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# Comparison of nurse attended and unattended automated office blood pressure with conventional measurement techniques in clinical practice

Elvira Fanelli [1,2] ✉, Silvia Di Monaco [1,2], Marco Pappaccogli [1], Elisabetta Eula [1], Chiara Fasano [1], Chiara Bertello [1], Franco Veglio [1] and Franco Rabbia [1]



Accuracy in blood pressure measurement is critical for proper hypertension diagnosis and treatment in clinical practice. Automated office blood pressure (AOBP) can simplify the measurement process, reducing human error and minimizing the white-coat effect in the unattended mode. The aim of this study was to compare AOBP, both unattended and nurse attended, with conventional office and out-of-office blood pressure measurement techniques. Four different methods of blood pressure measurement were performed in a cohort of hypertensive patients: conventional office blood pressure (OBP), unattended automated office blood pressure (uAOBP), nurse attended automated office blood pressure (nAOBP), and home blood pressure monitoring (HBPM). uAOBP and nAOBP were conducted with the same rigorous standardized procedure. We enrolled 118 consecutive patients. nAOBP values were slightly higher than uAOBP ones (respectively 132.8/73.3 ± 19.4/12.9 and 129.2/71.1 ± 19.0/12.3 mmHg), even if the difference was influenced by order of execution of AOBP measurement. nAOBP was significantly lower than HBPM and OBP (mean values 135.2/80.9 ± 16.6/8.1 and 140.9/84.6 ± 18.7/10.8 mmHg, respectively). AOBP, either attended or unattended, provides lower values than conventional OBP. uAOBP and nAOBP values showed small differences, even if they are not completely interchangeable. This evidence reflects a lower white-coat effect, even in nurse attended technique, but is also due to a lower measurement error through the application of a rigorous standardized protocol.

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## INTRODUCTION

Accuracy in blood pressure (BP) measurement is a key point in hypertension diagnosis and treatment. For a long time, auscultatory office blood pressure (OBP) measurement has been considered the gold standard technique. Nonetheless, several factors may contribute to OBP inaccuracy: (i) systematic methodological errors during BP recording, due to poor adherence to BP measurement recommendations; (ii) inadequate preparation of patient on behavior during measurement; (iii) white-coat effect related to the presence of medical staff [1, 2].

In the last years, oscillometric devices have gained growing diffusion, contributing to simplification of measurement and reduction of observer error [3, 4]. Furthermore, hypertension guidelines recommend the use of out-of-office techniques, in order to reduce the white-coat effect contribution in overestimating BP values; these techniques include home BP monitoring (HBPM) and the 24-h ambulatory BP monitoring (ABPM) [5, 6]. Additionally, in the office setting, oscillometric devices have been implemented by the development of automated office blood pressure (AOBP) measurement, which is completely conducted by a programmed device in a quiet room, separate from health staff; the BP device performs three to five sequential BP measurements and calculates BP mean [1].

Since its introduction, several studies have used AOBP measurements with either unattended (healthcare personnel absent during measurement) or attended methodology (healthcare personnel present) [7]. Unattended AOBP (uAOBP) provides more accurate BP readings when compared with conventional OBP, with good reproducibility in repeated office visits and in different settings, and has a good agreement with awake ABPM and HBPM values [8]. Furthermore, uAOBP minimizes the white-coat effect and has demonstrated a good correlation with intermediate measures of target organ damage [8–11]. Attended AOBP may be less standardized and less accurate; a recent meta-analysis has demonstrated that attended technique produces higher systolic and diastolic BP levels when compared with uAOBP, even in a high heterogeneity of included studies [12]. Part of this heterogeneity can be explained by the presence of different healthcare personnel during attended AOBP measurements. Previous studies have highlighted that nurse obtains systematically lower BP values than physician [13]; this observation has been attributed to a lower white coat effect, but may also be related to focused nurse educational programs [14]. Furthermore, nurse BP has demonstrated a good predictive value of hypertension-mediated organ damage [15].

[1]Department of Medical Sciences, University of Turin, Internal Medicine and Hypertension Unit, A.O.U. Città della Salute e della Scienza di Torino, Turin, Italy. [2]These authors equally contributed: Fanelli Elvira, Di Monaco Silvia. ✉email: elvirafanelli@hotmail.it

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The aim of this study was to compare uAOBP and attended AOBP conducted in presence of a nurse to conventional OBP and to an out-of-office technique (HBPM).

