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Comparison between an adapted protocol for home and ambulatory measurement for evaluating night-time blood pressure behaviour

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ABSTRACT

Background: The diagnosis and treatment of hypertension rely on the accuracy of blood pressure (BP) measurements obtained both in and out of the office during awake and sleep periods.
Objective: To evaluate whether a home blood pressure monitoring (HBPM) protocol incorporating morning, afternoon, and evening measurements supports the assessment of blood pressure behaviour during sleep and enhances the diagnosis of hypertension.
Methods: This cross-sectional study included 40 patients (73% women; age = 62.0 ± 13.2 years) who underwent 24-h ambulatory blood pressure monitoring (ABPM) and (five-day HBPM) with measurements taken across three time periods. The association between the sleep-wake dip recorded by ABPM and the night-day difference measured by HBPM was examined. Additionally, the sensitivity, specificity, predictive values, concordance index, Kappa coefficient, and area under the ROC curve (AUC) of mean BP values obtained from HBPM were compared with those from ABPM.
Results: Mean BP values obtained from HBPM were 126.2 ± 13.3/79.2 ± 9.1 mmHg, (daytime), 125.9 ± 16.4/78.7 ± 10.5 mmHg (evening), and 126.1 ± 14.3/78.9 ± 9.6 mmHg (total). For ABPM, mean values were 120.3 ± 12.5/74.5 ± 8.9 mmHg (awake), 116.5 ± 10.9/69.3 ± 8.0 mmHg (asleep), and 119.4 ± 11.4/73.4 ± 8.0 mmHg (total). Total HBPM outperformed daytime and evening HBPM in detecting abnormalities on ABPM (daytime, night-time, and 24 h), with higher sensitivity, negative predictive value (NPV), AUC, concordance index, and Kappa coefficient. The correlation between the day-night dip in ABPM and the night-day difference in HBPM was weak.
Conclusion: Including night-time measurements in the HBPM protocol improves the accuracy of hypertension diagnosis when compared to ABPM. However, the night-day BP difference captured by HBPM does not correspond to the day-night dip measured by ABPM.

PLAIN LANGUAGE SUMMARY

Blood pressure measurement devices for evaluating hypertensive patients

Hypertension is a major modifiable risk factor for cardiovascular and cerebrovascular diseases, and also, is the main cause of morbidity and mortality worldwide. To diagnose and manage hypertension properly, it is crucial to measure blood pressure (BP) accurately.
Blood pressure measurements should be taken during medical visits and at home through ambulatory blood pressure monitoring (ABPM) or home blood pressure monitoring (HBPM). Choosing the right device depends on individual needs. Often it is recommended a combination of clinic, ABPM or HBPM. The main disadvantage of HBPM is its inability to assess BP during sleep, and it is aggravated in Brazil by the lack of validated equipment for measurements during this period. Therefore, to fill this gap, this study proposed an adapted HBPM protocol, including measurements at night, executed immediately before bedtime.
This study demonstrated that the incorporation of nocturnal BP measurements into the traditional HBPM protocol resulted in greater accuracy in the diagnosis of hypertension when compared to ABPM, although the night-time-daytime blood pressure difference in HBPM does not reflect the day-night dip of ABPM. The use of a method that has a lower cost, such as HBPM, can promote the evaluation of a greater number of patients, enabling greater control of BP levels, and consequently, lower morbidity and mortality in the long term.

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Introduction

Arterial hypertension (AH) is a major modifiable risk factor for cardiovascular and cerebrovascular diseases and remains a leading cause of morbidity and mortality worldwide. AH is highly prevalent among adults and represents a critical public health issue [1].

Blood pressure (BP) measurement is essential for evaluating individuals with AH and should be performed both during clinical assessments and outside the clinical setting, using ambulatory blood pressure monitoring (ABPM) or home blood pressure monitoring (HBPM) [1,2]. HBPM allows for multiple readings at different times in the daily routine, reduces interpretative errors associated with BP variability, and, shows stronger associations with cardiovascular outcomes than office-based measurements. Between the two out-of-office approaches, ABPM enables the assessment of BP during sleep, whereas HBPM offers advantages in terms of accessibility and cost-effectiveness [3]. ABPM is currently considered the gold standard for diagnosing AH, and HBPM protocols recommend BP measurements across two different time points—morning and afternoon [4–6].

