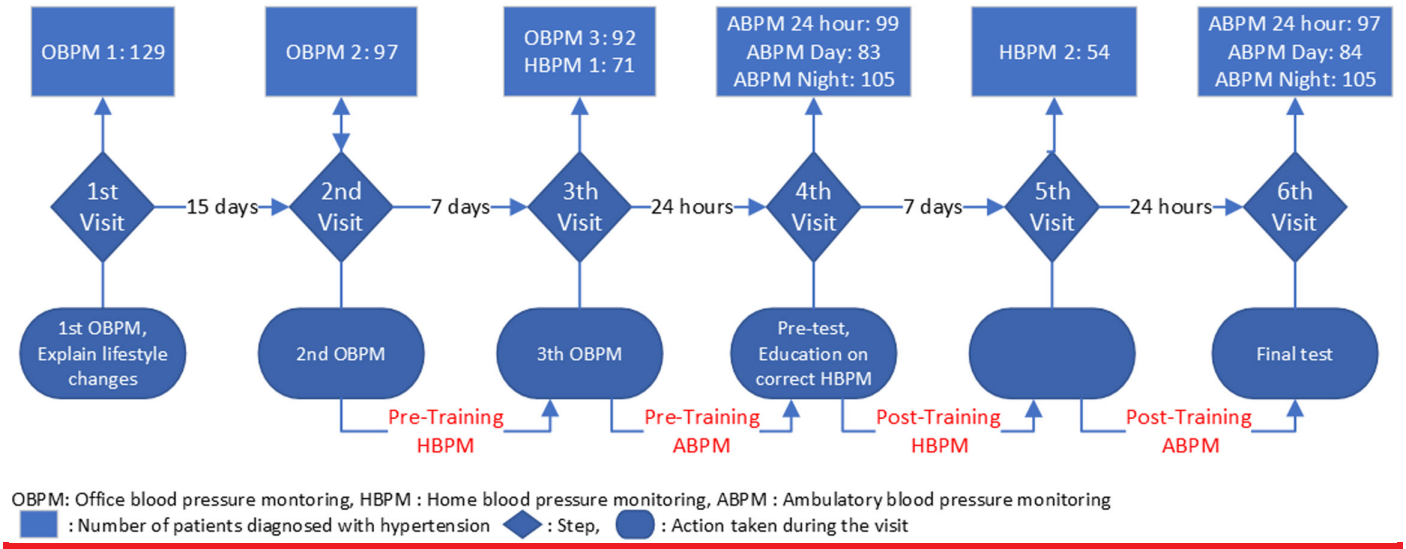

Figure 1. Implementation flow chart.

patients were asked to perform home measurements for one more week with the ABPM device as described in the training.[9]

- Visit 5: The records in the memory of the BP monitor were verified by comparing them with the records written by the patient. The patient was fitted with the same 24-hour ambulatory BP monitor for the second time.
- Visit 6: The ABPM was taken and uploaded to the system. The post-test was administered after the post-training measurements.

The present study was approved by the Local Ethics Committee (Approval number: 2020/521). Informed consent was submitted by all subjects when they enrolled.

Statistical Analysis

Sample size: Assuming a standard deviation of 10 mmHg, it was calculated that to find a 6 mm Hg difference in DBP "significant" by the home measurement method with an alpha of 5% (two-way) and a power of 90%, at least 60 individuals in each group (total sample size of 120 patients) were required.[11]

The suitability of the variables for normal distribution was determined by Shapiro-Wilk and Kolmogorov-Smirnov tests, skewness and kurtosis values, histogram graphs, mean ± SD, and median values. Numeric data that fit the normal distribution are expressed as arithmetic mean ± SD, and data not normally distributed are expressed as median with data range (minimum-maximum). Categorical data are expressed as counts and percentages. Paired-Samples *t*-test was used for comparisons between dependent groups of continuous numerical data that fit the normal distribution, and Wilcoxon Signed Ranks test was used for non-parametric data that did not fit the normal distribution. McNemar Chi-square test was used for comparisons of categorical data between dependent groups (repeated measurements). A value of $P < 0.05$ was considered to be statistically significant. Analyses were performed using SPSS 25.0 program.

RESULTS

The study included 129 patients [59 (45.7%) female and 70 (54.3%) male]. The mean age of the patients was 45.10 ± 10.91 years. Baseline characteristics of the patients included in the study are presented in Table 1.