## SUBJECTS AND METHODS

The study included hypertensive subjects, enrolled in the Hypertension Unit of A.O.U. Città della Salute e della Scienza di Torino, Italy.

uAOBP was performed with the same validated device Omron HEM-907XL (Omron, Kyoto, Japan). Three readings were automatically performed in a 2-min interval, after a resting period of 5 min. Before the beginning, a trained nurse chose the proper cuff and explained the entire procedure to the patient, giving complete instructions about the right posture and behavior during the measurement. The device detected systolic and diastolic BP of every measurement and related average values; recorded values were hidden until the end of uAOBP evaluation.

The same protocol was used in the presence of a nurse, not interacting with the patient, in order to obtain the nurse attended AOBP (nAOBP) readings. The order of execution of uAOBP and nAOBP was randomized. The randomization was performed using computer-generated balanced blocks, with blocks' size of 4 subjects and a 1:1 assignment ratio to each group.

These two BP measurements were followed by conventional OBP measurement, recorded by a physician during the medical evaluation with the same device, used in manual activation modality. The measurements were performed, in accordance with current Guidelines, with the patient in a seated position and the cuffed arm supported, after at least 5 min of rest, considering means of three consecutive readings [6].

Patients were instructed by telephone to properly execute HBPM the week before the medical evaluation. They were asked to perform 2 BP readings (the second measurement 1–2 min after the first one) in the morning and 2 readings in the evening for seven consecutive days, using their own devices. Patients reported all the collected data and the BP device model. We considered as home BP values the mean of all BP values obtained, except for those measured on the first day. Only the home pressure values obtained with ESH/ISH-validated automatic arm devices were included in the analysis [16, 17].

Data about biometrics, clinical history, and pharmacological treatment were collected for every patient during the medical evaluation. Written informed consent was collected from all participants. The study was approved by the local ethical committee (CEI 652).

The collected data were analyzed with the R software version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables normally distributed were expressed as mean ± standard deviation (SD), continuous variables non-normally distributed are expressed as median and interquartile range and categorical variables were expressed as absolute number and percentage. Statistical significance was fixed at 0.05. For the evaluation of agreement among BP measurement techniques, we performed the Bland–Altman analysis and expressed our results with boxplot and Bland–Altman plot. Locally estimated scatterplot smoothing curves were applied to each Bland–Altman plot. Analysis of variance and Bonferroni *T* test were used to compare BP differences among groups of age, sex, and other demographical and clinical characteristics.

## RESULTS

The overall population included 118 subjects, with a mean age of 58.6 ± 15.3 years and 51% of male sex prevalence. Anthropometric and clinical features are summarized in Table 1.

OPB, uAOBP, and nAOBP values were available for all study populations, while HBPM data were available only for 86 (78%) subjects. Average BP values for each technique (nAOBP, uAOBP, OBP, HBPM) are reported in Table 2 and Fig. 1.

Mean nAOBP was significantly lower than OBP, with a mean difference of −8.1 ± 15.7 mmHg for systolic blood pressure (SBP) and −11.4 ± 9.7 mmHg for diastolic blood pressure (DBP). On the other hand, 32 subjects (27.1%) presented higher nAOBP when compared with OBP; in this group, nine subjects (7.6%) presented HBPM values ≥ 135/85 mmHg with OBP whithin reference values.

Furthermore, uAOBP measurement showed slightly lower values compared with nAOBP, with a mean difference of 3.6 ± 12.2 mmHg for SBP and 2.3 ± 7.3 mmHg for DBP. Nevertheless, when comparing the two randomized groups for order of execution of uAOBP and nAOBP, nAOBP was significantly higher when this was the first performed measurement technique (difference 3.7 ± 3.8 vs 0.9 ± 8.9 mmHg respectively, $p = 0.03$).

Finally, HBPM showed higher values when compared with nAOBP and uAOBP, particularly for DBP (mean difference 2.8/7.5 ± 19.0/11.4 mmHg with nAOBP and 7.2/10.1 ± 18.3/10.5 mmHg with uAOBP). nAOBP and HBPM showed a trend to increasing differences in higher BP values range, both for SBP and DBP. A similar trend was found between uAOBP and HBPM.

