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ORIGINAL ARTICLE

Correlation between short-term blood pressure variability and left-ventricular mass index: a meta-analysis

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Long-term blood pressure variability (BPV) has been associated with cardiovascular events but the prognostic significance of short-term BPV remains uncertain, including its influence on the presence of target-organ damage, specifically left-ventricular hypertrophy. A meta-analysis exploring the correlation between short-term BPV and left-ventricular mass index was performed. Studies were identified by systematic searches in Pubmed and EMBASE. Any summary measure of short-term BPV obtained from ambulatory blood pressure monitoring was included. Twelve studies were included. Average real variability (ARV), s.d., weighted s.d. and coefficient of variation across 24 h/day/night periods were identified as measures of variability. Meta-analysis showed the pooled subgroup correlation coefficients of LVMI with 24 h systolic blood pressure (SBP) s.d., day SBP s.d., weighted s.d. SBP and 24 h ARV SBP were 0.22 (95% confidence interval (CI): 0.12–0.31), 0.19 (95% CI: 0.15–0.25), 0.23 (95% CI: 0.13–0.33), 0.37 (95% CI: 0.01–0.65), respectively. This meta-analysis suggests there is a weak positive correlation, between BPV and LVMI.
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Keywords: left-ventricular mass index; short-term variability; target-organ damage; variability indices

INTRODUCTION

Hypertension is a well-established risk factor for cardiovascular disease.[1,2] To date guidelines on the management of hypertension have focused on reducing mean blood pressure (BP), which is clearly important, but do not mention BP variability (BPV),[3] for which there is increasing evidence of prognostic value. Evidence from meta-analyses suggest that although different anti-hypertensive-drug classes have similar effects in terms of reducing BP levels, pronounced differences in their ability to reduce BPV are observed.[4,5] These differences in addition are accounted for effects on stroke risk independent of mean BP. Studies have also shown that systolic BP (SBP) variation from one visit to the next may be associated with a poor cardiovascular prognosis. In treated hypertensive patients enrolled in ASCOT-BPLA (Anglo-Scandinavian Cardiac Outcomes Trial–Blood Pressure Lowering Arm), higher visit-to-visit variability in SBP was associated with stroke and coronary events independent of mean BP.[6] In a population-based observational study, higher visit-to-visit variability in SBP was associated with increased mortality risk over a 14-year follow-up.[7] Importantly visit-to-visit BPV predicted all-cause mortality among those with normal BP, suggesting it may be a prognostic marker before hypertension develops.

Short-term BPV refers to fluctuations of BP across minutes or hours usually taken over a 24-h period and can be obtained through the use of ambulatory BP monitoring (ABPM).[8] The predictive value of short-term BPV is less well established than that of visit-to-visit variability. Hansen *et al.*[9] using a large population cohort (8938 subjects) explored the relationship between BPV recorded at base line with cardiovascular events over a median period of 11.3 years and determined that although short-term reading-to-reading BPV was an independent predictor, it did not contribute significantly to risk stratification over and beyond 24-h BP. Evidence from the ASCOT-BPLA trial which included both long and short-term variability suggests that although not as strong a predictor as visit-to-visit BPV, short-term BPV measured by the coefficient of variation still predicted risk of vascular events independently of average daytime mean SBP.[6]

The occurrence of major cardiovascular events is usually the result of long-term exposure to hypertension and other risk factors and is often preceded by the development of asymptomatic functional and structural abnormalities known as target-organ damage (TOD).[10] Little is known about the influence of short-term BPV on the presence of TOD, specifically left-ventricular hypertrophy (LVH). LVH can be determined by ECG or quantified more accurately by measuring left-ventricular mass by echocardiography and indexing this to body surface area to give the left-ventricular mass index (LVMI).[11] In their seminal paper, Parati *et al.*[12] demonstrated that higher diurnal BPV measured as 24 h s.d. was associated with an increased risk of LVH (determined by ECG) in 108 mild-to-severe essentially hypertensive patients. They also showed that for nearly any level of 24 h mean BP,

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subjects in whom the 24 h BPV was low had a lower prevalence and severity of TOD those in whom BPV was high, indicating an independent association. However as highlighted evidence since suggests the predictive value of short-term BPV remains unclear and may not contribute much more than mean levels alone.[9] To advance our knowledge of short-term variability, this review attempts to assess and quantify the correlation between BPV and LVMI. A meta-analysis on the various correlation coefficients will be performed.

