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Comparison of automated office blood pressure with office and out-off-office measurement techniques: a systematic review and meta-analysis.

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Abstract

Automated office blood pressure (AOBP) has emerged as valuable tool to assess patient's blood pressure (BP) status, but the lack of strong evidences to establish a threshold value for hypertension diagnosis limits its use in clinical practice.

We aimed at synthesizing the published literature through a meta-analysis of studies comparing AOBP with other BP measurement techniques and at analysing the differences between AOBP and physician's office BP, non-physician's office BP, daytime ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM). We searched PubMed database for articles published up to April 2018; eligible studies compared AOBP with office and/or out-of-office measurement techniques and reported the BP differences or BP values obtained. Twenty-six studies, for a total of 7,116 patients were included in the analysis. AOBP values were lower than physician (systolic blood pressure, SBP -10.48 mmHg [95% CI -13.15 to -7.81] / diastolic blood pressure, DBP -4.44 mmHg [95% CI -6.07 to -2.80]) and non-physician office ones (SBP -6.89 mmHg [95% CI -8.75 to -5.04] / DBP -3.82 mmHg [95% CI -4.86 to -2.78]). No significant differences were detected between AOBP and daytime ABPM (SBP -1.85 mmHg [95% CI -4.50 to 0.79] / DBP 0.12 mmHg [95% CI -1.42 to 1.66]) and HBPM (SBP -2.65 mmHg [95% CI -8.42 to 3.12]) / DBP -1.67 mmHg [95% CI -4.20 to 0.87]).

AOBP readings did not differ significantly from out-of-office blood pressure, still remaining an office technique; it may improve hypertension diagnosis by overcoming some of office BP limitations, including the white-coat effect.

Key words: hypertension; automated office blood pressure; meta-analysis; ambulatory blood pressure monitoring; white-coat effect.

Introduction

Office Blood Pressure (OBP) has been traditionally considered as the standard blood pressure (BP) measurement technique for hypertension diagnosis[1,2], however several factors may lead to inaccurate readings. OBP is in fact poorly reproducible, particularly the auscultatory method, it can be responsible for the white coat effect and does not allow to detect masked hypertension[3,4]. To overcome these limitations, besides the recommendation of using out-of-office techniques as ambulatory BP monitoring (ABPM) and home BP monitoring (HBPM)[1,2], a fully automated unattended BP measurement technique, referred to as Automated Office Blood Pressure (AOBP), has been developed and gained increasing popularity over the last years. It has been designed to record multiple BP readings in the healthcare centre, with the patient resting alone in a quiet room[5]. Three automated oscillometric devices, the BpTRU, the Microlife WhatchBP Office and the Omron 907 XL, are currently available and have been used to compare AOBP with other measurement techniques[6]. Since the first study with the BpTRU device[4], a number of reports demonstrated that BP values are lower when measured with AOBP compared with OBP, thus confirming the expected decrease in white coat effect[7-9]. Similarly, the correlation between AOBP readings and awake ABPM has been extensively investigated, producing conflicting results[4,10], while few studies analysed the relationship between AOBP and HBPM[11,12]. For all these advantages, AOBP could represent an attractive alternative or an integrative option for BP measuring in the office setting. The results of the SPRINT trial[13], in which AOBP was used as BP measurement technique, led the 2017 American College of Cardiology (ACC)/American Heart Association (AHA) hypertension guideline[2] to lower the diagnostic threshold for hypertension diagnosis to ≥130/80 mmHg.

Despite having emerged as a valuable tool to assess the patient's BP status, the lack of strong evidences to establish a threshold value for hypertension diagnosis[3,14] limits the use of AOBP in clinical practice and only the 2016 hypertension Canadian guideline[15] currently recommends AOBP as the preferred method to measure office BP.

Therefore, the aim of our study is to compare unattended AOBP measurement with office and out-of-office measurement techniques, such as physician and non-physician (nurses or technicians) office BP, daytime ABPM and HBPM through a meta-analysis.

Methods

All supporting data are available within the article and its online supplementary files.

Search strategies, eligibility criteria and information sources.

We conducted a systematic research through the PubMed database for publications on AOBP and its comparison with other BP measurement techniques, up to April 2018, without starting date restriction. Different keyword combinations were used to identify clinical studies on AOBP: in particular we chose as search terms for titles and abstracts: "unattended OR automated office OR unattended office" AND "blood pressure OR office blood pressure OR home blood pressure monitoring OR ambulatory blood pressure OR ABPM OR HBPM OR OBP". Then, we examined the www.clinicaltrials.gov website to identify published and on-going trials on AOBP.

Study selection and data collection process

Articles eligible for inclusion in the analysis were reports comparing AOBP with other BP measurement techniques, in particular, daytime ABPM, HBPM, classical physician's office and nurse or technicians office BP measurements. Studies were considered for inclusion if the reports satisfied the following inclusion criteria: (1) a

detailed study protocol; (2) use of unattended AOBP as BP measurement technique in accordance with the established recommendations[3,15]; (3) comparison between unattended AOBP readings and physician OBP and/or non physician (nurse or technician) OBP and/or daytime ABPM and/or HBPM; (4) unattended AOBP measured with one of the three validated available devices and reporting of the AOBP device used (BpTRU, BpTRU Medical Devices, Coquitlam, BC, Canada / Omron HEM-907, OMRON, Kyoto, Japan / MicrolifeWatchBP Office, Microlife, Tapei, Taiwan); (5) reporting of BP values or BP differences (between AOBP and an other BP measurement technique) obtained and reporting of a measure of variance as standard deviation (SD) or standard error (SE). Exclusion criteria were: I) incomplete or incorrect reporting data on BP values or differences; II) conference abstracts and other unpublished data; III) duplicate reporting (the manuscript with the largest sample of patients was selected); IV) AOBP readings not in agreement with the current recommendations[3,15] or using a not validated device.

Clinical data extraction and end points

Titles and abstracts of retrieved publications were reviewed. Firstly, articles were selected by title and abstracts and divergences were solved after consensus of two investigators (MP and FR). Then all the identifies studies were evaluated as complete reports, assessing eligibility and computerizing the relevant information. The references of eligible manuscripts were also inspected to identify possible duplicate publications of the same data or missing information. The following relevant data were extracted: general study characteristics (sample size, study design, AOBP device used, AOBP technique description adopted, authors, journal and year of publication), baseline characteristics of the study sample (age, sex, diabetes, antihypertensive therapy), BP values or BP differences for each BP measurement technique used.

