scientific reports

Check for updates

OPEN

# Are oscillometric PWV values truly interchangeable? A comparative study of brachial and equation-derived measurements

Marco Antonio Vieira-da-Silva[1,4]✉, Gilberto de Araujo Pereira[2], Livia Marchiori Vieira[3], Gabriel Victor Cardoso Novais[3], Marco Aurélio de Almeida[4], Jessica Roma Uyemura[4], Leticia Aparecida Barufi Fernandes[4], Kleber Aparecido de Oliveira[4], Valquiria da Silva Lopes[4], Tatiana Palotta Minari[4], Juan C. Yugar-Toledo[4], Luciana Neves Cosenso-Martin[4] & Jose Fernando Vilela-Martin[4]

**The carotid-femoral pulse wave velocity (cf-PWV) is the standard for arterial stiffness measurement. Other methods include brachial PWV (br-PWV) and equation-derived PWV (ePWV) calculated from cf-PWV studies. br-PWV can also be estimated (ebr-PWV). This study evaluated the correlation between br-PWV, ebr-PWV, and ePWV. It included 683 participants, who had their blood pressure (BP) and br-PWV measured. Ambulatory BP monitoring was also recorded. The ebr-PWV was calculated using a previously validated equation. Three different BP measurements were employed to calculate ePWV, incorporating age and mean BP: ePWV derived from office BP (ePWVOBP), ePWV derived from 24-h mean BP (ePWV24h) and ePWV derived from mean BP from br-PWV measurements (ePWVMoG). Concordance correlation coefficients (CCC) were used to assess agreement, while coefficients of determination ($R^2$) evaluated dependence on age and BP. Results showed that the mean br-PWV was 7.60 ± 1.74 m/s, lower than ebr-PWV (7.71 ± 1.85 m/s), ePWVOBP (8.99 ± 1.86 m/s), ePWV24h (8.30 ± 1.69 m/s), and ePWVMoG (8.96 ± 1.88 m/s) (all $p < 0.001$). Agreement was very strong between br-PWV and ebr-PWV (CCC = 0.984), but lower with ePWV methods. Bland–Altman analysis showed a small bias for ebr-PWV (-0.11 m/s) and larger differences for ePWV, with wider limits of agreement and evidence of proportional bias. Age and BP explained most of the variability across all PWV measures. In conclusion, although all PWV measures are strongly influenced by BP and age, br-PWV and ebr-PWV tend to underestimate values compared with other ePWV estimates. Therefore, oscillometric PWV values are not interchangeable with those obtained from cf-PWV-derived equations**

**Keywords** Arterial stiffness, Hypertension, Pulse wave velocity, Blood pressure

Hypertension is an important contributor to cardiovascular (CV) morbidity and mortality worldwide[1]. Arterial stiffness (AS) is a key pathophysiological feature of hypertension and aging. It expresses structural and functional changes in the arterial wall, which increase CV risk independent of blood pressure (BP) values[2–4]. Pulse wave velocity (PWV), particularly carotid–femoral PWV (cf-PWV), is considered the gold standard non-invasive measure of arterial stiffness and a robust predictor of cardiovascular outcomes[5,6].

Despite its clinical relevance, cf-PWV assessment is not routinely performed in daily practice due to its technical complexity, operator dependence, and limited availability. Therefore, other approaches have been developed, including oscillometric methods and equation-derived estimates[7]. Oscillometric devices such as the Mobil-O-Graph estimate PWV from brachial cuff recordings using proprietary algorithms, generating brachial PWV (br-PWV). However, these values are not directly measured, but rather derived from models that are largely dependent on age and BP[8,9].

In parallel, equation-derived PWV (ePWV) has been proposed based on large population datasets originally developed to establish reference values for cf-PWV[10]. These equations incorporate age and mean blood pressure

[1]Cardiac Diagnostic Centre (CDC), Dr. Thomaz Ulhoa, 544 Square, Uberaba 38025-050, Brazil. [2]Department of Nursing in Education and Community Health, Federal University of Triângulo Mineiro, Uberaba, Brazil. [3]Uberaba University, Uberaba, Minas Gerais, Brazil. [4]Department of Internal Medicine, São José do Rio Preto State Medical School, São José do Rio Preto, Brazil. ✉email: marcovieiravs@gmail.com

(MBP) and have demonstrated prognostic value across different populations[11–14]. Additionally, oscillometric PWV can be mathematically approximated through specific equations (ebr-PWV), which are derived from the same datasets used to generate device-based estimates[8,9].

Although these methods share common determinants such as age and blood pressure, they originate from different physiological models and mathematical structures. Whether these approaches can be used interchangeably remains uncertain. Therefore, the aim of this study was to assess the agreement between oscillometric PWV (br-PWV), its equation-derived counterpart (ebr-PWV), and equation-derived PWV based on cf-PWV datasets (ePWV), using different blood pressure inputs.