METHODS

Types of studies

Cohort, cross-sectional or case–control studies that explored the relationship between 24-h BPV and LVMI.

Study populations

Participants recruited to observational studies that underwent 24-h non-invasive ABPM and an assessment of LVMI. Studies of pregnant women and children were excluded.

Predictor variables

Any summary measure of short-term BPV, where short-term refers to variations across minutes or hours taken over a 24-h period obtained by non-invasive ABPM.

Outcomes

LVMI determined with echocardiography.

Search methods for identification of studies

Studies were identified by systematic searches in Pubmed and EMBASE (up to June 2015). The following search terms were used as keywords and/or MESH terms: (('ambulatory blood pressure' or 'blood pressure' or 'ambulatory blood pressure monitoring') or (short-term blood pressure) or (24 h blood pressure)) and (variability) and ('left ventricular hypertrophy' or 'left ventricular mass index') or ('end' or 'target' organ ('damage' or 'disease')). The full search strategy can be seen in the Supplementary Information, Appendix which includes different spellings and combinations of words.

Potentially relevant articles were identified and duplicates were removed. Only original research articles were included. We supplemented our electronic search by crosschecking the reference lists of all identified studies. There were no date or language restrictions. Non-English papers were translated with an online translation programme. The full texts of relevant articles were obtained and an independent reviewer reviewed selected papers against the inclusion criteria and assessed their quality using the guidelines recommended by Hayden *et al.*[13] for quality appraisal in systematic reviews of prognostic studies. Our systematic review and meta-analysis was conducted according to the checklist of Meta-analysis of Observational Studies in Epidemiology (MOOSE), and the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines (PRISMA), see Supplementary Information, Appendix.

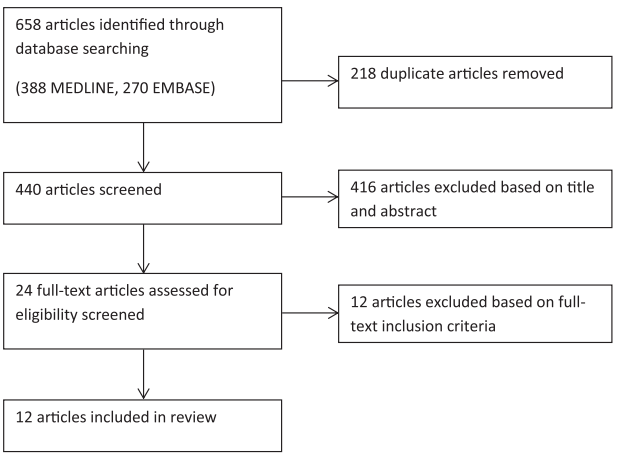

Figure 1 Flow diagram of study selection

Data extraction

The study characteristics extracted included sampling approach, study design, sample size, mean age, BPV index and value, mean LVMI, correlation coefficients and relative information, such as *P*-values and if it was indicated that they were statistically significant or not. The data was extracted independently by two researchers (JMM and AMOF).

Statistical analysis

For the meta-analysis, correlation coefficients were converted into Fisher's *z*-scores and s.e.m., which in turn were used to calculate 95% confidence intervals. The overall effect size was the weighted inverse variance of the adjusted individual effect sizes (*z*-scores). The overall effect sizes from the meta-analyses were then back transformed which corresponded to the overall correlation coefficients. Data from the various studies were pooled using the random-effects model. Heterogeneity between studies was assessed using the I^2 statistic. The Begg's test and Egger's test were used to assess the extent of publication bias. All analysis was performed using Stata software.[14]