Thirty-two patients were unable to provide complete HBPM measurements. When analyzing the subgroup of subjects unable of performing properly HBPM, no significant differences were observed in mean age, education level, mean BP, sex, number of anti-hypertensive drugs.

Fourty-one subjects also underwent ABPM measurement (Table 1s—Online Supplementary); in this subgroup, ABPM Daytime BP values were higher than AOBP, either unattended or nurse attended (Fig. 1s—Online Supplementary).

The differences between BP measurement techniques were not influenced by age, sex, antihypertensive drugs, BMI, smoking, renal function, hypercholesterolemia, Type 2 Diabetes Mellitus.

Bland–Altman plots are presented in Figs. 2, 3, and 4.

**Table 1.** Anthropometric and clinical features of the study population.

| | |
|---|---|
| Overall population (*n*) | 118 |
| Male (*n*, %) | 60 (50.9) |
| Age (years) | 58.6 ± 15.3 |
| BMI (Kg/m²) | 27.4 ± 3.7 |
| Waist circumference (cm) | 104.9 ± 14.9 |
| Treated hypertensives (*n*, %) | 111 (94.0) |
| Hypertension duration (years) | 10.8 ± 9.2 |
| Number of antihypertensive drugs (*n*) | 2 [1–3] |
| Smokers (*n*, %) | 14 (11.9) |
| eGFR (ml/min/1.73 m$^2$) | 89.6 ± 34.3 |
| Hypercholesterolemia (*n*, %) | 51 (43.2) |
| Type 2 Diabetes Mellitus (*n*, %) | 15 (12.7) |

*eGFR* estimated glomerular filtration rate.

**Table 2.** Mean blood pressure and standard deviations of different Blood pressure measurement techniques.

| | SBP (mmHg) | DBP (mmHg) |
|---|---|---|
| OBP | 140.9 ± 18.7 | 84.6 ± 10.8 |
| HBPM | 135.2 ± 16.6 | 80.9 ± 8.1 |
| nAOBP | 132.8 ± 19.4 | 73.3 ± 12.9 |
| uAOBP | 129.2 ± 19.0 | 71.1 ± 12.3 |

*OBP* office blood pressure, *HBPM* home blood pressure monitoring, *nAOBP* nurse attended automated office blood pressure, *uAOBP* unattended automated office blood pressure, *SBP* systolic blood pressure, *DBP* diastolic blood pressure.

## DISCUSSION

Precise determination of BP is critical to accurately diagnose and appropriately treat hypertension, to assess achievement of target BP, to predict and manage cardiovascular risk. Several BP measurement techniques are currently available; the introduction of automated BP measurement techniques has reduced human

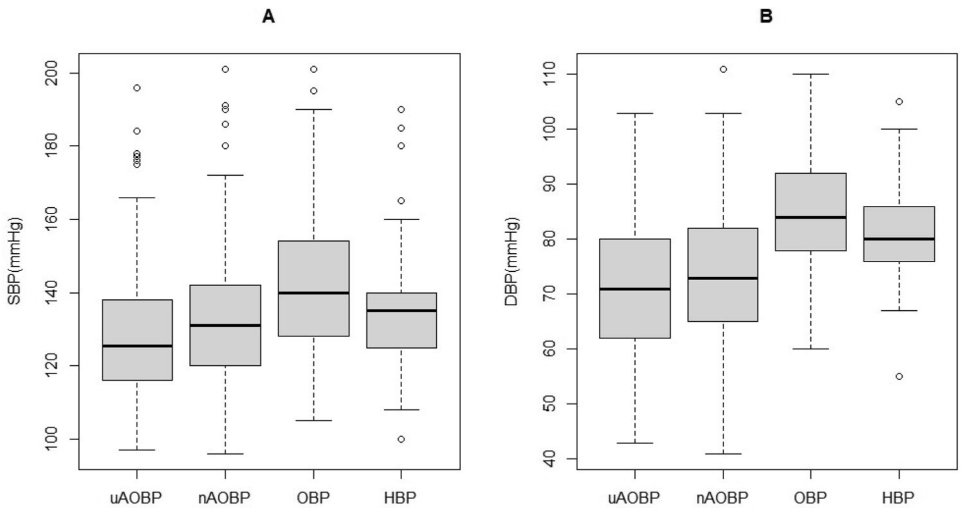


**Fig. 1 Boxplots of comparison of blood pressure with different measurement tecnique.** **A** Systolic blood pressure; **B** Diastolic blood pressure. *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *uAOBP* Unattended automated office blood pressure, *nAOBP* Nurse attended automated office blood pressure *OBP* Office blood pressure, *HBPM* Home blood pressure monitoring.