## Methods

The data used in this study were derived from a previously published cross-sectional dataset[15], collected at a center specializing in the diagnosis and treatment of non-communicable diseases in Brazil between May 2016 and April 2019. The study included 683 adults aged 18 years or older with elevated office blood pressure (≥ 140/90 mmHg), including both untreated individuals and patients receiving antihypertensive treatment. Participants were referred for ambulatory blood pressure monitoring (ABPM) to confirm the diagnosis of hypertension or to evaluate blood pressure control. All subjects had their demographic and clinical data collected, including a history of acute myocardial infarction, acute coronary syndrome, coronary or other arterial revascularization, stroke, transient ischemic attack, aortic aneurysm, peripheral artery disease, and severe chronic kidney disease (CKD). They also had their weight, height, and abdominal circumference (AC) measured. A trained nursing assistant recorded blood pressure measurements and performed pulse wave analysis (PWA).

### Blood pressure measurement

Office blood pressure (OBP) measurements followed current hypertension guidelines[16,17]. A nursing assistant utilized a Microlife BP3AC1-1PC (Onbo Electronic Co., Shenzhen, China) monitor. This device comes with a so-called "Average Mode," which takes three consecutive BP measurements and calculates the average value. The nursing assistant took two sets of three BP measurements for all subjects.

### Ambulatory blood pressure monitoring

ABPM was conducted over 24 h utilizing a Dyna-Mapa monitor (Cardios, São Paulo, Brazil), and the participants had an appropriately-sized cuff on their non-dominant arm. The readings were taken every 20 min during the day and every 30 min during the night, defined as the period between sleep onset and awakening. All standard protocols were strictly followed to ensure data quality[18].

### Pulse wave analysis

After BP measurements, participants rested for 10 min in a supine position before PWA was performed using the Mobil-O-Graph (I.E.M., Stolberg, Germany). Participants underwent four measurements of PWV[15]. The br-PWV value is the mean calculated from those measurements. The determination of PWA followed the recommendations of the 2012 Expert Consensus Document on Aortic Stiffness, in a quiet room with stable temperature[19]. Previous data have demonstrated that age and SBP were significant determinants of br-PWV according to the equation: estimated br-PWV (ebr-PWV) = $1.0796 - 0.0317 \times \text{Age} + 0.0015 \times \text{Age2} + 0.0325 \times \text{SBP}$[9]. The device automatically calculates the mean systolic and diastolic BP (br-BP) from four measurements, as well as the mean BP ($\text{MBP}_{\text{br-BP}}$). ebr-PWV was calculated using mean brachial systolic BP (br-SBP) provided by the Mobil-O-Graph.

### Calculation of estimated pulse wave velocity

ePWV was calculated using Eq. 1, derived from the Reference Values for Arterial Stiffness Collaboration, based on age and mean blood pressure (MBP)[10,11]:

$$\begin{aligned}\text{ePWV} = {} & 9.58748315543126 - 0.402467539733184 * \text{age} \\ & + 4.56020798207263 * 10 - 3 * \text{age2} \\ & - 2.6207705511664 * 10 - 5 * \text{age2} * \text{MBP} \\ & + 3.1762450559276 * 10 - 3 * \text{age} * \text{MBP} \\ & - 1.832150382185 * 10 - 2 * \text{MBP}.\end{aligned}$$

We used the average of the first set of three OBP measurements to estimate mean blood pressure (MBP). This was calculated as 40% of the office pulse pressure added to diastolic blood pressure (BP). The formula for MBP is: MBP = diastolic BP + 0.4 × (systolic BP—diastolic BP)[11]. The mean blood pressure from OBP (MBPOBP) was calculated using OBP values. We also calculated the 24-h average blood pressure (24-h BP) and derived the mean blood pressure from this average (MBP24hBP). Subsequently, we used MBPOBP to calculate the estimated pulse wave velocity from OBP (ePWVOBP) and used MBP-24 h to calculate the estimated pulse wave velocity from the twenty-hour average blood pressure (ePWV-24 h)[20,21].

The primary outcome of this study was the agreement between br-PWV and the other PWV methods (ebr-PWV, ePWVOBP, ePWV24h, and ePWVMoG), defined a priori and assessed using concordance correlation coefficients and Bland–Altman analysis.

### Statistical analysis

The descriptive analysis of the variables was based on measurements such as mean with standard deviation (SD), median with quartiles 1 and 3 (Q1-Q3) for numerical variables, and proportions (%) for categorical variables.