RESULTS

Basic characteristics of studies

After removal of 218 duplicates, a total of 440 articles were identified during the search, of which 416 were excluded based on their titles and abstracts alone; Figure 1. After reviewing the remaining 24 full-text articles, 12 were eligible for inclusion in the review; Table 1. Reasons for exclusion included articles did not calculate LVMI as an outcome, summary measures of variability were not calculated and no effect size was reported. Out of the 12 studies, 11 were cross-sectional and one had a case–control design. The population sample sizes ranged from 33 to 1822. The various indexes used in the studies along with their definitions are presented in Table 2. The s.d. of either 24 h/day/night BP readings were used as indexes of BPV in all studies with the exception of two: one which only reported coefficient of variation (CV);[15] and another study[16] only reported average real variability (ARV). In addition to s.d., two studies also included CV[17,18] and a further two included weighted s.d. (wSD).[19,20] Leoncini *et al.* [20] also explored ARV. The average value of 24 SBP s.d., day s.d., night s.d. had range 13.0–19.7, 10.9–19 and 11.5–13.6 mm Hg, respectively. As there were so few studies exploring the other indices, we have not reported their range here but can be found in Table 3. The correlation between 24 SBP s.d., day s.d., night s.d. and LVMI had range 0.05–0.52, 0.13–0.21 and 0.04–0.21, respectively. These correlations were all statistically significant with the exception of day s.d. ($r = 0.19$),[21] 24 h SBP s.d. ($r = 0.05$) and night s.d. ($r = 0.04$).[19] In the three studies in which it was explored, wSD had a significant correlation of $r =$ 0.15, 0.26 and 0.31.[19,20,22] Similarly in the two studies which examined 24-h SBP ARV, a significant correlation of 0.53 and 0.19 with LVMI was observed.[16,20]

Of the studies that adjusted for covariates (including mean BP), findings were mixed. Schillaci *et al.*[23] who considered 1822 untreated subjects with essential hypertension, reported a weak univarite correlation between daytime-and night-time s.d. and LVMI but the association did not persist after adjustment for various confounders. Similar findings were found by Roman *et al.*[18] who found daytime- and night-time s.d. were univariately associated with LVMI but the association did not persist after adjustment for confounders including average BP. Pascual *et al.*[24] also found similar results after adjustment for age, sex and mean BP.

Table 1 Study characteristics

Study	Population	Sampling approach	Design	n (women, %)	Mean age (s.d. or range), year	BPV index	Outcome measure
Colivicchi *et al.*[33]	Elderly untreated HTN males with matched normotensives	Convenience	Case–control	50 (0%)	74 (4)	24 h, day, night—s.d.	LVMI
Veerman *et al.*[21]	Referred to hypertension clinic because of suspected hypertension	Convenience	Cross-sectional	33 (48%)	41 (26–59)	Day—s.d.	LVMI
Schillaci *et al.*[23]	Hospital-based untreated HTN	Convenience	Cross-sectional	1822 (47%)	50 (12)	24 h, day, night—s.d.	LVMI
Pascual *et al.*[24]	Untreated HTN	Convenience	Cross-sectional	149 (33%)	38 (7)	24 h, day, night—s.d., CV	LVMI
Kristensen *et al.*[17]	Untreated HTN from general practice and subjects drawn at random from Danish national register	Convenience & random	Cross-sectional	566 (52%)	48 (20–79)	24 h, day, night—s.d.,CV	LVMI
Roman *et al.*[18]	Subjects from a worksite-based study and who were evaluated at a hospital	NR	Cross-sectional	511 (44%)	50 (12)	Day, night—s.d.,CV	LVMI
Polónia *et al.*[34]	Population sample	NR	Cross-sectional	743 (56%) 185 (LVMI measured)	52 (14)	Day—s.d.	LVMI
Tatasciore *et al.*[22]	Outpatients referred to clinic by GP	Convenience	Cross-sectional	180 (40%)	53 (8)	24 h, day, night—s.d. wSD	LVMI
Bilo *et al.*[19]	Two hypertension centres	NR	Cross-sectional	3863 (54%) 339 (50%) (Echo taken)	54 (12)	24 h, Day, night—s.d., wSD	LVMI
Zhang *et al.*[16]	Elderly hospitalised HTN and normotensive controls	Convenience	Cross-sectional	197 (35%)	76.5 (7.8)	24 h, day, night—ARV	LVMI
Ajayi *et al.*[15]	Nigerian HTN	Convenience	Cross-sectional	130 (26%)	54 (12) (31–85)	24 h—CV	LVMI
Leoncini *et al.*[20]	Untreated HTN attending outpatient clinic	Convenience	Cross-sectional	169 (33%)	47 (10)	24 h, day, night—s.d. ARV, wSD	LVMI

