







Review Article

Cardiovascular adaptation to whole-body vibration exercise in obese young adults: A systematic review, meta-analysis, and exploratory analysis of sex differences

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ABSTRACT

Background: Obesity is strongly associated with hypertension and autonomic dysfunction. Whole-body vibration exercise (WBVE) has been proposed as a low-impact intervention for improving cardiovascular function in obese adults, but sex-specific responses remain unclear. Objective: This study aimed to evaluate the effects of whole-body vibration exercise on blood pressure, autonomic function, and cardiac output in adults with obesity, and to explore potential sex differences in cardiovascular adaptations. Methods: We conducted a systematic review and meta-analysis of randomized controlled trials and quasi-experimental studies examining the effects of WBV on systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate variability (HRV), and cardiac output (CO) in adults with obesity. Electronic searches were conducted in PubMed, Scopus, Web of Science, Cochrane CENTRAL, Embase, CINAHL, and PEDro through June 2025 and updated on October 19, 2025. Two reviewers independently screened studies, extracted data, and assessed risk of bias. Blood pressure outcomes were measured with study-reported clinical devices, while HRV outcomes were obtained from ECG-based or validated HRV monitoring systems where reported. A random-effects meta-analysis was conducted; standardized mean differences (SMDs) with 95% confidence intervals (CIs) are reported. Heterogeneity was quantified using I^2 . Result: Ten studies ($n = 1,106$ participants) met inclusion criteria. Pooled analysis indicated a moderate reduction in SBP following WBVE (SMD = -0.42 ; 95% CI, -0.65 to -0.19 ; $I^2 = 45\%$). DBP showed a small-to-moderate reduction. Improvements in HRV, including greater HF power and reduced LF/HF ratio, were reported across five studies, suggesting increased parasympathetic modulation. Only two studies measured CO, finding transient acute increases. Female-only studies reported more consistent improvements than mixed-sex cohorts, but male-only data were sparse, preventing firm conclusions. Conclusion: Whole-body vibration exercise may modestly improve blood pressure and autonomic function in adults with obesity, although evidence regarding sex differences remains limited and inconclusive.

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Introduction

Obesity is no longer confined to middle-aged and older populations; its prevalence is rising at an alarming rate among young adults, reshaping the epidemiological landscape of cardiometabolic disease (Silva et al., 2024). Recent global estimates from the World Health Organization indicate sustained increases in overweight and obesity across individuals aged 18–39 years, with particularly

rapid growth in low- and middle-income countries (World Health Organization, 2023). Large-scale epidemiological analyses further demonstrate that the global prevalence of obesity has nearly tripled since 1975, with substantial increases observed among young adults in both high-income and transitioning economies (Afshin et al., 2017).

This trend is clinically concerning because early-onset obesity is strongly associated with accelerated vascular aging, heightened sympathetic activity, endothelial dysfunction, insulin resistance, and elevated blood pressure, pathophysiological disturbances that may begin silently in the third decade of life (Hall et al., 2019; Kachur et al., 2017). Emerging evidence shows that young adults with obesity are more likely to exhibit prehypertension, reduced heart rate variability, increased arterial stiffness, and adverse lipid profiles compared with their normal-weight peers, substantially elevating lifetime cardiovascular risk (Lloyd-Jones et al., 2017). Unlike later-life obesity, excess adiposity during early adulthood is associated with prolonged cumulative exposure to metabolic and hemodynamic stressors, thereby amplifying the risk of premature cardiovascular morbidity and mortality (Twig et al., 2016). Consequently, the rising burden of obesity among young adults represents not merely a demographic shift but a critical window for early intervention aimed at preventing progression from subclinical autonomic and vascular dysfunction to overt cardiovascular disease (Okuneye et al., 2026).

In Nigeria, population-based surveys report increasing prevalence of central obesity and hypertension among young adults, with higher rates observed in metropolitan areas where sedentary occupations and processed food consumption are more common (Adeloye et al., 2021). This epidemiological shift is accompanied by early manifestations of cardiometabolic risk, including elevated blood pressure, impaired glucose tolerance, dyslipidemia, and reduced heart rate variability, even among individuals under 40 years of age (Ogah et al., 2018).

Traditional aerobic and resistance exercise programs are effective in improving cardiovascular health (Andriana et al., 2025). However, adherence among individuals with obesity may be limited by joint discomfort, reduced mobility, and exercise intolerance. Whole-body vibration exercise (WBV) is an emerging low-impact alternative that generates neuromuscular activation through mechanical oscillations transmitted via a vibrating platform. These oscillations stimulate muscle spindles, evoke tonic vibration reflexes, and induce rhythmic muscle contractions that enhance venous return and transiently increase cardiac output (Cardinale & Bosco, 2018). Acute WBV exposure has been associated with reductions in peripheral vascular resistance and modest decreases in blood pressure, potentially mediated by enhanced endothelial shear stress and nitric oxide bioavailability (Figuerola et al., 2019; Lai et al., 2020; Taiwo et al., 2025). Repeated WBV training has also been shown to improve autonomic modulation, reflected by increases in parasympathetic HRV indices and reductions in sympathovagal imbalance (Liccardi et al., 2018).