The assumption of normality of the numerical variables was analyzed using the D'Agostino-Pearson test. Given the non-normal distribution of PWV variables non-parametric methods were applied. Paired comparisons used the paired Student's t-test and Wilcoxon signed-rank test, with consistent results. The concordance correlation coefficient (CCC), followed by simple linear regression between pairs of methods under study was used to evaluate the level of agreement between PWV-br and the others metrics, with the coefficient of determination ($R^2$) indicating the proportion of variance explained. Scatter plots were constructed with br-PWV on the x-axis and alternative PWV methods on the y-axis, consistent with method comparison analyses. Fisher's z-transformation was used to compare the CCC values and differences between $R^2$ values were assessed using the Forkman test. A Bland–Altman plot was constructed to complement the agreement analyses, incorporating the mean differences, the lower limit of agreement (LLA), the upper limit of agreement (ULA), and linear regression of the differences between paired means versus the mean of the paired methods, allowing for a more precise assessment of potential proportional bias. The significance level of the inferential procedures was 5%. Since age and blood pressure are major determinants of PWV, two regression models were evaluated to quantify their contribution to each PWV metric: Model 1 included age only, whereas Model 2 included both age and blood pressure[15,20,21]. As a sensitivity analysis, PWV metrics were also examined across age and mean brachial blood pressure (MBPbr-BP) quartiles to assess the consistency of the findings across different age and blood pressure categories (Supplementary Figure S1 and Supplementary Table S1). A two-sided p-value < 0.05 was considered statistically significant. Databases were created in Microsoft Excel, and statistical analyses were performed using MedCalc software.

## Ethical approval

The study was approved by the Human Research Ethics Committee of the Federal University of Triângulo Mineiro (protocol number 61985316.9.0000.5154). All participants provided written informed consent prior to enrollment. All methods were performed in accordance with the relevant guidelines and regulations, including the Declaration of Helsinki for medical research involving human participants.

# Results

## Study population

683 subjects underwent a valid PWA and their data were analyzed. Table 1 shows the most relevant clinical and demographic characteristics in the sample. The mean age was 48.0 ± 14.3 years, the BMI was 29.1 ± 6.5 kg/m$^2$, and the mean AC was 95.8 ± 12.2 cm. 49.8% of the participants were female and 69.9% were Caucasian. Treated hypertension occurred in 34.8% of participants; elevated BP in 32.9%; clinical CVD and CKD in 7.2%; diabetes in 10.7%; dyslipidemia in 28.1%; obesity in 39.2%; abdominal obesity in 53.9%; and smoking 7.3%.

Table 2 summarizes the BP values obtained from the different measurement methods. No significant differences were observed between systolic OBP and br-BP (p = 0.35). Diastolic OBP was slightly higher than br-BP, although the absolute difference was small (p = 0.02). As expected, 24-h BP values were consistently lower than both office and brachial measurements for systolic, diastolic, and mean BP (all p < 0.001). There were no significant differences between the MBP values of OBP and br-BP (p = 0.05). In contrast, MBP derived from 24-h BP measurements were significantly lower than the others (p < 0.001). Similar patterns were observed for median values, confirming the consistency of these findings across different measurements of central tendency, except for a significant difference between MBP from OBP and br-BP (p = 0.009).

| Clinical characteristics | Summary | |
|---|---|---|
| **Numeric** | **Mean ± SD** | **Median [Q1 -Q3]** |
| Age (yr) | 48.0 ± 14.3 | 48 [36—58.7] |
| BMI (kg/m$^2$) | 29.1 ± 6.5 | 28.3 [25.6 -31.6] |
| Abdominal circumference (cm) | 95.8 ± 12.2 | 96 [88- 104] |
| **Categorical** | **N [P%]** | |
| Caucasian | 461 (67.9) | |
| Females | 340 (49.8) | |
| Treated HTN | 238 (34.8) | |
| Non-treated HTN | 225 (32.9) | |
| CVD and CKD | 49 (7.2) | |
| Diabetes | 73 (10.7) | |
| Dyslipidemia | 192 (28.1) | |
| Body obesity | 268 (39.2) | |
| Smoking | 50 (7.3) | |
| Abdominal obesity | 368 (53.9) | |

**Table 1**. Main clinical and demographic characteristics of the sample. Data are demonstrated in absolute numbers (N), proportions (P%), mean ± standard deviation (SD), and median [quartile 1 and quartile 3]. SD, standard deviation; CI, confidence interval; Q1, quartile 1; Q3, quartile 3; HTN, hypertension; CVD, cardiovascular disease; CKD, severe chronic kidney disease; BMI, body mass index. *D'Agostino-Pearson test for normal distribution p < 0.0001.