Abbreviations: ARV, average real variability; CV, coefficient of variation; GP, general practitioner; HTN, hypertensives; LVH, left-ventricular hypertrophy; LVMI, left-ventricular hypertrophy index; NR, not reported; TOD, target-organ damage; wSD, weighted s.d.

Table 2 BPV definitions

Measure of BPV	Description
24 h s.d.	s.d. over 24 h period
Day s.d.	s.d. over day period usually 0900–2100 h
Night s.d.	s.d. over night period usually 0100–0600 h
wSD	wSD which is the mean of day and night s.d. values corrected for the number of hours included in each of the two sub-periods which attempts to eliminate the effect of nocturnal fall. wSD = ((day s.d. × day hours) + (night s.d. × night hours))/total number of hours
CV	Coefficient of variation = (s.d. over 24 h/mean 24 h) × 100
ARV	Average real variability which averages the absolute differences between successive readings which is the average absolute difference between successive readings. $ARV = \frac{1}{N-1}\sum_{k=1}^{N-1}\lvert BP_{k+1} - BP_k\rvert$, where k ranges from 1 to $N-1$ and N is the number of BP measurements

Abbreviations: ARV, average real variability; BP, blood pressure; BPV, blood pressure variability; CV, coefficient of variation; wSD, weighted s.d.

In contrast, Tatasciore *et al.*[22] in a study examining 180 untreated hypertensive patients, found daytime s.d. and wSD to be significantly associated with LVMI even after adjustment for other covariates, including mean BP. Similarly Bilo *et al.*[19] found wSD was significantly related to LVMI in a study which investigated 339 hypertensive patients. Zhang *et al.*[16] also found 24 h ARV to be significantly related to LVMI after adjustment.

Using the guidelines recommended by Hayden *et al.*,[13] the quality appraisal of each paper was assessed and is presented in Table 4.

Meta-analysis

Figure 2 presents converted correlation coefficients (*z*-scores) with subgroup meta-analysis reported for each BPV index. An overall *z*-score for all studies was omitted as combining different indexes would not be appropriate. After conversion from *z*-scores the pooled subgroup correlation coefficients of LVMI with 24 h SBP s.d., day SBP s.d., wSD SBP and 24 h ARV SBP were 0.22 (95% CI: 0.12–0.31), 0.19 (95% CI: 0.15–0.25), 0.23 (95% CI: 0.13–0.33) and 0.37 (95% CI: 0.01–0.65), respectively. All but one index (wSD) showed heterogeneity ($P<0.05$) across the studies and as a result random-effects models were used to combine coefficients. Begg's and Egger's tests indicated no evidence of publication bias within each variability index.

DISCUSSION

Overall our review suggests that there is a weak positive correlation, between BPV and LVMI. We carried out a separate analysis for each measure of variability, resulting in reduced power in the meta-analysis. Our review highlights the lack of good epidemiological studies exploring the relationship between BPV and LVMI. As 11 out of the 12 studies were cross-sectional, we cannot assess cause–effect relationships. Although all studies reported univariate coefficients,