Importantly, cardiovascular adaptation to exercise is not biologically uniform across sexes. Men and women differ in autonomic regulation, vascular structure, endothelial responsiveness, and fat distribution, and these factors directly influence hemodynamic control. Premenopausal women generally exhibit higher resting parasympathetic tone and greater endothelial nitric oxide production than men; this is partly attributed to estrogenic modulation of vascular smooth muscle and endothelial function (Stanhewicz et al., 2018). Conversely, men typically demonstrate higher sympathetic vasoconstrictor activity and greater central (visceral) adiposity, both of which are associated with elevated arterial stiffness and reduced baroreflex sensitivity (Joyner et al., 2016; Kachur et al., 2017).

These physiological differences suggest that responses to vibration-induced mechanical stimuli may be sex-dependent. WBV increases muscle pump activity and endothelial shear stress, both of which are influenced by baseline vascular compliance and autonomic tone. Enhanced endothelial sensitivity in women could potentiate vasodilatory responses to WBV, whereas higher sympathetic drive and visceral adiposity in men may attenuate shifts toward parasympathetic dominance. Moreover, sex-

specific adiposity patterns further modulate cardiovascular risk: visceral fat accumulation, which is more prevalent in men, is strongly associated with sympathetic overactivity, systemic inflammation, and impaired vascular compliance, whereas subcutaneous fat distribution, more common in women, is comparatively less deleterious for hemodynamic regulation (Karastergiou et al., 2016; Kachur et al., 2017).

Despite this strong mechanistic rationale, existing evidence remains fragmented. Most WBV trials have small samples, include predominantly female participants, or fail to report sex-stratified outcomes, making it difficult to determine whether cardiovascular benefits are similar in men and women. To date, no comprehensive synthesis has clearly examined whether sex composition moderates WBV-related changes in blood pressure, heart rate variability, or cardiac output in obese young adults. This gap limits the ability to make evidence-based, sex-sensitive exercise recommendations.

Clarifying potential sex-specific cardiovascular adaptations to WBV is clinically important, given the influence of sex hormones, body fat distribution, and sympathetic regulation on cardiovascular physiology. Precision exercise prescription increasingly emphasizes tailoring interventions based on biological and physiological characteristics. Therefore, this meta-analysis aims to evaluate sex-based differences in the effects of WBV exercise on systolic and diastolic blood pressure, heart rate variability, and cardiac output in obese young adults. By synthesizing findings from randomized controlled and quasi-experimental trials, this review seeks to determine whether WBV exerts differential cardiovascular and autonomic effects in males compared to females. The findings will have implications for sex-specific exercise prescription and the use of WBV as a targeted intervention for cardiovascular risk reduction in young adults with obesity.

Method

Protocol and Registration

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency and rigor. The protocol for this systematic review and meta-analysis was developed a priori and registered on the PROSPERO platform with registration number [CRD420251089928](#). The protocol specified eligibility criteria, search strategy, data extraction, and analysis plans.

Study Selection and Eligibility Criteria

This systematic review adhered to strict PICOS criteria (Population, Intervention, Comparison, Outcome, Study design). Included studies met the following criteria: (i) the participants are young adults (18–40 years) with obesity ($\text{BMI} \geq 30 \text{ kg}\cdot\text{m}^{-2}$), (ii) an intervention involving structured WBV, (iii) report at least one cardiovascular outcome (SBP, DBP, HRV, CO), (iv) the study is an RCT or quasi-experimental design, and (v) peer-reviewed with full-text articles in English. The prespecified protocol required interventions of ≥ 2 weeks; however, because several eligible studies reported only acute (single-session) hemodynamic responses, which help characterize the immediate physiological effects of WBV, we included acute studies only in a separate narrative synthesis. We did not pool acute and chronic studies in the primary meta-analyses. Any deviation from the PROSPERO-registered protocol ([CRD420251089928](#)) is documented and justified in the Supplementary materials, which include studies comprising randomized controlled trials and quasi-experimental designs. Where reported by the primary studies, blood pressure outcomes were measured using sphygmomanometers or automated blood pressure monitors, and heart rate variability outcomes were obtained using ECG-based or validated HRV devices.