The co-primary endpoints of our meta-analysis were the BP difference between AOBP and office BP and between AOBP and daytime ABPM, while the difference between AOBP and home blood pressure monitoring and non-physician office blood pressure were evaluated as secondary end-points. When possible, we performed a subgroup analysis for studies using BpTRU or the other two AOBP devices (Omron 907 XL and Microlife WatchBP Office).

Statistical analysis

Continuous variables were reported as median (IQR), while categorical variables were expressed as percentage (%). RevMan 5 (The Cochrane Collaboration, The Nordic Cochrane Centre, Copenhagen, Denmark) was used for the statistical main analysis, according to a random-effect (RE) model with generic inverse-variance weighting and results are expressed as mean change [95% confidence interval (C.I.)]. When studies did not report the BP difference and its SD, BP difference was calculated as the difference between AOBP and OBP/Non-physician OBP/daytime ABPM/HBPM readings, while the SD was calculated according to the following formula [$\sigma(\text{AOBP} - \text{other BP technique}) = \sqrt{\sigma(\text{AOBP})^2 + \sigma(\text{other BP technique})^2}$][16]. The proportion of variability explained by true heterogeneity (i.e. between-studies variability) was estimated by calculating the I^2 for each analysis, with I^2 values of 25% representing mild statistical inconsistency, 50% representing moderate statistical inconsistency, and 75% representing high statistical inconsistency. Assessment of publication bias was performed by inspection of funnel plots followed by the trim-and-fill procedure. Statistical significance of 0.05 was fixed for all hypothesis tests. We performed a meta-regression analysis using a random effect model to appraise the effect of age on the observed BP difference, using OpenMetaAnalyst for Sierra[17].

Finally, we explored quality of included trials according to Cochrane statements selection bias (allocation and random sequence generation) and attrition bias (incomplete outcome data).

Results

Characteristic of the included studies

We identified 316 potential publications that were evaluated for eligibility at title and abstract level (Fig. 1). Of the 49 full text records assessed, 23 were excluded: eight were duplicate reports, five did not use a validated AOBP device, in three studies AOBP readings were not taken in agreement with recommendations, five did not report any comparison between unattended AOBP and at least one of the other BP measurement techniques mentioned above and finally two studies were excluded because of missing data (Table S1). 26 studies published between 2003 and 2018, including a total of 7,116 patients were eligible for the analysis[4,8,10,12,15,18-38] Characteristics of the included studies are reported in Table 1. The studies were both cross-sectional (n=4), prospective (n=4), retrospective (n=3) or randomized clinical trial (n=2); in thirteen reports the study design was not specified (Table S2). Only attrition bias was relevant in 7 studies due to missing data (BP readings missing, patients lost at follow-up). 16 studies compared AOBP with traditional OBP taken by physicians [4,8,10,12,19,21-24,27,28,30,32-34,37]; 16 studies compared AOBP with awake ABPM [4,8,10,18,19,20,22,24-26,29,33-35,37,38]; AOBP was compared with HBPM in 7 studies [10,12,24,27,28,30,38] and with non-physician OBP in 10 studies [4,8,15,18-20,31,36-38].

Clinical characteristics of the included patients are summarized in the Appendix (Table S3); the median age of our subjects was 60.5 years [IQR 55.8-64] and 48.5%

[IQR 44.8-53.2] were men, 23.2% [IQR 18.8-35.6] were diabetic and 86.4% [IQR 54.3-99.2] were under antihypertensive therapy.

Comparison between BP measurement techniques

The difference between unattended AOBP values and those measured with OBP, daytime ABPM, HBPM and non-physician OBP was assessed; when possible, a subgroup analysis to compare BP difference obtained by using the BpTRU device with the one measured by using the Microlife WatchBP Office and the Omron HEM 907 XL instruments was performed.

Sixteen studies, for a total of 3,022 patients, compared AOBP with traditional OBP measurement. Both systolic and diastolic AOBP values were significantly lower in the AOBP group, by -10.48 mmHg [95% CI -13.15 to -7.81] and by -4.44 mmHg [95% CI -6.07 to -2.80] respectively (Figure 2). When the 4 studies, using the Microlife WhatchBP Office or the Omron HEM 907 XL (indicated as Other devices), were analysed separately, the results were comparable to those of the main analysis (SBP difference: -9.55 mmHg [95% CI -17.15 to -1.95]; DBP difference -4.70 mmHg [95% CI -8.03 to -1.38]).

Interestingly, the main pooled analysis of 16 studies comparing AOBP with daytime ABPM (with a total of 3,193 included patients) showed no significant differences between AOBP and daytime ABPM both for systolic (-1.85 mmHg [95% CI -4.50 to 0.79;) and diastolic values (0.12 mmHg [95% CI -1.42 to 1.66]) (Figure 3), that were consistent within the two subgroups analysed.

Seven studies were available for the comparison between AOBP and HBPM measurements. No significant differences were found for both systolic (-2.65 mmHg [95% CI -8.42 to 3.12]) and diastolic values (-1.67 mmHg [95% CI -4.20 to 0.87]) as

detailed in Supplemental Figure S1. When the 3 studies using the BpTRU device were analysed separately, both systolic (-7.84 mmHg [95% CI -12.50 to -3.18]) and diastolic (-4.21 mmHg [95% CI -5.45 to -2.96]) AOBP values were significantly lower than HBPM ones, while those taken with other devices did not differ significantly from home readings (4.83 mmHg [95% CI -2.16 to 11.82] and 1.24 mmHg [95% CI -0.10 to 2.59]) for systolic and diastolic BP, respectivel)y (Supplemental Figure S1).

In the last analysis comparing AOBP with office BP taken by nurses or technicians (non-physician OBP), BP difference was similar to that obtained comparing AOBP with OBP measured by physicians (-6.89 mmHg [95% CI -8.75 to -5.04] and -3.82 mmHg [95% CI -4.86 to -2.78], for systolic and diastolic BP respectively) (Supplemental Figure S2).

To explore a potential confounding effect of age on the results of the present meta-analysis we performed a meta-regression analysis for mean age, which did not show any significant effect on the evaluated outcomes (Supplemental Figure S3).

Visual inspection of the funnel plots did not show a skewed or asymmetrical distribution (Supplemental Figure S4 to S7).

Discussion

Auscultatory office BP measurement has been traditionally considered as the standard technique for hypertension diagnosis[1]. Although in a research setting the auscultatory method remains the standard approach for testing new BP measurement devices, it is now accepted that it can be relatively inaccurate in routine clinical practice[39,40]. In fact, the last ESH/ESC and ACC/AHA hypertension guidelines[1,2] acknowledge the importance of a new and fully automated oscillometric techniques, referred to as

AOBP, as useful mean to obtain accurate and reproducible BP readings in the office setting.