However, HBPM does not capture BP during sleep, a limitation that is more pronounced in Brazil due to the absence of validated devices for nocturnal measurements. In this study, we evaluated a modified HBPM protocol incorporating evening BP readings, performed immediately before sleep, to determine whether this approach provides additional insight into nocturnal BP behaviour and enhances the identification of AH.

Materials and methods

Study design

This cross-sectional study included a convenience sample of 40 adult patients aged ≥18 years with a diagnosis of hypertension, followed at a specialised outpatient clinic at a university hospital in Goiânia, Brazil.

Patients with arm circumference >42 cm and those with physical, cognitive, or intellectual limitations that prevented home measurements were excluded. Participants were also excluded if their ABPM exams had <16 valid daytime readings or <8 valid night-time readings, or if <14 valid BP readings were recorded on HBPM [1,4].

The study was approved by the Research Ethics Committee of the Federal University of Goiás (CAAE: 57899221.7.0000.5083). All participants received detailed information regarding the objectives, procedures, risks, and potential benefits. Informed consent was obtained after all queries were addressed.

Study protocol

All participants underwent 24-h ABPM using the DynaMapa device (Cardios, São Paulo, Brazil), with the appropriate cuff positioned on the left arm. The protocol included two initial office measurements in the seated position after 5 min of rest, with a 1-min interval between them. Recordings were obtained for >24 h at 20-min intervals during the day and 30-min intervals at night. Analyses included only participants with ≥16 valid daytime and ≥8 valid night-time readings. Abnormal BP thresholds on ABPM were defined as a 24-h average ≥130/80 mmHg, daytime average ≥135/85 mmHg, and night-time average ≥120/70 mmHg. Nocturnal dipping, defined as the percentage reduction in BP during sleep relative to waking values, was evaluated.

After ABPM removal, participants initiated HBPM using a validated HEM 7349 T device (Omron Healthcare, Kyoto, Japan), equipped with Bluetooth connectivity and automated memory for recording measurements. All readings were performed with the cuff placed on the left arm. Participants were instructed to record three seated BP measurements daily, on awakening (before antihypertensive intake and after morning micturition), in the afternoon, and in the evening, after 3 min of rest, before meals, and without talking or crossing their legs. This procedure was conducted over five consecutive days. Evening measurements were obtained immediately before sleep [4].

Total HBPM was defined as the average of all home BP readings, excluding day 1. Daytime HBPM was calculated using measurements from the morning and afternoon, while evening HBPM reflected readings obtained before sleep. The difference in mean BP between daytime and evening on HBPM was assessed. Only participants with ≥14 valid home measurements were included. HBPM values ≥130/80 mmHg were considered abnormal.

Participants received the HBPM device at the same facility where follow-up was conducted and were provided with detailed instructions for accurate measurement and device handling. These instructions were delivered by healthcare professionals trained in BP assessment. Additionally, data on sex, age, body mass index, and antihypertensive medication use were collected.

Statistical analysis

Continuous and categorical variables were presented as mean ± standard deviation and proportions, respectively. Analysis of variance (ANOVA) was used for comparisons of continuous variables and repeated measures. Cochran Q test was used for categorical variable analysis.

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and AUC were calculated for abnormal daytime, night-time, and total HBPM to detect abnormal BP on 24-h diurnal and sleep-time ABPM. Agreement between abnormal HBPM and abnormal ABPM was evaluated using agreement and Kappa coefficients. Pearson correlation was used to assess the relationship between day-night decline on ABPM and the difference between evening and daytime BP on HBPM.

Statistical significance was defined as $p < .05$. Analyses were performed using JAMOVI version 2.2.5 and IBM SPSS version 29.0.2.0.

Results

The mean age of the patients was 62.0 ± 12.1 years; 73% were women, the mean body mass index (BMI) was 29.87 ± 3.26 kg/m^2, and 92.5% were using antihypertensive medications. The mean number of valid BP measurements obtained by HBPM and ABPM was 36 ± 0 and 65 ± 12, respectively. The mean BP values for daytime HBPM, night-time HBPM, total HBPM, awake ABPM, sleep ABPM, and 24-h ABPM were 126.2 ± 13.3/79.2 ± 9.1 mmHg, 125.9 ± 16.4/78.7 ± 10.5 mmHg, 126.1 ± 14.3/78.9 ± 9.6 mmHg, 120.3 ± 12.5/74.5 ± 8.9 mmHg, 116.5 ± 10.9/69.3 ± 8.0 mmHg, and 119.4 ± 11.4/73.4 ± 8.0 mmHg, respectively (Table 1). Daytime, night-time, and total HBPM systolic BP values did not differ significantly between groups. Systolic BP values from daytime and total HBPM were higher than those obtained from ABPM. Evening HBPM systolic BP values were higher than ABPM values during sleep and across 24 h, but not compared to daytime ABPM values. Diastolic BP values from daytime, night-time, and total HBPM were similar but higher than ABPM values during wakefulness, sleep, and 24 h, with statistically significant differences observed across ABPM periods (Table 1).