| Blood pressure | Mean (a) ± SD | Median (b) [Q1 -Q3] |
|---|---|---|
| **OBP** | | |
| Systolic | 135 ± 17.1 | 134 [124—145] |
| Diastolic | 87 ± 11.2 | 87 [80—94] |
| MBPOBP | 106 ± 12.4 | 106 [98—114] |
| **br-BP** | | |
| Systolic | 135 ± 15.2 | 134 [124—144] |
| Diastolic | 86 ± 11.1 | 86 [79—94] |
| MBPbr-BP | 105 ± 11.9 | 105 [104- 106] |
| **24 h-BP** | | |
| Systolic | 123 ± 12.3 | 122[115—130] |
| Diastolic | 78 ± 10.5 | 78 [71—85] |
| MBP24hBP | 96 ± 10.5 | 96 [89—103] |

**Table 2**. Blood pressure values used to calculate estimated PWV. SD, standard deviation; OBP, office blood pressure; br-BP, brachial blood pressure mean of four values of Mobil-O-Graph; 24 h-BP, twenty-four-hour BP average from ABPM; MBP, mean blood pressure. (a) p-values for mean comparisons (paired Student's t-test); (b) p-values for median comparisons (Wilcoxon signed-rank test). Results were consistent across methods. *D'Agostino-Pearson test for normal distribution $p < 0.0013$.

| PWV | Mean (a) ± SD | Median (b) [Q1 - Q3] |
|---|---|---|
| br-PWV | 7.60 ± 1.74 | 7.27 [6.27—8.63] |
| ebr-PWV | 7.71 ± 1.85 | 7.32 [6.26—8.80] |
| ePWVOBP | 8.99 ± 1.86 | 8.69 [7.53—10.17] |
| ePWV24h | 8.30 ± 1.69 | 8.02 [7.04—9.18] |
| ePWVMoG | 8.96 ± 1.88 | 8.62 [7.48—10.04] |

**Table 3**. Mean pulse wave velocity values. PWV, pulse wave velocity; SD, standard deviation; CI, confidence interval; br-PWV, mean of pulse velocity measured by Mobil-o-Graph; ebr-PWV, mean estimated by equation of pulse wave velocity by Mobil-o-Graph; ePWVOBP, calculated pulse wave velocity from Eq. 1 utilizing mean OBP; ePWV24h calculated pulse wave velocity from Eq. 1 utilizing mean 24 h-BP, ePWVMoG, calculated pulse wave velocity from Eq. 1 utilizing MBP of br-BP. (a) p-values for mean comparisons (paired Student's t-test); (b) p-values for median comparisons (Wilcoxon signed-rank test). Results were consistent across methods. *D'Agostino-Pearson test for normal distribution $p < 0.0001$.

Table 3 shows the PWV values of all metrics. Mean br-PWV (7.60 ± 1.74 m/s) was significantly lower than all other estimates (all $p < 0.001$). There was no significant difference between ePWVOBP and ePWVMoG ($p = 0.06$). Median values showed a similar pattern, with br-PWV consistently lower than the other methods and significant differences in the other comparisons, including between ePWVOBP and ePWVMoG ($p < 0.006$).

## Primary agreement analyses

Figure 1 shows the relationships between br-PWV and other PWV methods. A very strong agreement was observed between br-PWV and ebr-PWV ($Pc = 0.984$), whereas only moderate agreement was found with ePWVOBP, ePWV24h, and ePWVMoG. The CCC was significantly higher for ebr-PWV compared with all other methods ($p < 0.001$). Regression analyses demonstrated a strong dependence of br-PWV on all PWV estimates. ebr-PWV explained the largest proportion of its variance ($R^2 = 0.98$), while ePWVOBP, ePWV24h, and ePWVMoG showed lower but still substantial explanatory power. There were no significant differences between models in terms of $R^2$ comparisons, except between ebr-PWV and ePWV-24 h ($p = 0.04$).

Figure 2 shows the Bland–Altman analyses of the comparison between br-PWV and the other PWV metrics. A consistent negative bias was observed across all comparisons, indicating that br-PWV systematically underestimated values relative to other PWV metrics (all $p < 0.001$). ebr-PWV showed the lowest mean difference (-0.11 m/s), with relatively narrow limits of agreement (-0.70 to 0.48 m/s). The other PWV metrics showed larger biases, with the largest being -1.39 for ePWVOBP, and wider limits of agreement (-2.73 to -0.07), thus suggesting significant variability between approaches. Regression analyses of the differences demonstrated significant proportional bias in most comparisons ($p < 0.001$), indicating that disagreement increased across the range of PWV values, except for ePWV-24 h. This indicates a consistent bias that does not necessarily preclude comparability between methods.