Post-test scores increased after training (from 19 (14-26) pre-training to 26 (23-29) post-training (median (min-max); $P < .001$), showing that adherence to the guideline recommendations on HBPM with training increased significantly.

Systolic and diastolic BP as well as heart rate measured with the HBPM device were decreased after training compared to the pre-training course (Table 2). However, none of these values measured with ABPM (including daytime, nighttime, and 24 hours) were different between pre- and post-training measurements (Table 3).

When HBPM and ABPM measurements before and after the training were compared, ABPM values were higher than those of HBPM both before and after training. However, the difference increased after training, mainly due to the decreased values of HBPM after training (Table 4). Consistent with these findings, the number of patients meeting the hypertension criteria with HBPM decreased from 71 (55%) to 54 (41.9%) after training ($P = .006$), whereas the number of patients diagnosed as hypertensive did not change with daytime ABPM (82 (64.3%) before vs. 84 (65.1%) after training; $P = 1.000$) (Table 5).

Before and after the training, the diagnosis of HT by HBPM and ABPM was compared. Before the training, 76.7% of the patients were diagnosed with HT with 24-hour ABPM and 64.3% with daytime ABPM, while 55.0% of the patients were diagnosed with HT with HBPM ($P < .001$, $P = .043$, respectively). After the training, the percentage of HT diagnosis with 24-hour ABPM and with daytime ABPM was 75.2% and 41.9%, respectively ($P < .001$). This difference still remained statistically significant after only the daytime values of ABPM were taken for HT diagnosis (65.1% for ABPM vs. 41.9%; $P < .001$) (Table 6).

Table 1. Baseline Characteristics of the Patients

Socio-demographic Characteristics	n (%)
Age (years), mean ± SD	45.10 ± 10.91
Sex	
Female	59 (45.7)
Male	70 (54.3)
Educational level	
Less than high school	54 (41.9)
High school	22 (17.1)
University or higher	53 (41.1)
Tobacco and tobacco products use status	
Smoking	42 (32.6)
Quit smoking	25 (19.4)
Never smoked	62 (48.1)
Alcohol use status	
Yes	4 (3.1)
No	125 (96.9)
Use of salt status	
Frequently	45 (34.8)
Sometimes	64 (49.7)
Never	20 (15.5)
Physical activity status	
Yes	33 (25.6)
No	96 (74.4)
History of diabetes	
Yes	5 (3.9)
No	124 (96.1)
History of cardiovascular disease	
Yes	8 (6.2)
No	121 (93.8)
History of blood pressure monitoring	
Yes	59 (45.7)
No	70 (54.3)
Family history of hypertension	
Yes	100 (77.5)
No	29 (22.5)

The number of patients diagnosed with hypertension according to different measurement methods at HBPM and ABPM Day is shown in Figure 2.

DISCUSSION

The results of this study show that training on and good adherence to HBPM instructions caused lower BP values to be obtained and a smaller number of patients to receive a diagnosis of hypertension compared to those before structured training. Contrary to our hypothesis, with training and adherence to the instructions, the gap between HBPM and daytime ABPM widened in terms of BP values, and the number of patients diagnosed with hypertension decreased when daytime ABPM is taken as a standard.

It has been shown that both OBPM and out-of-office BP elevation are associated with cardiovascular, cerebrovascular, and renal disease.[12-14] Standard OBPM is the best-studied method for diagnosing hypertension, assessing the protective effect of antihypertensive treatment, and monitoring BP goals with therapeutic interventions. Although inaccurate results are encountered due to inadequate standardization and improper measurements, OBPM is still a frequently

Table 2. Comparison of Home Blood Pressure Monitoring and Pulse Rate Measurements of Patients Before and After Training (n = 129)

	Before Training	After Training	P*
Morning SBP, mm Hg	126.72 ± 13.29	120.80 ± 12.97	<.001
Morning DBP, mm Hg	84.68 ± 8.37	81.65 ± 7.74	<.001
Morning pulse rate	78.20 ± 11.92	73.98 ± 10.24	<.001
Evening SBP, mm Hg	129.44 ± 13.89	124.40 ± 13.41	<.001
Evening DBP, mm Hg	85.18 ± 8.70	81.93 ± 8.49	<.001
Evening pulse rate	78.99 ± 10.61	73.91 ± 9.59	<.001

*Paired-Samples t-test. Variables are expressed as mean ± SD. DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 3. Comparison of Ambulatory Blood Pressue Monitoring and Pulse Rate Measurements of the Patients Before and After the Training