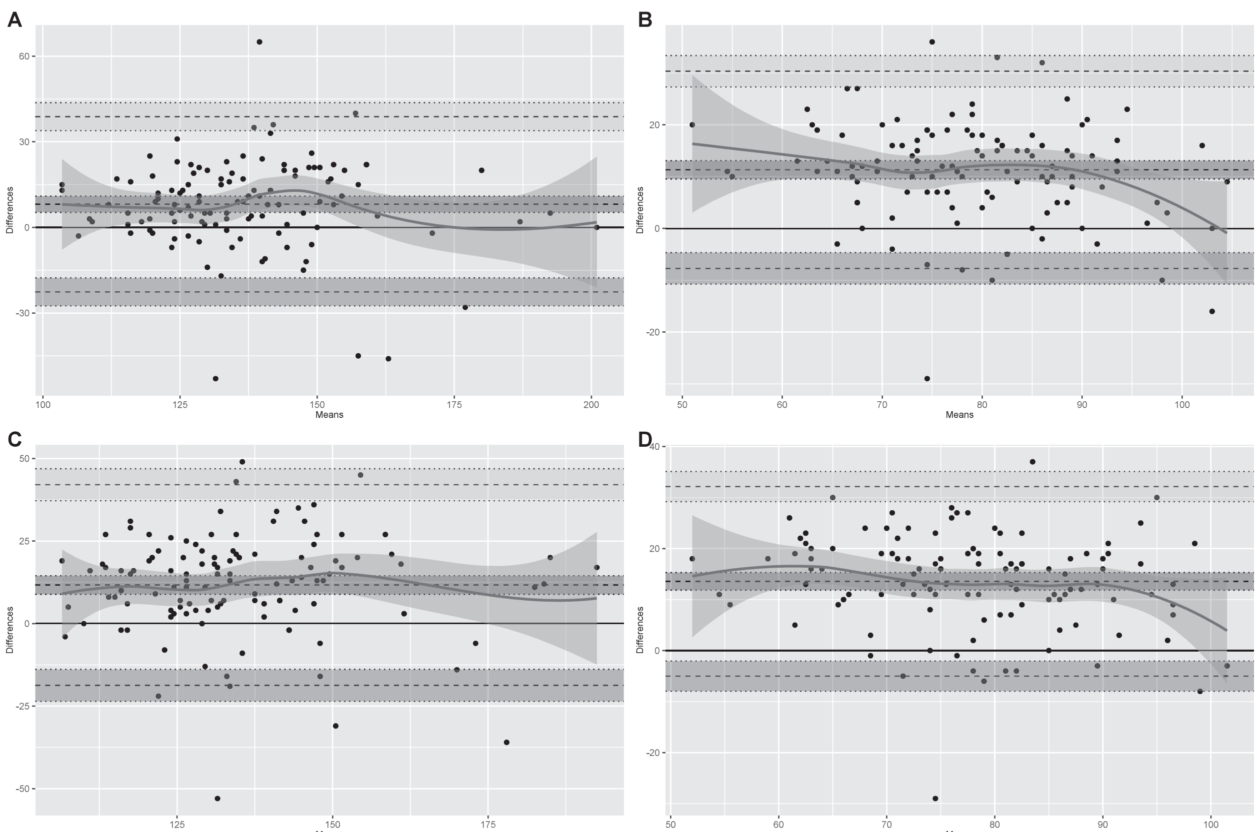


**Fig. 2 Bland–Altman plots of comparison between office blood pressure and automated office blood pressure techniques.** In the Figure, comparison of Office Blood Pressure (OBP), respectively with nurse attended blood pressure (nAOBP) for systolic (**A**) and diastolic values (**B**) and with unattended blood pressure (uAOBP) for systolic (**C**) and diastolic values (**D**). **A** Mean difference 8.1 mmHg (95% CI 5.3–11.0 mmHg); upper 95% LoA 38.8 mmHg (95% CI 33.9–43.7 mmHg); lower 95% LoA −22.6 mmHg (95% CI −27.5 to −17.7 mmHg). **B** Mean difference 11.3 mmHg (95% CI 9.5–13.1 mmHg); upper 95% LoA 30.3 mmHg (95% CI 27.3–33.4 mmHg); lower 95% LoA −7.7 mmHg (95% CI −10.8 to −4.7 mmHg). **C** Mean difference 11.7 mmHg (95% CI 8.9–14.5 mmHg); upper 95% LoA 42.1 mmHg (95% CI 37.2–46.9 mmHg); lower 95% LoA −18.7 mmHg (95% CI −23.6 to −13.9 mmHg). **D** Mean difference 13.6 mmHg (95% CI 