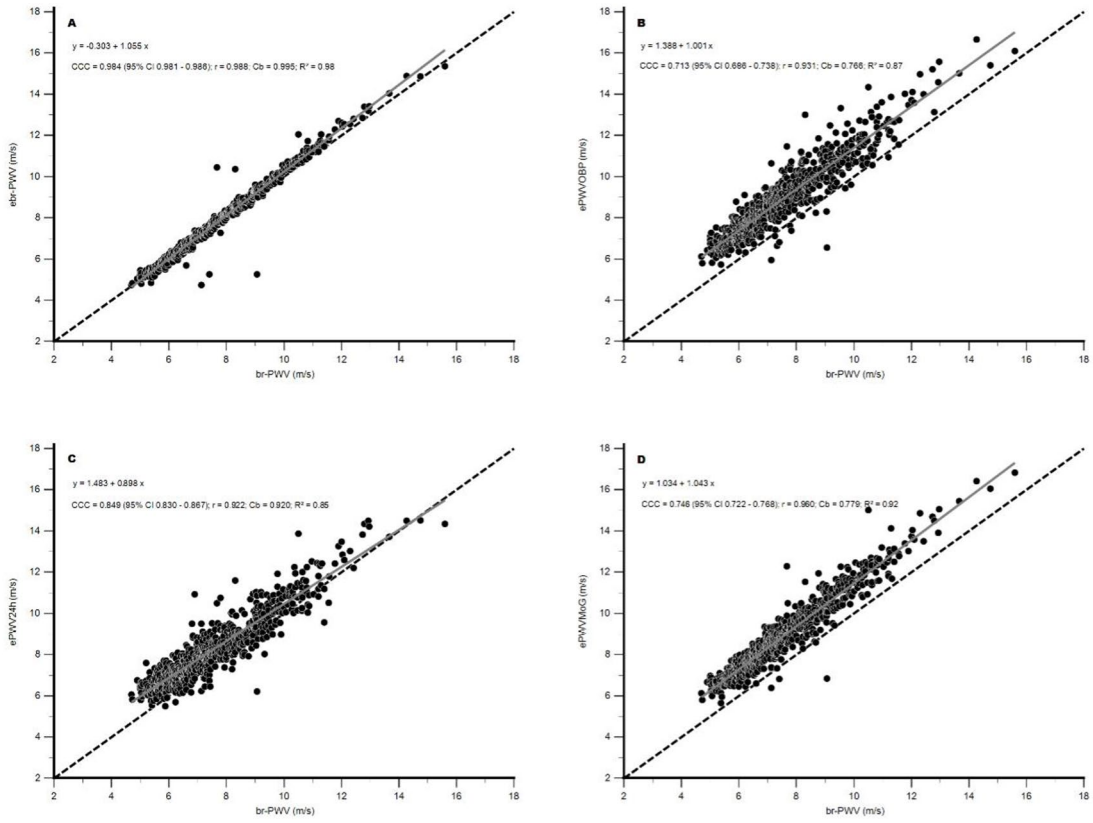



**Fig. 1**. Scatter plots showing the relationships between br-PWV and other PWV methods. Agreement was assessed using Lin's concordance correlation coefficient (CCC). Linear regression lines (solid gray) are shown, with coefficients of determination ($R^2$) indicating the proportion of variance explained. br-PWV, mean of pulse velocity measured by Mobil-o-Graph; ebr-PWV, mean estimated by equation of pulse wave velocity by Mobil-o-Graph; ePWVOBP, calculated pulse wave velocity from Eq. 1 utilizing mean OBP; ePWV24h calculated pulse wave velocity from Eq. 1 utilizing mean 24 h-BP; ePWVMoG, calculated pulse wave velocity from Eq. 1 utilizing MBP of br-BP. CCC, concordance correlation coefficient; r, Pearson correlation coefficient; $C_b$, the bias correction factor; $R^2$, the coefficient of determination represents the proportion of variance in br-PWV explained by each method

## Sensitivity analyses

To further assess whether differences among PWV methods were influenced by age and blood pressure levels, PWV metrics were analyzed across age and mean brachial blood pressure (MBPbr-BP) quartiles (Supplementary Figure S1 and Supplementary Table S1). All PWV metrics increased progressively from the lowest to the highest quartiles of age and MBPbr-BP. Across most categories, ePWV-derived metrics showed higher values than br-PWV and ebr-PWV. Importantly, the magnitude of the differences between methods remained relatively stable across quartiles, supporting the findings of the primary agreement analyses.

Supplementary table S2 presents the results of regression analysis models. Age explained a large proportion of PWV variability across all methods. The addition of systolic blood pressure further increased the explanatory power, with the fully adjusted models explaining approximately 83–96% of the variance. Overall, PWV measures were more strongly associated with age than with blood pressure, with only minor differences between methods. Differences between methods were modest. A small difference was observed between br-PWV and ePWVOBP in Model 1, whereas no significant differences were found in the fully adjusted model.