The prevalence of arterial hypertension based on daytime HBPM, night-time HBPM, total HBPM, awake ABPM, sleep ABPM, and 24-h ABPM was 52.5%, 50%, 47.5%, 15%, 50%, and 22.5%, respectively (Table 1). The prevalence of hypertension according to daytime, evening, and total HBPM did not differ significantly between groups; however, prevalence was higher when assessed by awake and 24-h ABPM.

Awake-sleep decline based on ABPM was observed in 15% of participants. The median systolic BP reduction from wakefulness to sleep was −4.5 (−8.0; 1.7) mmHg, and for diastolic BP, −6.0 (−9.7; 0.7) mmHg. The mean percentage reductions were −4.0% (−7.0; 1.7) for systolic and −8.0% (−13.0; 0.7) for diastolic BP. In HBPM, the median day–night BP difference was 0.5 (−5.7; 5.7) mmHg for systolic and 1.5 (−0.7; 3.0) mmHg for diastolic BP. The percentage reductions were 0.5% (−4.7%; 4.0) for systolic and 1.5% (−0.7%; 3.7) for diastolic BP.

The correlation between awake-sleep decline by ABPM and the day–night BP difference by HBPM was strong, with $r = -0.82$ (95% CI: −0.38 to 0.23) for systolic BP and $r = 0.14$ (95% CI: −0.18 to 0.33) for diastolic BP.

Total HBPM demonstrated the best performance in identifying abnormalities on 24-h, awake, and sleep ABPM, showing higher sensitivity (89%, 100%, and 60%, respectively), NPV (95%, 100%, and 62%, respectively), AUC (0.767, 0.809, and 0.625, respectively), agreement index (57%, 48%, and 61%, respectively), and Kappa coefficient (0.34, 0.24, and 0.25, respectively) compared to daytime and night-time HBPM (Tables 2–4).

Discussion

In this study, we evaluated an adapted HBPM protocol that included measurements in the morning, afternoon, and evening, and yielded two key findings. First, the average of BP values obtained across these three periods (total average) showed superior

Table 1. Blood pressure obtained by home blood pressure monitoring (HBPM) and ambulatory blood pressure monitoring (ABPM).

	HBPM			ABPM			
	Daytime	Night-time	Total	Awake	Sleep	24H	p values
PAS, mmHg	126.2 ± 13.3	125.9 ± 16.4	126.1 ± 14.3	120.3 ± 12.5^{aΩ}	116.5 ± 10.9^{a,b,c}	119.4 ± 11.4^{a,b,c}	<.001
PAD, mmHg	79.2 ± 9.1	78.7 ± 10.5	78.9 ± 9.6	74.5 ± 8.9^{a,b,c,e}	69.3 ± 8.0^{a,b,c}	73.4 ± 8.0^{a,b,c}	<.001
Hypertension, %	52.5	50	47.5	15^{a,b,c,e}	50	22.5^{a,b,c,e}	<.001

PAS: Systolic Blood Pressure; PAD: Diastolic Blood Pressure.
[a]$p < .05$ compared with daytime and total HBPM using the Bonferroni post-hoc test.
[b]$p < .05$ compared with nocturnal HBPM using the Bonferroni post-hoc test.
[c]$p < .05$ compared with total HBPM using the Bonferroni post-hoc test.
[d]$p < .05$ compared with awake ABPM using the Bonferroni post-hoc test.
[e]$p < .05$ compared with sleep ABPM using the Bonferroni post-hoc test.

Table 2. Performance of HBPM ≥130/80 mmHg in identifying 24-h ABPM ≥130/80 mmHg.