The main finding of this meta-analysis of 26 studies, is that AOBP technique measurement provides significantly lower BP values than the office one, whilst AOBP readings were not significantly different from the evaluated out-of-office techniques (daytime ABPM and HBPM). Furthermore, our data demonstrated discrepancies in terms of BP values among the different devices validated for AOBP.

The white coat effect (defined as rise of office BP values in a clinical setting induced by an alerting reaction to physicians or nurses[1] can, at least partly account for the observed difference in BP values between AOBP and OBP. Several factors have been shown to affect the occurrence of the white coat effect such as age, female sex and non-smoking habit[1,41]. To evaluate a possible confounding effect of age on the observed difference between OBP and AOBP we performed a meta-regression analysis, which did not show any significant impact of age on the evaluated outcomes. Significant evidence, including a recent meta-analysis[42], indicates that BP values taken by physicians are systematically higher than those recorded by nurses[43,44]. In our meta-analysis we found that Office BP values, even when measured by nurses (or technicians), were significantly higher than AOBP ones, making it possible to assume that the BP rise induced by nurses is enough to overestimate BP in many patients. to consider the OBP measured by nurses as overestimating BP values in a majority of the patients.

Furthermore, AOBP allows to overcome some important limitations of OBP measurements, including the absence of a period of rest before the readings, conversation with patient and the “Hawthorne Effect”. Finally, OBP does not allow to

detect masked hypertension and requires confirmation by out-of-office techniques for hypertension diagnosis or treatment titrating.

By integrating the results of previous studies[8-10,33], our results showed that AOBP values are not statistically different to those measured with out-of-office techniques (ABPM and HBPM), strongly recommended by all the international hypertension guidelines[1,2]. In particular, no significant differences were found between AOBP and both HBPM and daytime ABPM values in the overall cohort of patients.

Evidence demonstrated that both AOBP and daytime ABPM correlate better than office BP with cardiovascular outcomes[45] and intermediate measures of target organ damage including intima media thickness[46] and left ventricular mass index[47].

Furthermore, AOBP is less expensive than ABPM and can overcome some limitations of HBPM, that can be affected by technical inaccuracies and by mistakes in under-reporting or over-reporting data[48,49], with HBPM readings reported by patients markedly different from those stored in the device memory.

In the comparison between AOBP and out-of-office techniques, subgroup analysis showed that AOBP systolic BP values, measured with Omron HEM 907 XL and WatchBP Office, were between 10 to 5 mmHg higher than those measured by using BpTRU; on the other hand, differences in diastolic BP were smaller. These findings are in agreement with previous reports. In fact, some studies and a meta-analysis, all reporting AOBP values obtained by using the BpTRU, showed significant differences in terms of BP values between AOBP and daytime ABPM, in particular with systolic AOBP levels being lower than ABPM[50-52]. Another study[53] compared BpTRU readings with those taken by using the WatchBP Office in a severely obese population: the mean BpTRU values were 9.4 (11.6)/3(7.7) mmHg lower than WatchBP Office measurements, underlying a marked difference and “the need for

formal validation of the devices". On the contrary, Myers et al.[54] showed no significant differences for systolic BP by using the BpTRU or Omron HEM 907 XL devices, but only 50 subjects were recruited for the analysis.

Various factors could be responsible for this discrepancy, such as differences in the devices internal algorithm and differences in threshold values for small cuffs between BpTRU and Omron HEM 907 XL[55,56], and lower mean BP values[31]. We acknowledge that, even if the results of the subgroup analysis confirmed previous reports, it is difficult to make robust conclusions due to the small number of included studies. It appears reasonable to suggest the constant use of the same device while readings translation or comparison between different AOBP devices should be done with extreme caution.

In conclusion, the routine use of AOBP could reduce the risk of hypertension over-diagnosis and over-treatment[57,58] and allow to overcome several OBP technique limitations as mentioned above. The results of this meta-analysis, indicating that AOBP readings did not differ significantly from out-of-office measurements, provide further evidence to establish the cut-off for hypertension diagnosis with AOBP technique, thereby contributing to the diffusion and implementation of its routinely use into clinical practice.

Perspectives

AOBP is an emerging BP measurement technique and may improve hypertension diagnosis by overcoming some of Office BP limitations, mostly through the elimination of white-coat effect. The differences in BP values across different AOBP devices, the absence of an accepted AOBP threshold for hypertension diagnosis limit its use. Based on the data of the present meta-analysis, AOBP threshold for the

diagnosis of hypertension should be considered the same as for daytime ABPM and HBPM. This will allow the diffusion of this technique and facilitate the interpretation and generalization of the findings of the clinical trials in which this BP measurement technique is adopted.

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None.

References

1. Bryan W, Mancia G, Spiering W et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension. . Eur Heart J 2018;00:1-98 doi:10.193/eurheartj/ehy339.
2. Whelton PK, Carey RM, Aronow WS et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2018;71(19):e127-e248.
3. Myers MG, Godwin M, Dawes M, Kiss A, Tobe SW, Kaczorowski J. Measurement of blood pressure in the office: recognizing the problem and proposing the solution. Hypertension 2010;55:195-200.
4. Myers MG, Valdivieso MA. Use of an automated blood pressure recording device, the BpTRU, to reduce the “white coat effect” in routine practice. Am J Hypertens 2003;16:494-7.
5. Myers MG. The great myth of office blood pressure measurement. J Hypertens 2012;30:1894-1898.
6. Myers MG. Automated Office Blood Pressure Measurement. Korean Circ J 2018;48(4):241-250.
7. Beckett L., Godwin M. The BpTRU automatic blood pressure monitor compared to 24-h ambulatory blood pressure monitoring in the assessment of blood pressure in patients with hypertension. BMC Cardiovasc Disord 2005;5:18.