## Discussion

N this study, we evaluated the agreement between oscillometric PWV (br-PWV), its equation-derived counterpart (ebr-PWV), and equation-derived PWV (ePWV) derived from cf-PWV reference datasets. The main findings were: (1) near-perfect agreement between br-PWV and ebr-PWV; (2) only moderate agreement between br-PWV and ePWV, regardless of the blood pressure source; and (3) a strong dependence of all PWV estimates on age and BP, with differing contributions across methods.

A key observation is that the very strong agreement between br-PWV and ebr-PWV contrasts with the only moderate agreement observed between br-PWV and ePWV. Although all these methods incorporate age and BP, they are not mathematically or physiologically equivalent. Indeed, the ebr-PWV equation is derived from oscillometric PWV datasets and therefore intrinsically reproduces the same underlying signal as br-PWV. In contrast, ePWV equations were developed from cf-PWV datasets and include different weightings of age,

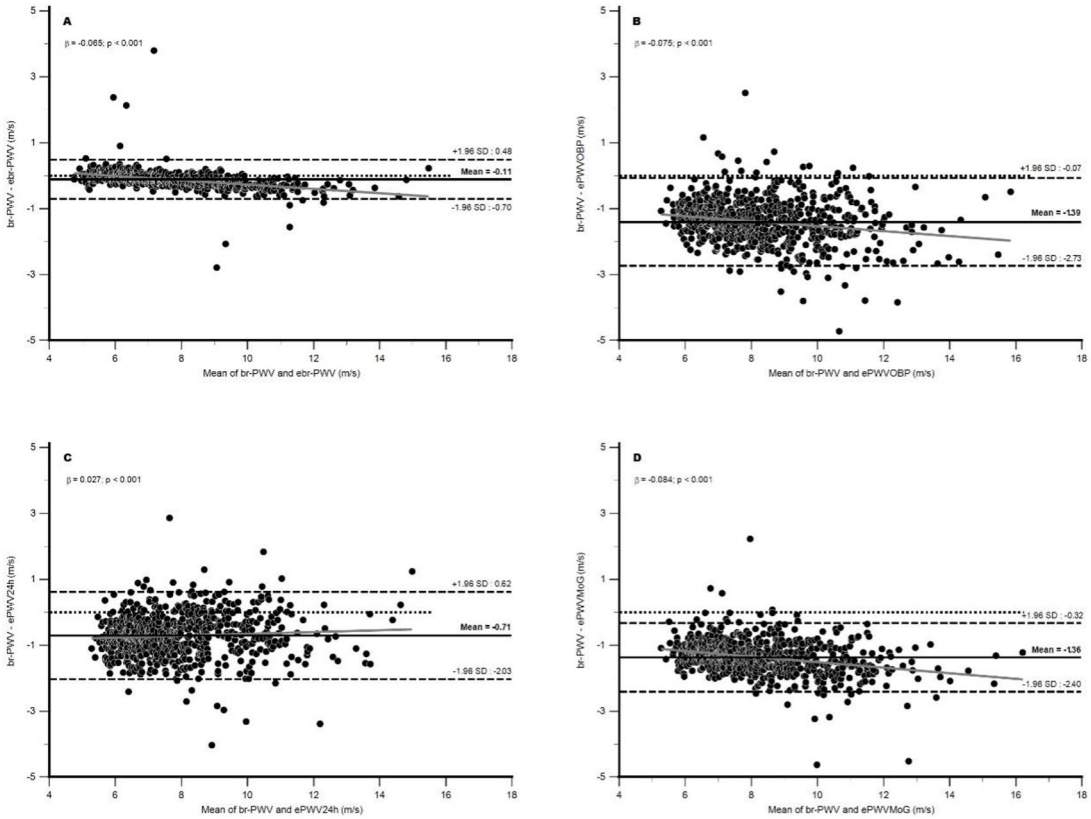



**Fig. 2**. Bland–Altman plots comparing br-PWV with other PWV methods. Bland–Altman plots showing the agreement between br-PWV and other PWV metrics (ebr-PWV, ePWVOBP, ePWV24h, and ePWVMoG). The central line represents the mean difference (bias), and the upper and lower lines indicate the limits of agreement (± 1.96 SD). Regression lines of the differences against the mean (solid gray lines) are shown to assess proportional bias across the range of PWV values. br-PWV, mean of pulse velocity measured by Mobil-o-Graph; ebr-PWV, mean estimated by equation of pulse wave velocity by Mobil-o-Graph; ePWVOBP, calculated pulse wave velocity from Eq. 1 utilizing mean OBP; ePWV24h, calculated pulse wave velocity from Eq. 1 utilizing mean 24 h-BP, ePWVMoG, calculated pulse wave velocity from Eq. 1 utilizing MBP of br-BP

BP, and interaction terms. Thus, shared predictors do not imply interchangeable estimates when equations are derived from distinct reference methods and mathematical frameworks.