		24-h ABPM					
	AUC	Sensibility (%)	Specificity (%)	NVP (%)	PPV (%)	Agreement Index (%)	Kappa Coefficient
HBPM daytime	0.735	89	58	95	38	53	0.25
HBPM night-time	0.679	78	58	90	35	48	0.19
HBPM total	0.767	89	64	95	42	57	0.34

ABPM: Ambulatory Blood Pressure Monitoring; HBPM: Home Blood Pressure Monitoring; NVP: Negative Predictive Value; PPV: Positive Predictive Value.

Table 3. Performance of home blood pressure monitoring (≥130/80 mmHg) in identifying sleep ambulatory blood pressure monitoring (≥120/70 mmHg).

		Awake ABPM					
	AUC	Sensibility (%)	Specificity (%)	NVP (%)	PPV (%)	Agreement index (%)	Kappa coefficient
HBPM daytime	0.779	100	56	100	28	44	0.16
HBPM night-time	0.794	100	59	100	30	46	0.16
HBPM total	0.809	100	62	100	31	48	0.24

NVP: Negative Predictive Value; PPV: Positive Predictive Value.

Table 4. Performance of home blood pressure monitoring (≥130/80 mmHg) in identifying sleep ambulatory blood pressure monitoring (≥120/70 mmHg).

		Sleep ABPM					
	AUC	Sensibility (%)	Specificity (%)	NVP (%)	PPV (%)	Agreement index (%)	Kappa coefficient
HBPM daytime	0.575	60	55	58	57	58	0.15
HBPM night-time	0.600	60	60	60	60	60	0.20
HBPM total	0.625	60	40	62	50	61	0.25

NVP: Negative Predictive Value; PPV: Positive Predictive Value.

performance in identifying arterial hypertension compared with the average of morning and afternoon values (usual protocol) and isolated evening values. Second, a weak correlation was observed between the day–night BP difference measured by HBPM and the sleep–wake BP decline assessed by ABPM.

Another notable finding was the weak correlation between the day–night BP difference assessed by HBPM and the sleep–wake decline evaluated by ABPM, which is typically defined as a 10%–20% reduction in BP during sleep relative to daytime values [7]. This decline is mediated by the autonomic nervous system, characterised by predominant parasympathetic activity during sleep, reduced catecholamine secretion, peripheral vasodilation, and a decrease in heart rate. The renin–angiotensin–aldosterone system exhibits lower activity at night, further contributing to the reduction in BP [8]. The absence or attenuation of BP dipping has been associated with elevated cardiovascular risk and may indicate underlying conditions such as obstructive sleep apnoea or resistant hypertension, both of which increase the risk of cardiovascular morbidity [9,10]. These findings highlight the importance of evaluating nocturnal BP regulation and the role of autonomic modulation in achieving expected nocturnal BP reductions [7,8].

Previous investigations using HBPM devices capable of obtaining nocturnal measurements have reported values similar to night-time averages obtained by ABPM, despite the reduced number of measurements during sleep in HBPM. These findings reinforce the physiological basis of nocturnal BP decline linked to autonomic, hormonal, and metabolic adaptations, and underscore the need for appropriate measurement technologies in this context [11,12].

Although the mean systolic and diastolic BP values obtained by HBPM did not differ significantly, these values were consistently higher than those recorded by ABPM. This finding aligns with previous studies indicating that HBPM tends to yield higher BP values than ABPM. However, it contrasts with other studies in which the reverse relationship was reported. The relatively small sample size may have limited the ability to fully explore this discrepancy [4,13,14]. Additionally, the HBPM protocol involving measurements across three time periods demonstrated greater agreement with ABPM in detecting BP abnormalities than the usual protocol and isolated evening measurements, with the evening average showing the poorest performance. These findings suggest that improved diagnostic accuracy for arterial hypertension is more strongly associated with the increased number of measurements rather than the inclusion of evening measurements alone. HBPM protocols with a higher number of readings have been associated with greater reliability of home BP values and stronger correlation with cardiovascular outcomes, supporting their utility in the diagnosis and monitoring of arterial hypertension [15,16].

Several limitations should be acknowledged. The cross-sectional design precludes inference of causal relationships, and the absence of follow-up data on cardiovascular events limits assessment of the prognostic relevance of the HBPM protocol. The relatively small sample size may have reduced the statistical power for certain analyses.

In conclusion, the adapted HBPM protocol that incorporated night-time measurements demonstrated greater diagnostic accuracy for arterial hypertension than the usual HBPM protocol or ABPM. However, the day–night BP difference obtained by HBPM did not correlate with the sleep–wake BP decline measured by ABPM.

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