Table 3 Extracted results

Study	*SBP variability* s.d.	*Mean LVMI* (s.d.) $g\,m^{-2}$	*Multivariate analysis adjusted for*	*Method of adjustment for mean BP*	*Correlation Coefficient (r)*	*Beta coefficients (multivariate analysis) β (s.e.m.)*
Colivicchi *et al.*[33]	16.2 (3.5) 24 h s.d. 19 (5.4) day s.d. 12 (2.9) night s.d.	134.9 (27.5) (LVH = 16%)	—	—	$r = 0.52$† 24 h s.d. (HTN only) r = NS day and night s.d.	—
Veerman *et al.*[21]	12.7 (7.5-22) day s.d.	115 (67-153) (LVH = 13%)	Day BP	Regression	$r = 0.19$ day SBP s.d. r = 0.35* day DBP s.d.	3.16 (1.18)* Day DBP s.d.
Schillaci *et al.*[23]	NR	NR	Age, body height, 24 h BP, DBP, BMI, duration of hypertension, alcohol, smoking	Subjects divided into similar levels of BP, then subdivided if below or above median BPV & separately a regression analysis	($r = 0.13$, $P < 0.01$) day SBP s.d. ($r = 0.1$, $P < 0.01$) night SBP s.d. r = NS day and night DBP s.d.	NS
Pascual *et al.*[24]	14.0 (3.4) 24 h s.d. 10.3 (2.4) 24 h CV 10.9 (2.8) day s.d. 13.8 (3.3) day CV 11.7 (3.5) night s.d. 11.7 (3.7) night CV	126 (34.6)	Age, sex, BP	Regression	$r = 0.23$† (24 h and day SBP s.d.) r = NS (24 h, day, night DBP s.d. and CV; 24 h, day, night SBP CV and night SBP s.d.)	0.87 (0.83) 24 h SBP s.d.
Kristensen *et al.*[17]	NR	102.7 (28.3)	—	—	$r = 0.24$ (p < 0.01)	NR
Roman *et al.*[18]	NR	NR	Age, age^2, sex, basal SBP or DBP, serum cholesterol, smoking, anti-hypertensive medication	Regression	$r = 0.29$‡both day & night SBP s.d. $r = 0.19$‡ DBP s.d. day $r = 0.26$‡ DBP s.d. night $r = 0.08$ SBP CV day $r = 0.022$ SBP CV night $r = 0.00$ DBP CV day $r = 0.06$ DBP CV night	NS
Polónia *et al.*[34]	13.2 (3.4) day SBP s.d. 14.3 (3.4) 24 h SBP s.d. 11.5 (3.8) night SBP s.d.	100 (40)	—	—	$r = 0.162$* day SBP s.d.	—
Tatasciore *et al.*[22]	13.0 (4.1) 24 h SBP 10.9 (4.0) 24 h DBP	96.7 (17.8)	Age, sex, alcohol, triglycerides, SBP, DBP, SBP load, DBP load	Regression	$r = 0.312$‡ 24 h SBP s.d. r = NS—24 h DBP $r = 0.310$‡ wSD SBP r = NS wSD DBP	0.633 ($P = 0.028$) 24 h SBP
Bilo *et al.*[19]	NR for echocardiographic group	109.5 (33.8)	24 h BP, sex	Regression	$r = 0.05$ 24 h SBP s.d. $r = 0.15$† 24 h wSD $r = 0.16$† day SBP s.d. $r = 0.04$ night SBP s.d.	0.15 ($P < 0.01$) 24 h wSD SBP 0.16 ($P < 0.01$) day SBP s.d. 0.04 (p = NS) 24 h s.d.
Zhang *et al.*[16]	11.9 (2.6) 24 ARV SBP 8.6 (2.6) 24 ARV DBP 9.3 (2.3) day ARV SBP 8.2 (2.1) day ARV DBP 9.2 (3.3) night ARV SBP 7.8 (2.1) night ARV DBP	145.1 (43.2)	Age, duration of HTN, total cholesterol, low-density lipoprotein cholesterol, 24 h BP	Regression	$r = 0.525$† 24 h ARV SBP r = NS NR 24 h ARV DBP	0.593† 24 h ARV SBP
Ajayi *et al.*[15]	NR	109.65 (38.1)	—	—	$r = 0.379$* 24 h CV SBP $r = 0.124$ 24 h CV DBP	—
Leoncini *et al.*[20]	19.7 (5.9) 24 h s.d. 18.5 (6.3) day s.d. 13.6 (5.5) night 16.8 (5.3) 24 h wSD 15.1 (4.8) 24 h ARV 15.9 (5.7) day ARV 13.0 (5.3) night ARV 15.1 (5.0) wARV (All SBP, DBP not displayed)	46 (11) (LVM g $m^{-2.7}$)	Office BP, age, BMI, sex, smoking, triglycerides, cholesterol, glucose, duration of HTN, AASI	Logistic regression	$r = 0.24$† 24 h s.d. $r = 0.19$* 24 h ARV $r = 0.26$‡ 24 h wSD $r = 0.21$† day s.d. $r = 0.21$† night s.d. $r = 0.19$* day ARV $r = 0.14$ night ARV all for LVMI indexed for BSA	Odds ratio reported but for overall TOD presence (2 or more) 1.103 (1.003–1.212)† 24 h s.d. 1.114 (1.012–1.227)† day s.d. 1.140 (1.004–1.295)† 24 h ARV