	Before Training	After Training	P*
ABPM (24 hours)			
SBP, mm Hg	129.40 ± 10.80	128.74 ± 11.30	.408
DBP, mm Hg	84.43 ± 8.85	83.94 ± 8.55	0.312
ABPM (daytime)			
SBP, mm Hg	131.73 ± 11.08	130.70 ± 11.68	.185
DBP, mm Hg	86.66 ± 9.26	85.93 ± 8.58	.186
ABPM (nighttime)			
SBP, mm Hg	121.54 ± 11.90	122.09 ± 12.67	.583
DBP, mm Hg	77.30 ± 9.74	77.96 ± 9.90	.359
ABPM MAP, mm Hg	104.98 ± 8.98	104.36 ± 9.08	.263
ABPM Pulse rate	76.33 ± 8.84	76.26 ± 9.67	.892
ABPM Pulse pressure	44.78 ± 7.35	44.78 ± 7.68	.988

*Paired-Samples t-test. Variables are expressed as mean ± SD. ABPM, ambulatory blood pressure monitoring; DBP, diastolic blood pressure; MAP, mean arterial pressure; SBP, systolic blood pressure.

Table 4. Comparison of ABPM (Daytime) and HBPM Mean Blood Pressures of Patients Before and After Training (n = 129)

	HBPM	ABPM (daytime)	P*
Before training			
SBP, mm Hg	128.08 ± 13.13	131.73 ± 11.08	.001
DBP, mm Hg	84.93 ± 8.22	86.66 ± 9.26	.015
After training			
SBP, mm Hg	122.61 ± 12.73	130.70 ± 11.68	<.001
DBP, mm Hg	81.80 ± 7.75	85.93 ± 8.58	<.001

*Paired-Samples t-test. Variables are expressed as mean ± SD. ABPM, ambulatory blood pressure monitoring; DBP, diastolic blood pressure; HBPM, home blood pressure monitoring; SBP, systolic blood pressure.

Table 5. Comparison of Hypertension Diagnosis by Ambulatory Blood Pressure Monitoring and Home Blood Pressure Monitoring Before and After Training (n = 129)

		After training			
		Normal n (%)	HTN n (%)	Total n (%)	P*
Before training	ABPM (24 hours)				
	Normal	22 (68.8)	8 (8.2)	30 (23.3)	.815
	HTN	10 (31.3)	89 (91.8)	99 (76.7)	
	Total	32 (24.8)	97 (75.2)	129 (100.0)	
	ABPM (daytime)				
	Normal	37 (82.2)	9 (10.7)	46 (35.,7)	1.000
	HTN	8 (17.8)	75 (89.3)	82 (64.3)	
	Total	45 (34.9)	84 (65.1)	129 (100.0)	
	ABPM (nighttime)				
	Normal	14 (58.3)	10 (9.5)	24 (18.6)	1.000
	HTN	10 (41.7)	95 (90.5)	105 (81.4)	
	Total	24 (18.6)	105 (81.4)	129 (100.0)	
	HBPM				
	Normal	49 (65.3)	9 (16.7)	58 (45.0)	.006
	HTN	26 (34.7)	45 (83.3)	71 (55.0)	
	Total	75 (58.1)	54 (41.9)	129 (100.0)	

*McNemar Ki-square test. Variables are expressed as n (%). ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring; HTN, hypertension.

Table 6. Comparison of Patients' Status of Hypertension Diagnosis with Ambulatory Blood Pressure Monitoring and Home Blood Pressure Monitoring Before and After Training (n = 129)

		HBPM			P*
		Normal n (%)	HTN n (%)	Total n (%)	
Before training	ABPM (24 hours)				
	Normal	28 (48.3)	2 (2.8)	30 (23.3)	<.001
	HTN	30 (51.7)	69 (97.2)	99 (76.7)	
	Total	58 (45.0)	71 (55.0)	129 (100.0)	
	ABPM (daytime)				
	Normal	37 (63.8)	9 (12.7)	46 (35.7)	.043
	HTN	21 (36.2)	62 (87.3)	83 (64.3)	
	Total	58 (45.0)	71 (55.0)	129 (100.0)	
After training	ABPM (24 hours)				
	Normal	29 (38.7)	3 (5.6)	32 (24.8)	<.001
	HTN	46 (61.3)	51 (94.4)	97 (75.2)	
	Total	75 (58.1)	54 (41.9)	129 (100.0)	
	ABPM (daytime)				
	Normal	37 (49.3)	8 (14.8)	45 (34.9)	<.001
	HTN	38 (50.7)	46 (85.2)	84 (65.1)	
	Total	75 (58.1)	54 (41.9)	129 (100.0)	