11.8–15.3 mmHg); upper 95% LoA 32.1 mmHg (95% CI 29.2–35.1 mmHg); lower 95% LoA −5.0 mmHg (95% CI −8.0 to −2.0 mmHg). *OBP*, Office Blood pressure, *uAOBP* unattended automated office blood pressure, *CI* Confidence Interval, *LoA* Limit of agreement.

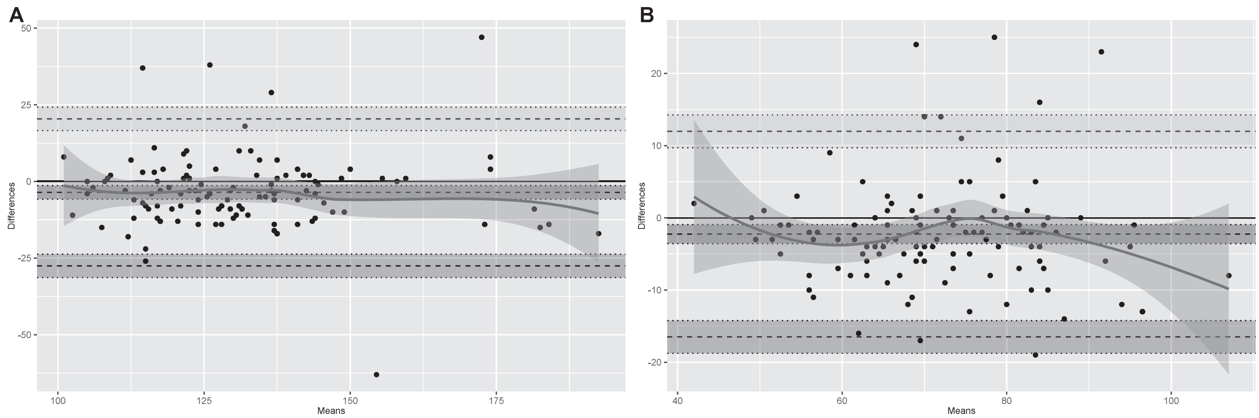


**Fig. 3 Bland–Altman plots of comparison between unattended and nurse attended blood pressure. A** Comparison of systolic values. Mean difference −3.5 mmHg (95% CI −5.8 to −1.3 mmHg); upper 95% LoA 20.4 mmHg (95% CI 16.6–24.2 mmHg); lower 95% LoA −27.6 mmHg (95% CI −31.4 to −23.7 mmHg). **B** Comparion of diastolic values. Mean difference −3.6 mmHg (95% CI −5.8 to −1.3 mmHg); upper 95% LoA 20.4 mmHg (95% CI 16.6–24.2 mmHg); lower 95% LoA −27.5 mmHg (95% CI −31.4 to −23.7 mmHg). *uAOBP* unattended automated office blood pressure, *nAOBP* nurse attended automated office blood pressure, *CI* Confidence Interval, *LoA* Limit of agreement.