8. Myers MG, Valdivieso M, Kiss A. Use of automated office blood pressure measurement to reduce the white coat response. J Hypertens 2009;27:280-6.
9. Myers MG, Godwin M, Dawes M, Kiss A, Tobe SW, Kaczarowki J. The conventional versus automated measurement of blood pressure in the office (CAMBO) trial: masked hypertension sub-study. J Hypertens 2012;30:1937-41.
10. Myers MG, Valdivieso M, Chessman M, Kiss A. Can sphygmomanometers designed for self-measurement of blood pressure in the home be used in office practice? Blood Pressure Monitoring 2010;15:300-304.
11. Sheppard JP, Holder R, Nichols L, Bray E, Hobbs FD, Mant J, Little P, Williams B, Greenfield S, McManus RJ. Predicting out-of-office blood pressure level using repeated measurements in the clinic: an observational cohort study. J Hypertens 2014;32:2171-2178.
12. Filipovský J, Seidlerová J, Kratochvíl Z, Karnosová P, Hronová M, Mayer O Jr. Automated compared to manual office blood pressure and to home blood pressure in hypertensive patients. Blood Pressure 2016;25(4):228-234.
13. SPRINT Research Group. Wright JT Jr, Williamson JD, Whelton PK et al. A randomized trial of intensive versus standard blood pressure control. N Engl J Med 2015;373:2103-16.
14. Wohlfahrt P, Cífková R, Movsisyan N, Kunzová Š, Lešovsk J, Homolka M, Soška V, Bauerová H, Lopez-Jimenez F, Sochor O. Threshold for diagnosing hypertension by automated office blood pressure using random sample population data. J Hypertens 2016;34:2180-2186.
15. Leung AA, Nerenberg K, Daskalopoulou SS et al. Hypertension Canada's 2016 Canadian hypertension education program guidelines for blood pressure

measurement, diagnosis, assessment of risk, prevention, and treatment of hypertension. Can J Cardiol 2016;32:569-88.

16. Glantz SA. Statistica per Discipline Biomediche 6th edizione. McGraw-Hill 2007.
17. Byron W, Dahabreh IJ, Trikalinos TA, Lau J, Trow P & Schmid CH (2012). Closing the Gap between Methodologists and End-Users: R as a Computational Back-End. Journal of Statistical Software, 49, 5. (Version 0.1503) [Software]. Software available from doi:http://www.cebm.brown.edu/openmeta/index.html.
18. Edwards C, Hiremath S, Gupta A, McCormick BB, Ruzicka M. BpTRUth: do automated blood pressure monitors outperform mercury? J Am Soc Hypertens 2013;7:448-453.
19. Culleton BF, McKay DW, Campbell NR. Performance of the automated BpTRU™ measurement device in the assessment of white-coat hypertension and white-coat effect. Blood Pressure Monitoring 2006;11:37-42.
20. Armstrong D, Matangi M, Brouillard D, Myers MG. Automated office blood pressure – being alone and not location is what matter most. Blood Pressure Monitoring 2015;20:204-208.
21. Myers MG, Valdivieso M, Kiss A. Consistent relationship between automated office blood pressure recorded in different settings. Blood Pressure Monitoring 2009;14:108-111.
22. Myers MG, Godwin M, Dawes M, Kiss A, Tobe SW, Curry F, Kaczorowski J. Conventional versus automated measurement of blood pressure in primary care patients with systolic hypertension: randomised parallel design controlled trial. BMJ 2011;342:d286.

23. O'shaughnessy MM, Newman CA, Kinsella SM, Reddan DN, Lappin DW. In-office assessment of blood pressure in chronic kidney disease: usual measurement versus automated BpTRU measurement. Blood Pressure Monitoring 2011;16:124-128.
24. Lamarre-Cliché M, Cheong NN, Larochelle P. Comparative assessment of four blood pressure measurement methods in hypertensives. Can J Cardiol. 2011;27(4):455-60.
25. Myers MG, Valdivieso M. Evaluation of an automated sphygmomanometer for use in the office setting. Blood Pressure Monitoring 2012;17:116-119.
26. Andreadis EA, Agaliotis GD, Angelopoulos ET, Tsakanikas AP, Kolyvas GN, Mousoulis GP. Automated office blood pressure is associated with urine albumin excretion in hypertensive subjects. Am J Hypertens 2012;25(9):969-973.
27. Andreadis EA, Papademetriou V, Geladari CV, Kolyvas GN, Angelopoulos ET, Aronis KN. Home, automated office, and conventional office blood pressure as predictors of cardiovascular risk. J Am Soc Hypertens 2017;11(3):165-170.
28. Bhatnagar A, Pein U, Markau S, Weigand K, Fornara P, Girndt M, Seibert E. Influence of SPRINT study type automated office blood pressure measurements on hypertension diagnosis in kidney transplant patients. Kidney Blood Press Res 2018;43:310-317.
29. Ringrose JS, Cena J, Ip S, Morales F, Hamilton P, Padwal R. Comparability of automated office blood pressure to daytime 24-hour ambulatory blood pressure. Can J Cardiol 2018;34:61-65.

30. Bauer F, Seibert FS, Rohn B, Bauer KAR, Rolshoven E, Babel N, Westhoff TH. Attended versus unattended blood pressure measurement in a real life setting. Hypertension 2018;71:243-249.
31. Rinfret F, Cloutier L, Wistaff R, Birnbaum LM, Cheong NN, Laskine M, Roederer G, Van Nguyen P, Bertrand M, Rabasa-Lhoret R, Dufour R, Lamarre-Cliche M. Comparison of different automated office blood pressure measurement devices: evidence of nonequivalence and clinical implications. Can J Cardiol 2017;33:1639-1644.
32. Filipovský J, Seidlerová J, Ceral J, Vysočanová P, Špác J, Souček M, Řiháček I, Mateřánková M, König P, Rosolová H. A multicentre study on unattended automated office blood pressure measurement in treated hypertensive patients. Blood Pressure 2018;4:188-193.
33. Godwin M, Birtwhistle R, Delva D, Lam M, Casson I, MacDonald S, Seguin R. Manual and automated office measurements in relation to awake ambulatory blood pressure monitoring. Fam Pract 2011;28:110-117.
34. Siddiqui M, Judd EK, Oparil S, Calhoun DA. White-coat effect is uncommon in patients with refractory hypertension. Hypertension 2017;70:645-651.
35. Padwal RS, Townsend RR, Trudeau L, Hamilton PG, Gelfer M. Comparison of an in-pharmacy automated blood pressure kiosk to daytime ambulatory blood pressure in hypertensive subjects. J Am Soc Hypertens 2015;9(2):123-129.
36. Rinfret F, Cloutier L, L'Archevêque H, Gauthier M, Laskine M, Larochelle P, Ilinca M, Birnbaum L, Ng Cheong N, Wistaff R, Van Nguyen P, Roederer G, Bertrand M, Lamarre-Cliche M. The gap between manual and automated

office blood pressure measurements results at a hypertension clinic. Can J Cardiol 2017;33:653-657.