*McNemar Ki-square test. Variables are expressed as n (%). ABPM, ambulatory blood pressure monitoring; HBPM, home blood pressure monitoring; HTN, hypertension.

used BP measurement method.[2,15] In clinical studies, when OBPM and ABPM are compared, there are opinions that office measurements are inadequate in predicting cardiovascular outcomes and do not have sufficient reliability.[16-19]

There are suggestions that ambulatory monitoring may lead to more appropriate treatment targeting, rather than initiating antihypertensive treatment based solely on office measurements.[20]

Of the 129 patients included in our study who were considered hypertensive according to office BP, 99 patients (76.7%)

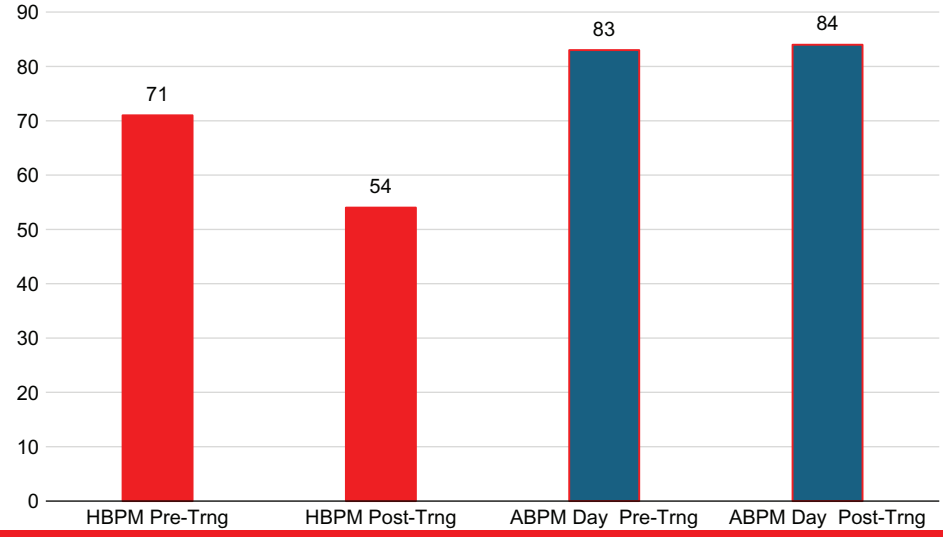

Figure 2. Comparison of those diagnosed with hypertension at HBPM and ABPM Day (n=129). HBPM, Home Blood Pressure Monitoring; ABPM, Ambulatory Blood Pressure Monitoring; Pre-Trng, Pre-Traning; Post-Trng, Post-Traning.

met the hypertension criteria according to their ABPM (24 hours) (Table 5). As supported by a substantial number of studies, relying solely on single office measurements would overestimate the number of hypertensive patients.

On the other hand, HBPM is an alternative out-of-office BP monitoring method that is widely used in clinical practice and advised by the guidelines to be used for this purpose.[21] The diagnostic performance of HBPM has been shown to be slightly higher than OBPM, and both methods have similar prognostic value.[19]

Home blood pressure monitoring and ABPM provide multiple measurements taken outside the office in the individual's usual environment. There are methodological differences between HBPM and ABPM. Although HBP is measured only at home in a standardized sitting situation throughout the day, ABPM is measured in different situations such as lying, sitting, and standing, and during daytime activities and night sleep in different environments such as work and home. Despite this difference, the criteria for HT diagnosis with HBPM and daytime values of ABPM are the same (≥135/85 mm Hg). In our study, even if only the daytime values of ABPM were used, the frequency of HT diagnosis was still higher with ABPM compared to HBPM (64.3% for ABPM vs. 55.0%; $P = .043$) (Table 6).

Home blood pressure monitoring has important limitations such as the necessity of patient education, measurement with unstandardized devices, and anxiety during measurement.[21]

It has been shown that accurate reporting of measurements should be ensured in HBPM, and that measurements reported by patients differ from frequently measured values. In surveys of primary care physicians conducted in different countries, it has been reported that the reliability of patients' home BP readings is questionable and that their clinical use is unreliable.[22-24]

It is conceivable that standardizing the measurement method, appropriate measurement conditions, and patient education may increase the reliability of HBP measurements. In our study, appropriately calibrated devices that store records were used.