The observed systematic bias further supports these differences. br-PWV systematically underestimated values compared with ePWV across all comparisons. Our finding reinforces results of previous studies showing that oscillometric PWV tends to yield lower values than cf-PWV-based estimates[9]. Also, Bland–Altman analyses demonstrated not only fixed bias but also proportional bias, indicating that disagreement increases across the range of measurements. This suggests that the divergence between methods is not uniform, but becomes more pronounced at higher PWV levels, likely reflecting increasing AS.

Another important aspect is the role of BP input. Although office BP is conventionally used to calculate ePWV, we included 24-h BP and device-derived BP to evaluate the impact of alternative variables on the agreement of PWV metrics. These variations influenced absolute values; however, they did not improve agreement with br-PWV. This supports the idea that differences between methods are not solely driven by the source of BP, but by the structure of the equations and the vascular phenotype they model as well.

From a methodological perspective, it is important to acknowledge the inherent mathematical dependency between PWV, age, and BP. Logically, part of the observed correlation reflects the effect of common variables used to calculate ePWV metrics rather than true agreement between them. This highlights the importance of using agreement analyses, such as concordance correlation coefficients and Bland–Altman plots, rather than relying exclusively on correlation metrics.

From a clinical perspective, our results have important implications. Oscillometric PWV and equation-derived PWV should not be used interchangeably in clinical practice or research. Misclassification of AS may occur, particularly in individuals with higher PWV values. Therefore, PWV measurements should always be interpreted within the context of the method used, and direct comparisons across techniques should be avoided.

Age and BP are major determinants of PWV and are incorporated into most equation-derived approaches. Consistent with this, all PWV metrics increased progressively across age and MBPbr-BP quartiles in the sensitivity analyses. Nevertheless, the differences between methods were maintained across categories, indicating that the lack of interchangeability cannot be attributed only to age or BP distributions. These findings support

the view that differences in measurement methodology and equation structure also contribute to the observed disagreement between PWV estimates.

The present findings also reinforce the need for method-specific reference values and clinically validated cut-off points. Since agreement between methods was limited, applying thresholds derived from one PWV technique to another may result in misclassification of vascular risk and treatment response.

This study has some limitations. First, different devices were used to measure office BP, ambulatory BP, and brachial BP during pulse wave analyses. However, no significant differences were observed between office BP and brachial BP values. Therefore, it is unlikely that inter-device variability influenced the results. As expected, 24-h BP values were lower than office measurements, reflecting known physiological differences rather than device-related biases. Second, the cross-sectional design limits causal inference and generalizability to broader populations. Finally, no gold standard cf-PWV measurements were available for direct comparison. However, the study also has important strengths, including a relatively large sample size, standardized measurement protocols, and the use of multiple analytical approaches to assess agreement.

Although PWV metrics share the same main determinants, this study directly compares oscillometric and equation-derived PWV using different BP inputs, including 24-h measurements. These findings highlight the limitations of PWV estimation methods and support a more cautious interpretation in clinical practice.

In conclusion, PWV estimates are strongly influenced by age and blood pressure and are not interchangeable across methods. The nearly perfect agreement between br-PWV and ebr-PWV reflects their shared derivation, whereas the lower agreement with ePWV is explained by differences in equation structure and underlying models. Age accounted for most of the variability across all PWV measures, with additional contribution from blood pressure. PWV values should therefore be interpreted according to the method used, and direct comparisons across techniques should be avoided.

## Data availability

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Received: 1 February 2026; Accepted: 25 August 2026
Published online: 07 September 2026