37. Andreadis EA, Geladari CV, Angelopoulos ET, Savva FS, Georgantoni AI, Papademetriou V. Attended and unattended automated office blood pressure measurements have better agreement with ambulatory monitoring than conventional office readings. J Am Heart Assoc 2018;7:e008994.
38. O'Shaughnessy MM, Durcan M, Kinsella SM, Griffin MD, Reddan DN, Lappin DW. Blood pressure measurement in peritoneal dialysis: which method is best? Perit Dial Int 2013;33:544-51.
39. Graves JW, Nash C, Burger K, Bailey K, Sheps SG. Clinical decision-making in hypertension using an automated (BpTRU) measurement device. J Hum Hypertens 2003;17:823-827.
40. Burgess SE, MacLaughlin EJ, Smith PA, Salcido A, Benton TJ. Blood pressure rising: differences between current clinical and recommended measurement techniques. J Am Soc Hypertens 2011;5:484-488.
41. Franklin SS, Thijs L, Asayama K, Li Y, Hansen TW, Boggia J et al. The Cardiovascular Risk of White-Coat Hypertension. J Am Coll Cardiol. 2016;68(19):2033-2043.
42. Clark CE, Hovarth IA, Taylor RS, Campbell JL. Doctors record higher blood pressures than nurses: systematic review and meta-analysis. Br J Gen Pract 2014;64(621):e223-32.
43. Mancia G, Parati G, Pomidossi G, Grassi G, Casadei R, Zanchetti A. Alerting reaction and rise in blood pressure during measurement by physician and nurse. Hypertension 1987;9(2):209-2015.

44. Grassi G, Seravalle G, Buzzi S, et al. Muscle and skin sympathetic nerve traffic during physician and nurse blood pressure measurement. J Hypertens 2013;31(6):1131-1135.
45. Kaczorowski J, Chambers LW, Dolovich L et al. Improving cardiovascular health at population level: 39 community cluster randomised trial of Cardiovascular Health Awareness Program (CHAP). BMJ 2011;342:d442.
46. Campbell NR, McKay DW, Conradson H, Lonn E, Title LM, Anderson T. Automated oscillometric blood pressure versus auscultatory blood pressure as a predictor of carotid intima-medial thickness in male fire-fighters. J Hum Hypertens 2007;21:588-90.
47. Andreadis EA, Agaliotis GD, Angelopoulos ET, Tsakanikas AP, Chavelas IA, Mousoulis GP. Automated office blood pressure and 24-h ambulatory measurements are equally associated with left ventricular mass index. Am J Hypertens 2011;24:661-6.
48. Myers MG. Self-measurement of blood pressure at home: The potential for reporting bias. Blood Press Monit 1998;3(Suppl 1):S19-S22.
49. Mengden T, Hernandez Medina RM, Beltran B, Alvarez E, Kraft K, Vetter H. Reliability of reporting self-measured blood pressure values by hypertensive patients. Am J Hypertens 1998;11:1413-1417.
50. Padwal R, Ringrose JS. Comparability of Automated Office Blood Pressure to Daytime 24-Hour Ambulatory Blood Pressure – Reply to Editorial from Dr Myers. Can J Cardiol. 2018;34(1):93.e1.
51. Jegatheswaran J, Ruzicka M, Hiremath S, Edwards C. Are automated blood pressure monitors comparable to ambulatory blood pressure monitoring? A systematic review and meta-analysis. Can J Cardiol 2017;33:644-52.

52. Drawz PE, Pajewski NM, Bates JT, Bello NA. Effect of intensive versus standard clinic-based hypertension management on ambulatory blood pressure: novelty and significance. Hpertension 2017;69:42-50.
53. Padwal RS, Majumdar SR. Comparability of two commonly used automated office blood pressure devices in the severely obese. Blood Press Monit. 2016;21(5):313-5.
54. Myers MG, Valdivieso M, Kiss A, Tobe SW. Comparison of two automated sphygmomanometers for use in the office setting. Blood Press Monit 2009;14(1):45-7.
55. Omron Healthcare Inc. IntelliSense Blood Pressure Monitor Model HEM 907XL. Vol 2017.
56. BpTRU Medical Devices. Operator's Manual. Vol. 20172014.
57. Graves JW, Sheps SG. Does evidence-based medicine suggest that physicians should not be measuring blood pressure in the hypertensive patient. Am J Hypertens 2004;17(4):354-360.
58. Lovibond K, Jowett S, Barton P, Caulfield M, Heneghan C, Hobbs FD, Hodgkinson J, Mant J, Martin U, Williams B, Wonderling D, McManus RJ. Cost-effectiveness of options for the diagnosis of high blood pressure in primary care: a modelling study. Lancet 2001;378(9798):1219-1230.

Novelty and Significance

What Is New?

- This is the first meta-analysis comparing AOBP with office and out-of-office blood pressure measurement techniques.
- Office blood pressure values measured both by physicians and nurses are significantly higher than AOBP ones;
- There are no differences between AOBP values and day-time ABPM or HBPM

What Is Relevant

- AOBP allows to overcome the white-coat effect on the diagnosis of hypertension and is less expensive than ABPM
- AOBP values are comparable with those measured with out-of-office techniques and therefore the threshold for the diagnosis of hypertension should be considered the same;
- The use of the same AOBP device should be preferable and readings translation or comparison between different AOBP devices should be done with extreme caution.

Summary

Automated Office Blood Pressure (AOBP) is a fully automated unattended blood pressure technique, which records multiple BP readings with the patient resting alone in a quiet room. Despite the obvious advantage of eliminating the white coat effect, the lack of a universally accepted cut-off for hypertension diagnosis limits its use. The results of the present meta-analysis indicating that AOBP readings are not significantly different from out of office values,

contribute to expanding our knowledge on this technique and provide strong evidence for establishing a cut-off for hypertension diagnosis.

Figure Legends

Figure 1. **Flow chart of literature search and study selection.**

Figure 2. **Comparison between AOBP and Office BP. A) SBP difference between AOBP and Office BP. B) DBP difference between AOBP and Office BP.**

Forest plot of the BP difference between AOBP and Office BP. Central squares of each horizontal line represent the mean BP difference for each study. Horizontal lines indicate the range of the 95% CI and the vertical line indicates a BP mean difference of 0 (which indicates no differences in BP values between the two measurement techniques).

Figure 3. Comparison between AOBP and daytime ABPM. A) SBP difference between AOBP and daytime ABPM. 2) DBP difference between AOBP and daytime ABPM.