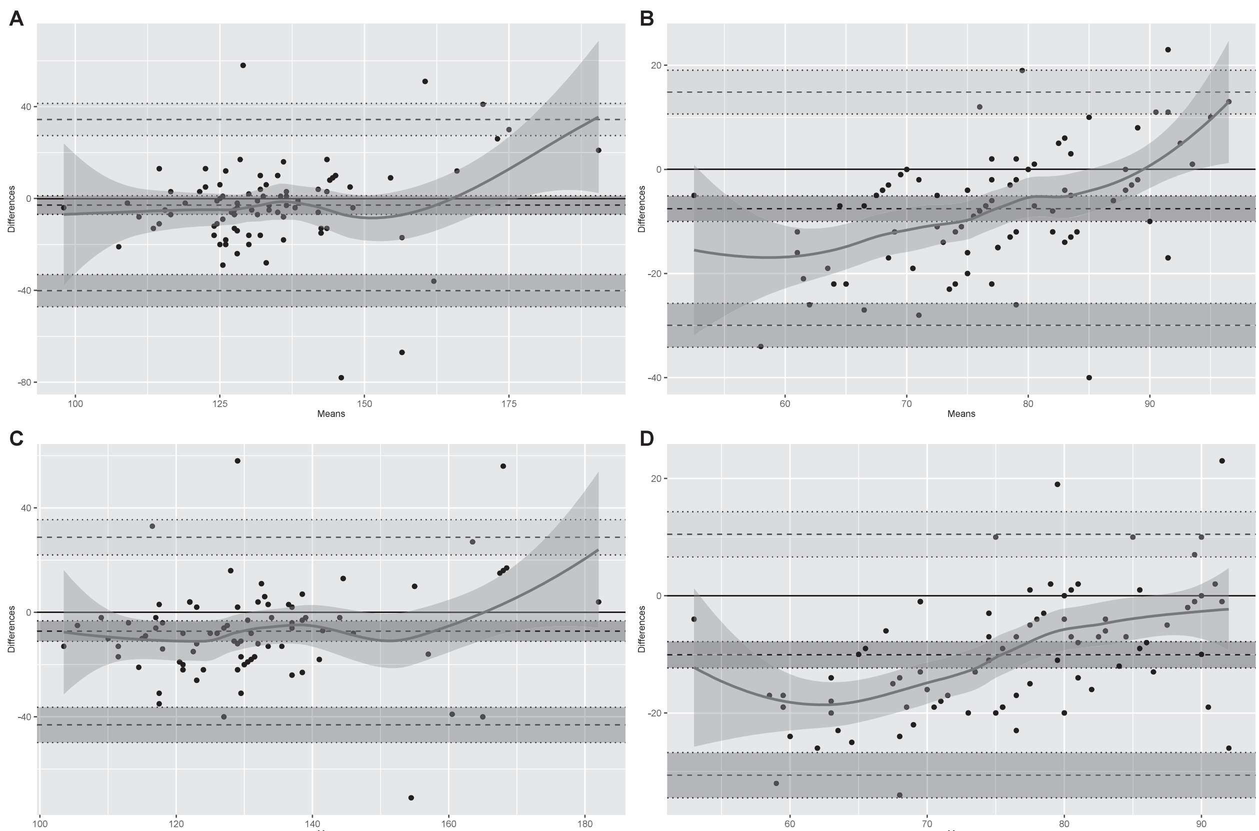


**Fig. 4 Bland–Altman plots of comparison between automated office blood pressure technique and home blood pressure.** In the Figure, comparison of Home blood pressure (HBPM), respectively with nurse attended (nAOBP) for systolic (**A**) and diastolic values (**B**) and unattended (uAOBP) for systolic (**C**) and diastolic values (**D**). **A** Mean difference −2.8 mmHg (95% CI −6.9 to 1.2 mmHg); upper 95% LoA 34.4 mmHg (95% CI 27.4–41.4 mmHg); lower 95% LoA −40.2 mmHg (95% CI −47.1 to −33.1 mmHg). **B** Mean difference −7.5 mmHg (95% CI −10.0 to −5.1 mmHg); upper 95% LoA 14.8 mmHg (95% CI 10.6–19.0 mmHg); lower 95% LoA −29.9 mmHg (95% CI −34.1 to −25.7 mmHg). **C** Mean difference −7.2 mmHg (95% CI −11.1 to −3.2 mmHg); upper 95% LoA 28.8 mmHg (95% CI 22.0–35.5 mmHg); lower 95% LoA −43.1 mmHg (95% CI −49.8 to −36.3 mmHg). **D** Mean difference −10.1 mmHg (95% CI −12.3 to −7.8 mmHg); upper 95% LoA 10.5 mmHg (95% CI 6.6–14.3 mmHg); lower 95% LoA −30.6 mmHg (95% CI −34.5 to −26.8 mmHg). *HBPM* Home blood pressure monitoring, *nAOBP* nurse attended automated office blood pressure, *uAOBP* unattended automated office blood pressure, *CI* Confidence Interval, *LoA* Limit of agreement.

error, but improvement in BP assessment performance is still necessary [18]. Training courses, monitoring of measurement procedures, and application of standardized protocols may represent instruments for further reducing inaccuracy.