## References

1. World Health Organisation. *Global Report on Hypertension: The Race Against a Silent Killer* [Internet]. www.who.int. https://www.who.int/publications/i/item/9789240081062 (2023).
2. Safar, M. E. et al. French Study Group on Arterial Stiffness. Interaction between hypertension and arterial stiffness. *Hypertension* **72**, 796–805 (2018).
3. Chirinos, J. A., Segers, P., Hughes, T. & Townsend, R. Large-artery stiffness in health and disease. *J. Am. Coll. Cardiol.* **74**, 1237–1263 (2019).
4. Safar, M. E. et al. Arterial dynamics, cardiac hypertrophy, and antihypertensive treatment. *Circulation* **75**, I156–I166 (1987).
5. Townsend, R.R., Wilkinson, I.B., Schiffrin, E.L., Avolio, A.P., Chirinos, J.A., Cockcroft, J.R. et al. American Heart Association Council on Hypertension. Recommendations for improving and standardising vascular research on arterial stiffness: A scientific statement from the American Heart Association. *Hypertension* **66**, 698–722 (2015).
6. Boutouyrie, P., Chowienczyk, P., Humphrey, J. D. & Mitchell, G. F. Arterial stiffness and cardiovascular risk in hypertension. *Circ. Res.* **128**, 864–886 (2021).
7. Segers, P., Rietzschel, E. R. & Chirinos, J. A. How to measure arterial stiffness in humans. *Arterioscler. Thromb. Vasc. Biol.* **40**, 1034–1043 (2020).
8. Salvi, P. et al. Unreliable estimation of aortic pulse wave velocity provided by the Mobil-O-Graph algorithm-based system in Marfan syndrome. *J. Am. Heart Assoc.* **8**, e04028 (2019).
9. Schwartz, J. E., Feig, P. U. & Izzo, J. L. Jr. Pulse wave velocities derived from cuff ambulatory pulse wave analysis. *Hypertension* **74**, 111–116 (2019).
10. Reference Values for Arterial Stiffness Collaboration. Determinants of pulse wave velocity in healthy people and in the presence of cardiovascular risk factors: "Establishing normal and reference values". *Eur. Heart J.* **31**, 2338–2350 (2010).
11. Greve, S. V. et al. Estimated carotid-femoral pulse wave velocity has a similar predictive value as measured carotid-femoral pulse wave velocity. *J. Hypertens.* **34**, 1279–1289 (2016).
12. Ji, C. et al. Estimated pulse wave velocity and cardiovascular events in Chinese. *Int. J. Cardiol. Hypertens.* **117**, 100063 (2020).
13. Hametner, B. et al. Aortic pulse wave velocity predicts cardiovascular events and mortality in patients undergoing coronary angiography: A comparison of invasive measurements and noninvasive estimates. *Hypertension* **77**, 571–581 (2021).
14. Stamatelopoulos, K. et al. Pisa COVID-19 Research Group; Newcastle COVID-19 Research Group. Estimated pulse wave velocity improves risk stratification for all-cause mortality in patients with COVID-19. *Sci. Rep.* **11**, 20239 (2020).
15. Silva, M. A. V. et al. Correlation between short-term blood pressure variability parameters with mobil-O-graph pulse wave velocity. *Clin. Hypertens.* **28**, 5 (2022).
16. Muntner, P. et al. Measurement of blood pressure in humans: A scientific statement from the American Heart Association. *Hypertension* **73**, e35-66 (2019).
17. Mancia, G. et al. 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension Endorsed by the European Renal Association (ERA) and the International Society of Hypertension (ISH). *J. Hypertens.* **41**, 1874-207122 (2023).
18. Stergiou, G. S. et al. 2021 European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement. *J. Hypertens.* **39**, 1293–1302 (2021).
19. Van Bortel, L. M. et al. Expert consensus document on the measurement of aortic stiffness in daily practice using carotid-femoral pulse wave velocity. *J. Hypertens.* **30**, 445–448 (2012).
20. Silva, M.A. et al. Correlation between estimated pulse wave velocity values from two equations in healthy and under cardiovascular risk populations. *PLoS ONE* **19**, e0298405-5 (2024).
21. Vieira-da-Silva, M. A. et al. The correlation between age, blood pressure variability and estimated pulse wave velocity. *Sci. Rep.* **15**, 6990 (2025).

## Acknowledgements
We extend our gratitude to all those who contributed their time and effort to this study, including employees, nurses, and physicians. We would also like to thank all the individuals who generously agreed to participate in this study.

## Author contributions
MAVS: conceptualization, methodology development, formal analysis, resources provision, data curation management activities, writing - original draft preparation, writing - review & editing prep, visualization preparation, project administration management, final approval of the version to be submitted; GAP: methodology development, investigation conducting, data curation management activities, final approval of the version to be submitted, writing - original draft Preparation; LMV, GVCN, MAA, JRU, LABF, KAO, VSL, TPM, JYT and LNCM: investigation conducting, data curation management activities, final approval of the version to be submitted, writing - original draft Preparation; JFVM : conceptualization, methodology development, writing - review & editing prep, supervision oversight and leadership responsibility, final approval of the version to be submitted. All authors read and approved the final manuscript.

## Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declarations

## 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/s41598-026-68989-3.

**Correspondence** and requests for materials should be addressed to M.A.V.-d.-S.

**Reprints and permissions information** is available at www.nature.com/reprints.

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2026