Forest plot of the BP difference between AOBP and daytime ABPM. Central squares of each horizontal line represent the mean BP difference for each study. Horizontal lines indicate the range of the 95% CI and the vertical line indicates a BP mean difference of 0 (which indicates no differences in BP values between the two measurement techniques). DT_ABPM = daytime ABPM.

1 **Tables**

Studies	**AOBP Device**	**Sample size**	**Type of comparison**	**AOBP Description**
Myers M.G., *Am J Hypertens.* 2003[4]	BpTRU	22	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 3 readings with 2-min interval. Average obtained using the three measurements.
Culleton B.F., *Blood Press Monit.* 2006 [19]	BpTRU	107	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 5 readings over 25 min with 5-min interval.
Myers M.G., *Blood Press Monit.* 2009* [21]	BpTRU	62	AOBP *vs.* Office BP	AOBP undertaken in the absence of a healthcare professional; 5 readings with 1 or 2-min interval. Average obtained using the five measurements.
Myers M.G., *J Hypertens.* 2009 [8]	BpTRU	309	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 5 readings with 1 or 2-min interval.
Myers M.G., *Blood Press Monit.* 2010 [10]	BpTRU	300	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 5 readings with 1-min interval.
O'shaughnessy M.M., *Blood Press Monit.* 2011 [23]	BpTRU	80	AOBP *vs.* Office BP	AOBP undertaken in the absence of a healthcare professional; 6 readings with 2-min interval. Average obtained discarding the first and using the remaining five.
Godwin M. *Fam Pract.* 2011 [33]	BpTRU	654	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1 or 2-min interval. Average obtained discarding the first and using the remaining five.
Myers M.G., *BMJ* 2011† [22]	BpTRU	555 (total) 299 *vs* 249	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 5 readings with 2-min interval.
Lamarre-Clichè M. *Can J Cardiol.* 2011 [24]	BpTRU	99	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.

Myers M.G. *Blood Press Monit.* 2012 [25]	Microlife WatchBP Office	100	AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 3 readings with 1-min interval.
Andreadis E.A. *Am J Hypertens.* 2012‡ [26]	Microlife WatchBP Office	162	AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval.
Edwards C., *J Am Soc Hypertens.* 2013 [18]	BpTRU	329	AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
O'shaughnessy M.M., *Perit Dial Int.* 2013 [38]	BpTRU	17	AOBP *vs.* non-physician BP AOBP *vs.* daytime ABPM AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 5 readings with 2-min interval.
Armstrong D., *Blood Press Monit.* 2015 [20]	BpTRU	422	AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 5 readings with 2-min interval.
Padwal R.S. *J Am Soc Hypertens.* 2015 [35]	Microlife WatchBP Office	100	AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 5 min of rest, 3 readings with 1-min interval.
Filipovský J. *Blood Press.* 2016§ [12]	BpTRU	353 (total) 114	AOBP *vs.* Office BP (*n* = 353) AOBP *vs.* HBPM (*n* = 114)	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
Wohlfahrt P. *J Hypertens.* 2016 [15]	BpTRU	2145	AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
Rinfret F *Can J Cardio.* 2017a‖ [31]	BpTRU[c]; Omron HEM 907 XL[d]	65[c] 64[d]	AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 5 min of rest, 3 readings with 1-min interval for Omron HEM 907 XL device; 6 readings with 1-min interval, average obtained discarding the first and using the remaining five, for the BpTRU device.
Andreadis E.A. *J Am Soc Hypertens.* 2017 [27]	Microlife WatchBP Office	211	AOBP *vs.* Office BP AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval.
Rinfret F. *Can J*	BpTRU	288	AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 6 readings

Cardiol. 2017b[6]				with 1-min interval. Average obtained discarding the first and using the remaining five.
Siddiqui M. *Hypertension* 2017 [34]	BpTRU	31	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
Bauer F. *Hypertension* 2018# [30]	Omron HEM 907 XL	107	AOBP *vs.* Office BP AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 5 min of rest, 3 readings with 1-min interval.
Filipovský J. *Blood Press.* 2018** [32]	BpTRU	172	AOBP *vs.* Office BP	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
Bhatnagar A. *Kidney Blood Press. Res* 2018 [28]	Omron HEM 907 XL	120	AOBP *vs.* Office BP AOBP *vs.* HBPM	AOBP undertaken in the absence of a healthcare professional; 5 min of rest, 3 readings with 1-min interval.
Ringrose J.S. *Can J Cardiol.* 2018 [29]	BpTRU	96	AOBP *vs.* daytime ABPM	AOBP undertaken in the absence of a healthcare professional; 6 readings with 1-min interval. Average obtained discarding the first and using the remaining five.
Andreadis E.A. *J Am Heart Assoc.* 2018*** [37]	Omron HEM 907 XL	146	AOBP *vs.* Office BP AOBP *vs.* daytime ABPM AOBP *vs.* non-physician BP	AOBP undertaken in the absence of a healthcare professional; 5 min of rest, 3 readings with 1-min interval.

1. Main characteristics of the 24 studies meeting inclusion criteria.

*Overlap population with Myers M.G., *J Hypertens* 2009[8]. The reported OBP measurement was performed by a specialist during follow-up visit, while in Myers M.G., *J Hypertens* 2009[8], it was performed by the family physician and was therefore included; data on nonphysician-OBP and daytime ABPM were excluded. In this study, office BP was measured twice by the hypertension specialist: during the first visit, and on a follow-up visit, with an interval between the first and second consultant of 61 days. Considering the long interval time, only the first office BP measurement was considered in the analysis. †In this study, OBP was measured twice, before and after the enrollment. Only BP values measured after the enrolment were included in the analysis. ‡Overlap population with *Andreadis EA J Am Soc Hypertens 2017* [27], only the comparison between AOBP and daytime ABPM was included in the analysis. §In this study, mean HBPM values were available only in 114 of 353 patients. ||Prospective randomized factorial parallel 4-group study comparing AOBP estimated by BpTRU and Omron HEM 907 devices in closed *vs.* open areas. Only data comparing non-physicians OBP with AOBP taken in closed areas with either

BpTRU or Omron HEM 907 devices were included in the analysis. ¶AOBP *vs.* OBP taken by trained nurse in both research and clinical settings were compared. Only data about the clinical setting were considered. #Patients were divided into two groups: group 1 comparing unattended AOBP with OBP and HBPM, while group 2 comparing unattendend AOBP with attendend AOBP and HBPM. Only data regarding Group 1 were included in our analysis. **The study evaluates the relationship between unattended AOBP, attended OBP and ABPM. Attended OBP was performed with both auscultatory method (*n*=172) and oscillometric devices (*n*=102), therefore only auscultatory data were considered (larger sample of patient). ***[T]the study reported both auscultatory and oscillometric OBP readings for all patients. We only considered oscillometric data (to avoid rounding off of readings to the nearest zero value).