Results of our study highlighted that AOBP, either attended or unattended, provides lower values than conventional OBP. It is probably due to the limitation of white-coat response to physicians, as previously described [3]. This evidence is in line with the results of several previous studies [19] and underlines the need of identifying different reference BP values for AOBP and OBP, both for hypertension diagnosis and for assessment of BP control in treated subjects, as these represent two distinct measurement techniques.

The comparison of nAOBP and uAOBP showed a difference in BP values, even if small and on average clinically not significant. This difference is likely not attributable to measurement methodology, as similar rigorous standardized procedures have been applied in nAOBP and uAOBP. The white-coat effect due to healthcare professionals presence is probably partially implied in this evidence, with an attenuated, but still present, adrenergic response during nurse compared to physician BP measurement session [20]. Nonetheless, the difference between uAOBP and nAOBP was further attenuated when attended technique was performed after unattended one, minimizing the conceivable contribution of nurse white-coat effect. Adaptation to measurement and longer resting time are probably implied and contribute to the observed difference between nAOBP and uAOBP.

Furthermore, nurse BP values were more similar to uAOBP than to OBP and a higher difference between physician BP values (OBP) and nurse BP values (nAOBP) was observed in comparison with previously reported in other studies [13]. This evidence suggests the importance of a rigorous standardized procedure and a stage of visit completely dedicated to BP measurement, in reducing inaccuracy. On additional support, in our study HBPM showed higher values when compared to uAOBP and nAOBP, suggesting that, even in presence of proper education of the patient, HBPM may lessen accuracy and be a less standardizable technique, except to strict experimental conditions [21]. Thirty-two patients were unable to complete the home measurement protocol, despite previous provided instructions and the availability of validated HBPM devices. In addition to this evidence, a significant proportion of subjects presented higher AOBP when compared with OBP and had uncontrolled Home BP values, suggesting the potential application of this technique in screening for masked hypertension [22].

In the subgroup of subjects who underwent ABPM, AOBP values were lower when compared to Daytime ABPM; these results are in agreement with previous evidence [23], even though the small size of the sample does not allow definite conclusions.

In conclusion, AOBP, both unattended and nurse attended, is a technique that allows a limitation of white-coat effect and improvement of accuracy, by reduction of measurement error, application of a standardized protocol, and control of interfering factors, through a measurement-dedicated stage of the visit. It can be also useful in identifying subjects with masked hypertension. nAOBP and uAOBP demonstrated lower values when compared to out-of-office techniques, with higher accuracy and a potential valuable predictive value of cardiovascular risk and hypertension mediated organ damage.

The main limitations of this study are represented by: (I) the availability of ABPM measurement only for a subgroup of patients, as comparison out-of-office technique; (II) the availability of HBPM measurement only for a subgroup of patients, because of the inability of 32 subjects to perform the home measurement, despite detailed preliminary instruction.

**Summary Table**

What is known about topic

- Automated office blood pressure measurement reduces the white-coat effect and observer error in blood pressure assessment.
- Nurse blood pressure measurement usually results in lower blood pressure values when compared to physician measurement.

What this study adds

- Blood pressure values are not only influenced by the white-coat effect but particularly by procedure standardization.
- Automated office blood pressure measurement showed lower values even when compared to home blood pressure.
- Automated office blood pressure measurement, even in attended technique, demonstrated potential as a screening method for masked hypertension.

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## COMPETING INTERESTS

The authors declare no competing interests.

## ADDITIONAL INFORMATION

**Supplementary information** The online version contains supplementary material available at https://doi.org/10.1038/s41371-021-00575-8.

**Correspondence** and requests for materials should be addressed to E.F.

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