Abbreviations: AASI, arterial stiffness index based; ARV, average real variability; BP, blood pressure; BSA, bovine serum albumin; CV, coefficient of variation; DBP, diastolic BP; HTN, hypertensives; LVH, left-ventricular hypertrophy; LVMI, left-ventricular hypertrophy index; SBP, systolic BP; TOD, target-organ damage; NR, not reported; NS: non-significant; SBP, systolic blood pressure; wSD, weighted s.d.
*$P < 0.05$; † $P < 0.01$; ‡$P < 0.001$.

Table 4 Quality assessment

Study	*Study participation*	*Study attrition*	*Prognostic factor measurement /outcome measurement*	*Confounding measurement and account*	*Analysis*
Colivicchi *et al.*[33]	No	No	Yes	No	No
Veerman *et al.* [21]	Partly	No	Partly	No	No
Schillaci *et al.*[23]	Yes	Partly	Yes	Yes	Yes
Pascual *et al.*[24]	Partly	Partly	Partly	Partly	Partly
Kristensen *et al.*[17]	Partly	No	Yes	No	No
Roman *et al.*[18]	Partly	No	Partly	Partly	Yes
Polónia *et al.*[34]	Partly	No	Partly	No	No
Tatasciore *et al.*[22]	Yes	Yes	Yes	Yes	Yes
Bilo *et al.*[19]	Partly	Partly	Partly	Partly	Partly
Zhang *et al.*[16]	Partly	No	Yes	Yes	Partly
Ajayi *et al.*[15]	Partly	No	Yes	No	Yes
Leoncini *et al.*[20]	Partly	Yes	Yes	Partly	Partly