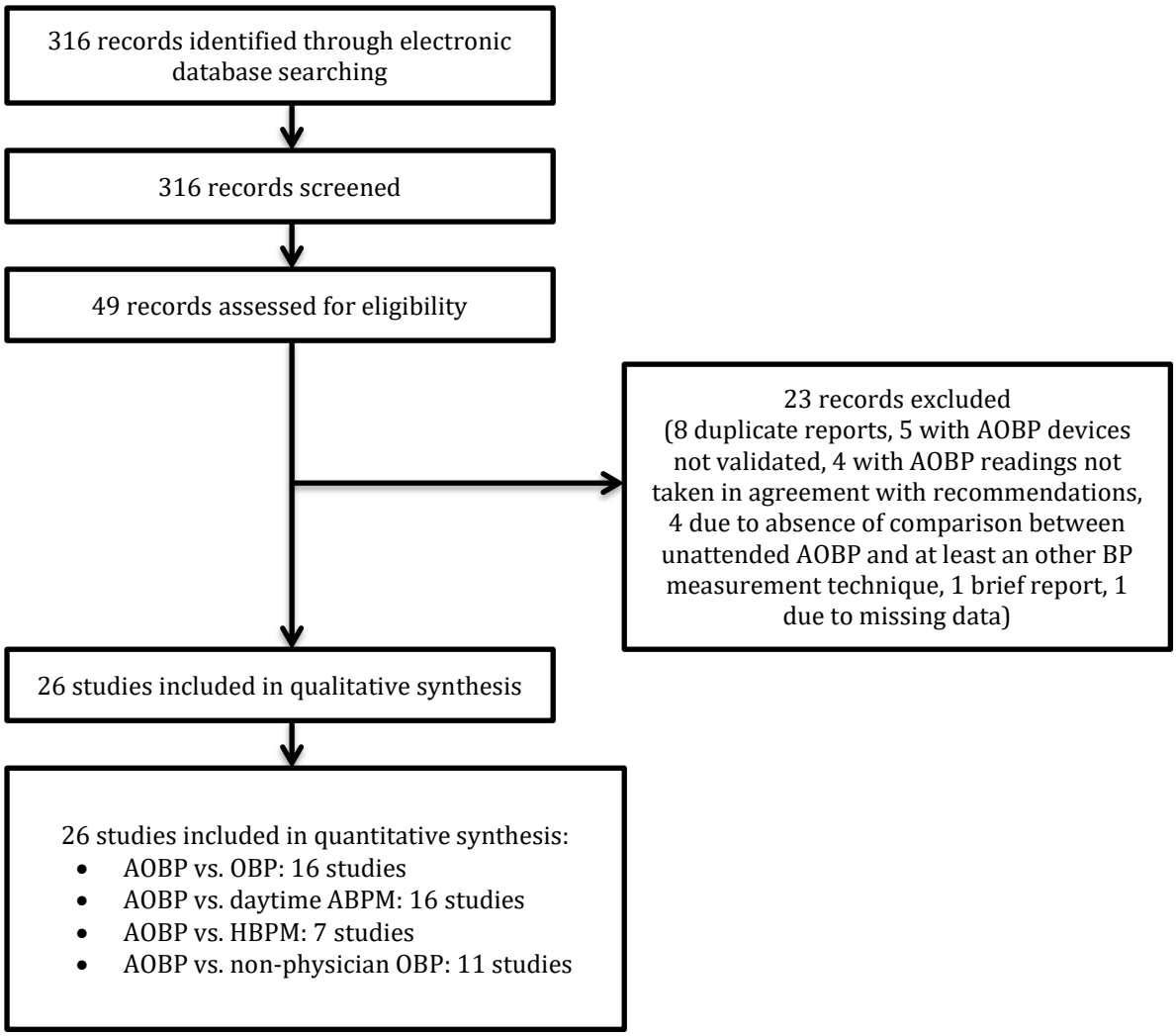

Figure 1. Flow chart of literature search and study selection.

ABPM indicates ambulatory BP monitoring; AOBP, automated OBP; BP, blood pressure; HBPM, home BP monitoring; and OBP, office BP.