After training, the measurements were extremely standardized and made in resting and proper sitting conditions, in isolated environments, at least twice and after emptying the bladder, as stated in the guidelines. As a result, the frequency of HT diagnosis according to home measurements decreased from 55.0% to 41.9% after the training ($P = .006$) (Table 5). As expected, 24-hour ABPM and HT diagnosis status did not change between the 2 measurements as training did not change the ABPM style. We hypothesized that training would decrease the difference in HT diagnosis between the ABPM and HBPM systems as supposed to be, but unexpectedly, this difference increased, raising the question of which method is the best for out-of-office measurement and has the best prognostic value.

Our study showed that "dedicated" training increased patient compliance and worked well regarding standardization, as the "correct blood pressure measurement score" increased significantly. In a study examining how closely patients attending a hypertension clinic complied with recommendations for appropriate home BP measurement, it was concluded that patients tend to show their compliance in measuring better than they actually do.[25] It has been shown that more than half of the patients record their home BP readings when symptoms occur rather than at the recommended times.[8] In our study the measurements were independent of the symptoms and were made according to the guidelines. Another point is that it has been noted that patients may tend to make their home readings look better than they really are, and devices with memory should therefore be used.[25] Therefore, we verified the patient recordings with the device memory, which showed excellent patient self-recordings.

The reason why the post-training BP values were lower may be that the measurements were made in an extremely isolated and "sterile" environment, as guidelines stated. But it is an important concern how much the BP values obtained with this strategy reflect daily life and predict the prognosis. It is known that OBPM, HBPM, and ABPM measurements each provide different and complementary information about the clinical situation. There is no clear information on which patients and when ABPM or HBPM should be used. The decision to use ABPM or HBPM may be the patient's preference and is also related to the availability and reimbursement policy of health care systems. It is often not possible to use these methods, particularly ABPM, in daily practice, which may make HBPM the preferred out-of-office BPM method. Training of patients who are being evaluated with HBPM is an essential step for standardization, as verified in our study. This study also showed that standardization in HBPM, as recommended in guidelines, decreased the mean BP values as well as the number of HT diagnoses in comparison to daytime ABPM. But the difference in HT diagnosis between the ABPM and HBPM increased. Considering the high prevalence of HT in the population, this difference may have a major impact not only on an individual level but also on the population level and in the determination of health care policies.

Study Limitations

There are several limitations in this study.

First, this study is not designed to provide prognostic data on which method is the best in terms of non-clinical (proteinuria, left ventricular hypertrophy, etc.) or clinical (stroke, myocardial infarction, etc.) endpoints. Obviously, the best method of out-of-office measurements and new thresholds could be defined with such studies.

Second, no verification could be made regarding how well the patients complied with the training provided. However, post-test scores increased according to self-reported questionnaires.

Third, a substantial number of patients did not have hypertension with both modalities. Because the main purpose of out-of-office BP measurement methods is to eliminate white coat hypertension, this result was consistent with real life.

We believe that the design of the study and the careful application of the study protocol are the major strengths of the current study. Before evaluation with out-of-office methods, we gave time for the implementation of lifestyle changes. In addition, we used exactly the same automated HBP and ABP devices for the particular patient before and after training. Also, there was no loss to follow up.

CONCLUSION

The training of patients to standardize HBPM has an important effect on the diagnosis of HT, with lower BP values and fewer patients diagnosed with HT in a group of patients with office BP between 140-180/90-110 mm Hg and without a previous hypertension diagnosis. Compared with ABPM, the number of HT diagnoses was less with HBPM and decreased after training to standardize the HBPM method. It can be speculated that current recommendations on HBPM may not reflect BP in daily life and underestimate the number of hypertensive patients. Rather than measurement at predefined times, multiple random measurements might be preferred. In order to test this hypothesis, prospective studies with clinical or non-clinical endpoints are needed.

Ethics Committee Approval: The present study was approved by the University of Health Sciences Gülhane Scientific Research Ethics Committee (Approval date: 29.11.2020, Approval number: 2020/521).

Informed Consent: Informed consent was submitted by all subjects when they enrolled.

Peer-review: Internally peer-reviewed.

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