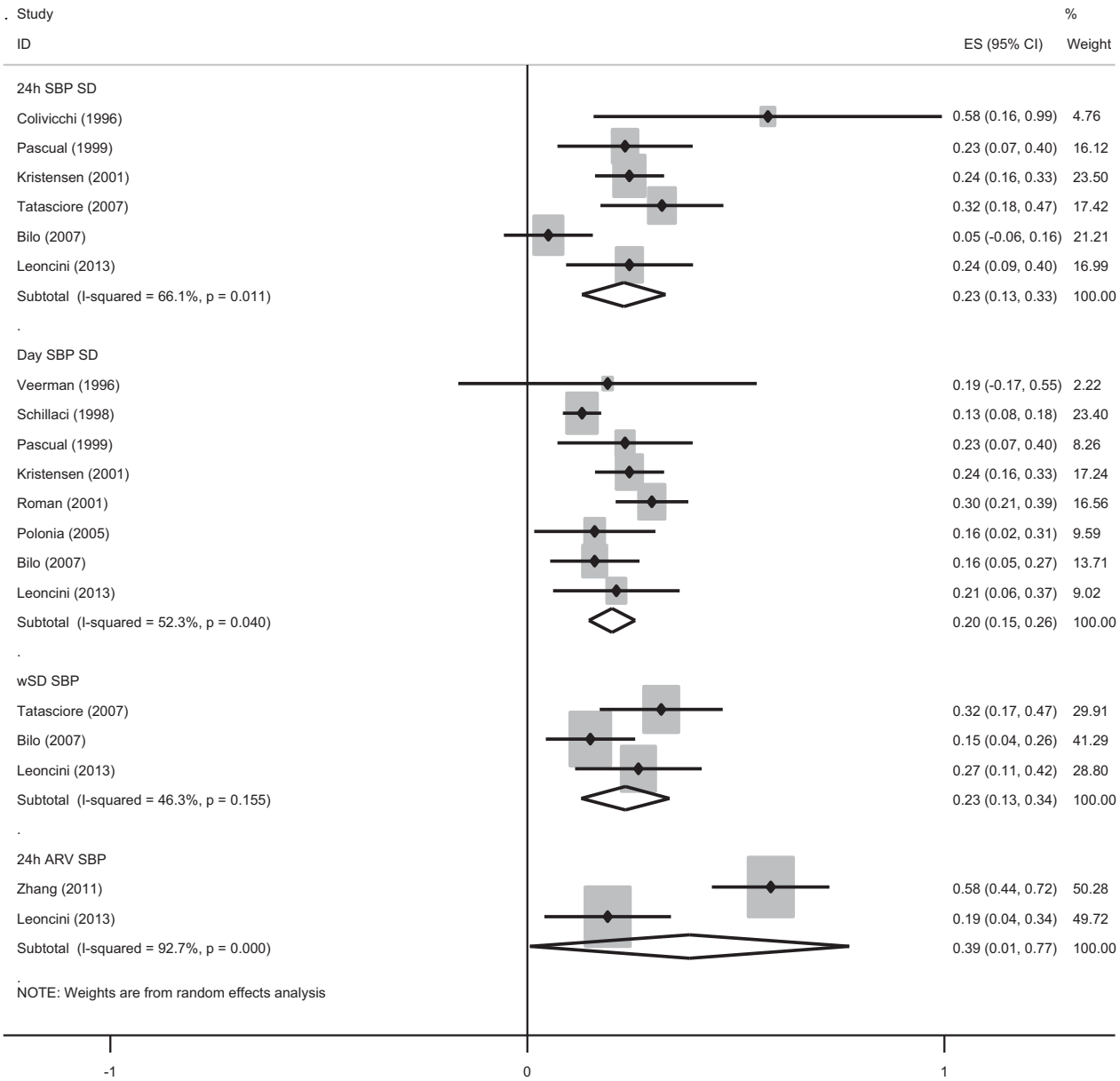

Figure 2 Pooled meta-analysis of *z*-scores by BPV index. A full color version of this figure is available at the *Hypertension Research* journal online.

we found just over half of the studies did any further analysis or appropriate adjustment for covariates. Despite these limitations, the results are still worth exploring and the review raised some important issues in relation to BPV in general and also specifically to LVMI.

Veerman *et al.*[21] reported a non-significant correlation with day s.d. We cited the small sample size ($n=33$) as a potential reason for the discrepancy between day s.d. compared with the other studies. Bilo *et al.*[19] also reported a non-significant correlation of LVMI with 24 h s.d., but interestingly in the same study found both day s.d. and wSD were significantly correlated with LVMI even after adjustment. This finding highlights that results are sensitive to the index chosen and leads to the issue of variability measurement.

Most studies have used s.d. as a measure of BPV and the appropriateness of such an index has been disputed because it only reflects the dispersion of measurements around a single value (mean) not accounting for the order, in which BP measurements were obtained.[25,26] The discrepancies between day and 24 h s.d. in the study by Bilo *et al.*[19] may be explained by the fall of BP at night (dip). A large dip which is known to be associated with healthier individuals will lead to a larger 24 h s.d. The wSD attempts to remove the effect of the dip and was found to be significantly correlated unlike the 24 h s.d. This suggests that perhaps s.d., at least over 24 h may not be a good measure of BPV. Mena *et al.*[25] first explored, and later Pierdomenico *et al.*,[26] ARV in relation to BP which is the average absolute difference between successive readings, and is thought to give a true reflection of real variability. In both studies high ARV was found to be an independent predictor of cardiovascular risk in hypertension patients while high s.d. was not. The two studies that included ARV in this review both found a significant correlation with LVMI.[16,20] In one study association remained significant after adjustment,[16] while the other study found it to be an independent predictor of multiple TOD where the majority of these had LVH.[20] As ARV is thought to give a true reflection of real variability it may be the most appropriate marker of short-term BPV over other indexes and could potentially be used to predict outcome in patients even before BP becomes elevated and ultimately provide a means of identifying at risk patients before they develop hypertension.