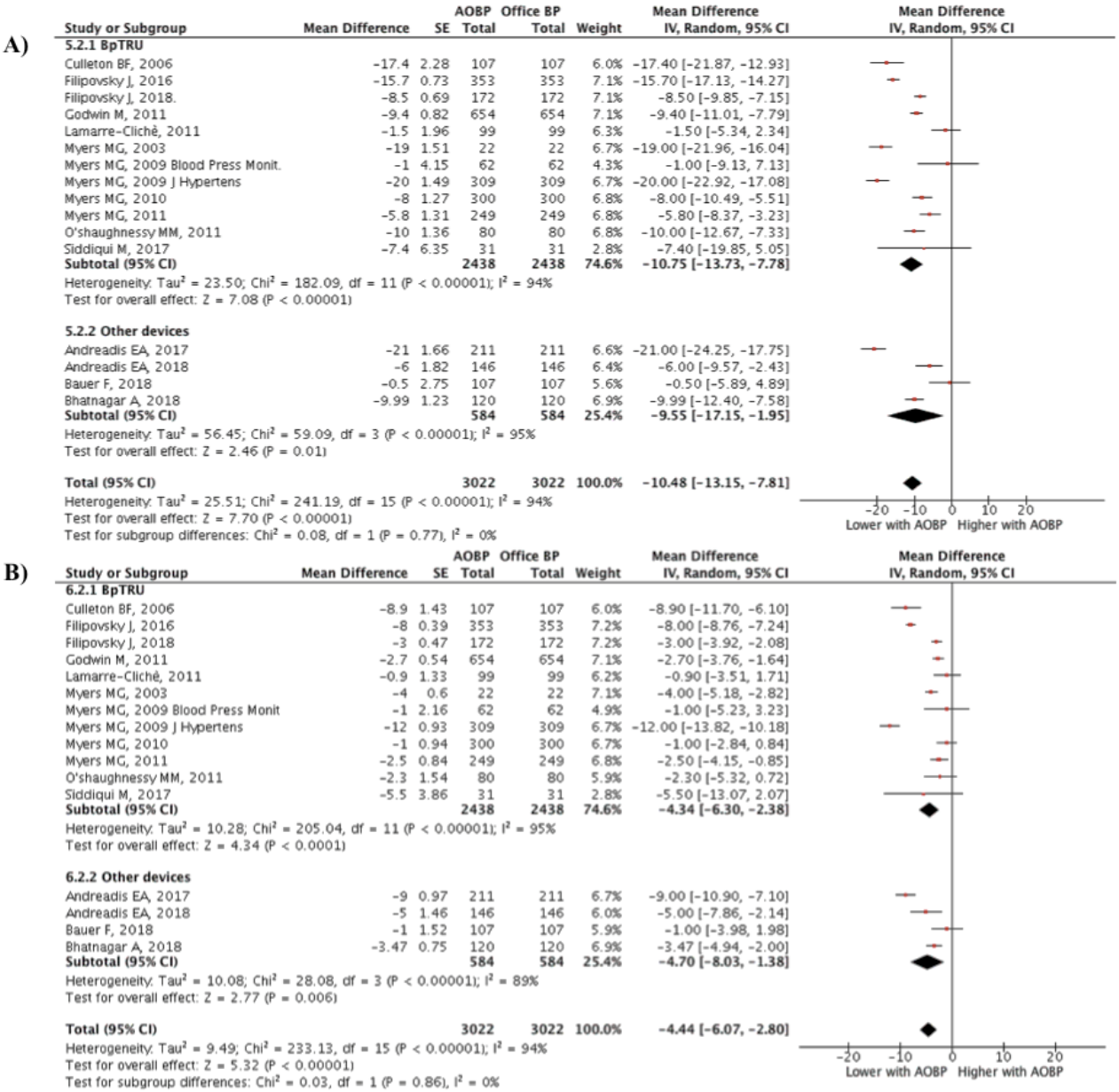

Figure 2. Comparison between automated office BP (AOBP) and office BP (OBP). **A**, Systolic BP difference between AOBP and OBP. **B**, Diastolic BP difference between AOBP and OBP. Forest plot of the BP difference between AOBP and OBP. Central squares of each horizontal line represent the mean BP difference for each study. Horizontal lines indicate the range of the 95% CI, and the vertical line indicates a BP mean difference of 0 (which indicates no differences in BP values between the 2 measurement techniques).

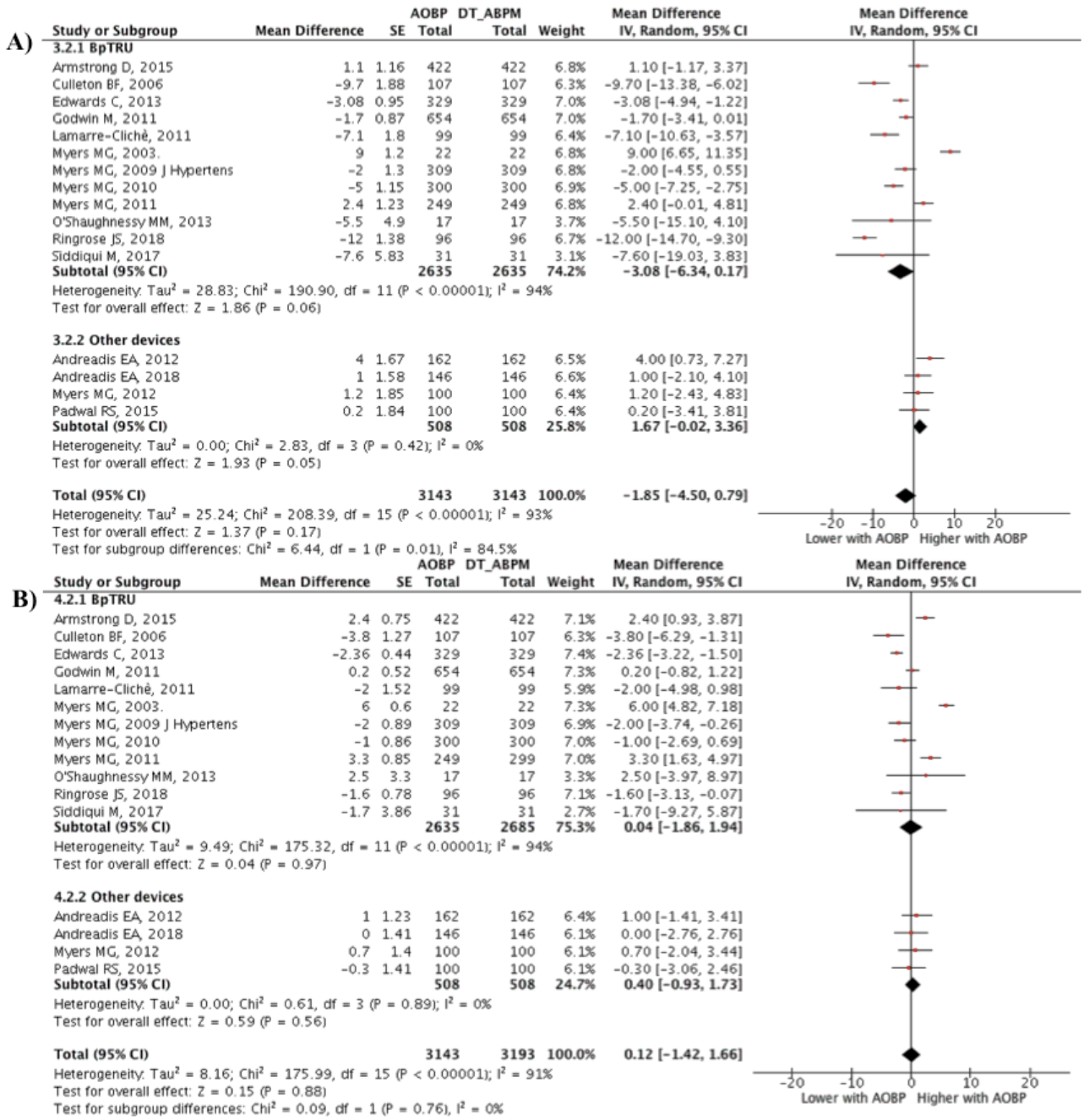

Figure 3. Comparison between automated office BP (AOBP) and daytime ambulatory BP monitoring (ABPM). **A**, Systolic BP difference between AOBP and daytime ABPM (DT_ABPM). 2) Diastolic BP difference between AOBP and DT_ABPM. Forest plot of the BP difference between AOBP and DT_ABPM. Central squares of each horizontal line represent the mean BP difference for each study. Horizontal lines indicate the range of the 95% CI, and the vertical line indicates a BP mean difference of 0 (which indicates no differences in BP values between the 2 measurement techniques).