Other studies exploring the relationship between BPV and TOD have found varied results. As mentioned, Parati *et al.*[12] found an association between 24 h BPV and severity of TOD (a score based on presence of LVH, chest X-ray abnormalities, abnormalities of the fundus plus a clinical event and/or a renal abnormality). The same group conducted another follow-up study with a follow-up period of 7 years to assess the prognostic relevance of short-term BPV on 73 hypertensive patients.[27] They found an independent association between 24 h BPV at baseline and TOD at follow-up. Similarly, in another study of over 700 hypertensive and normotensive patients, daytime systolic s.d. was found to be associated with degree of TOD. However in the same study, after adjustment for mean BP no strong association was found between BPV and LVH.[28] Hansen *et al.*[9] explored the relationship between BPV and cardiovascular events. ARV predicted all fatal and nonfatal outcomes even after adjustment for mean BP but found that it added only 0.1% to the explained risk of an event occuring. They concluded that the main risk factor remained mean BP.

As the studies are cross-sectional in nature we are not able to determine whether higher BPV initiates increases in LVMI or do increases in LVMI represent a risk factor for increased BPV rather than being a consequence of it. It is however argued that vascular hypertrophy induced by exaggerated and large BPV may lead to an impaired arterial distensibility of the large arteries, resulting in increased cardiac afterload and as a result increases LVMI.[29] Clinical trials have recently shown that some classes of anti-hypertensive drugs significantly outperform others in terms of lowing BPV, and that this reduction in short-term and long-term BPV contributes to the prevention of cardiovascular events in hypertensive patients.[6,30] Results indicate that calcium channel blockers and to a lesser extent thiazide diuretics are superior to other drugs in reducing BPV and preventing stroke and other vascular events compared with the older β-blocker atenolol which increases BPV.[4,31] Similar findings were reported in a more recent observational study assessing the efficacy of mono and combination therapy on short-term BPV of 2780 hypertensive patients.[32] Again calcium channel blockers, followed by diuretics were correlated with lower short-term BPV compared with angiotensin-2-receptor blockers, angiotensin converting enzyme inhibitors and β blockers. In addition, combination of calcium channel blockers's and diuretics resulted in the lowest BPV compared with others. In those with marked BPV, the prescribing of these drugs may offer a better alternative and could help reduce the risk of LVH especially in individuals where hypertension has not yet developed.

The major limitation of this review is that we have pooled together studies in a meta-analysis in regard to their correlation coefficients which are a very weak marker of association. As a result of using correlation coefficients there is an implicit assumption that the association between BPV and LVMI is linear which in reality may not be the case. The strength of this review is its focus on short-term BPV, which has recently been receiving growing attention. It is also the first review to our knowledge that quantifies the correlation between BPV and LVMI. The review identifies a research gap where stronger epidemiological studies are needed to explore the relationship further and understand the prognostic value, if any, of short-term BPV.

CONFLICT OF INTEREST

JMM is currently receiving funding from the Health Research Board Ireland: PhD Scholars programme. AMOF is currently receiving funding from a Health Research Board Ireland research training fellowship for healthcare professionals and has received the John Feely research bursary from the Irish Heart Foundation to support this work. She has also received payment unrelated to the submitted work through her institution for the development of the European Society of Cardiology e-learning platform. APF has no conflicts of interest to declare. PMK has received grants from the Health Research Board Ireland and the European Union FP7 for activities outside of the submitted work.

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Supplementary Information accompanies the paper on Hypertension Research website (http://www.nature.com/hr)