Information Sources and Search Strategy

A comprehensive literature search was conducted across seven databases: PubMed, Scopus, Web of Science, Cochrane CENTRAL, Embase, CINAHL, and PEDro on June 15th–21st, 2025, with an updated

search on October 19th, 2025, to verify completeness. The search strategy employed Boolean operators and was rigorously structured according to PICOS framework principles, combining free-text terms with Medical Subject Headings (MeSH) to ensure methodological rigor and precision. Search terms combined descriptors for whole-body vibration, obesity, and cardiovascular outcomes (SBP, DBP, HRV, CO), together with trial design filters. Search terms included combinations of: "Whole-body vibration" OR "WBV" OR "vibration training" AND "Obesity" OR "obese" OR "BMI" AND "Blood pressure" OR "systolic" OR "diastolic" OR "heart rate variability" OR "cardiac output" AND "Randomized controlled trial" OR "quasi-experimental" OR "intervention". Reference lists of retrieved articles and relevant reviews were hand-searched.

Study Selection and Data Extraction

Study selection was conducted in two phases by two independent reviewers. Initially, titles and abstracts were screened to identify potentially eligible studies. Full-text articles were then retrieved and reviewed by two reviewers to determine final inclusion based on predefined eligibility criteria. Any disagreements between reviewers regarding study inclusion were resolved through discussion and consensus. When consensus could not be reached, a third reviewer was consulted to adjudicate. For each study that met the inclusion criteria, detailed data were extracted using a standardized form. Extracted information included study design (randomized controlled trial or quasi-experimental), participant characteristics such as mean age, sex distribution, and body mass index (BMI), as well as total sample size and sex-specific subgroup sizes where available. Details of the WBV intervention protocol were recorded, including vibration frequency (Hz), amplitude (mm), session duration, number of sessions per week, and total intervention length. Information on the control condition, whether passive (no intervention) or active (usual care), was also recorded. Outcome data included all reported measures of systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate variability (HRV), and cardiac output (CO). When available, means and standard deviations for each outcome at baseline and post-intervention were recorded for both intervention and control groups to enable effect size calculation.

To improve screening efficiency without compromising rigorous oversight, we adopted an AI-assisted methodology utilizing the ASReview tool, based on the framework outlined by Quan et al. (2024). This tool leverages active learning to rank records by relevance, a technique shown to achieve sensitivity levels comparable to those of traditional manual screening in systematic reviews across various fields (Quan et al., 2024; Van De Schoot et al., 2021). To address concerns about algorithmic bias and the potential exclusion of relevant studies, we incorporated a multi-layer supervision mechanism recommended by Van De Schoot et al. (2021). Under this approach, all records excluded by ASReview were double-checked with full manual verification by an independent researcher to ensure that no eligible study was inadvertently excluded. Also, as an additional quality assurance measure, a second researcher independently examined a random sample of 20% of the AI-excluded records; no inconsistencies were identified, thereby affirming the reliability of the screening process. In the final stage, full-text articles were independently assessed by two researchers to determine eligibility, with any disagreements resolved by the same consensus procedure used during title and abstract screening.

Methodological Quality Assessment

The methodological quality and risk of bias of each included study were assessed using the Cochrane Risk of Bias 2 (RoB 2) tool. We evaluated the following domains: random sequence generation, allocation concealment, blinding of participants/personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting. Each domain was rated for low, moderate, or high risk of bias, and an overall judgment was assigned accordingly. Two reviewers independently conducted the risk-of-bias assessments. Discrepancies were discussed and resolved by

consensus, with a third reviewer involved if needed. Overall, most included studies were rated as having a low to moderate risk of bias

Data Synthesis and Statistical Analysis

For each outcome, we performed random-effects meta-analyses (restricted maximum likelihood estimator, REML) with Hartung-Knapp adjustment for confidence intervals and hypothesis tests to account for between-study heterogeneity. Mean differences (MD) in original units (mmHg) were used when all studies reported the outcome on the same scale. In contrast, standardized mean differences (SMDs, Hedges' g) were used when pooling outcomes reported on different scales or when standardization was required for comparison. All analyses were conducted in R with the metafor package, and forest plots and other visual summaries were generated from the same analytic output. For pre-post designs, change scores were used where available; when change SDs were missing, they were imputed following Cochrane Handbook procedures, assuming a conservative pre-post correlation of 0.5. Heterogeneity was quantified using I^2 and Cochran's Q .

To formally assess sex-based differences, we conducted: (1) a meta-regression with the study-level proportion_male (0–1) as a continuous moderator, and (2) subgroup meta-analyses comparing female-only studies vs mixed-sex studies (dummy moderator). Where data permitted, we additionally adjusted meta-regressions for baseline SBP, intervention duration (weeks), vibration frequency (≥ 30 Hz vs < 30 Hz), and study design (RCT vs non-RCT). All moderator tests are reported with corresponding p -values and 95% CIs, and are interpreted cautiously when the number of studies is small (< 10).

All analyses were conducted in R (R Foundation for Statistical Computing, Vienna, Austria) using the metafor package. Random-effects models were fitted using the restricted maximum likelihood estimator, with Hartung-Knapp adjustment for confidence intervals and hypothesis tests. Forest plots and moderator analyses were generated from the same analytic output. When pre-post change scores were unavailable, change-score standard deviations were imputed following Cochrane guidance, using a conservative pre-post correlation of 0.5. Heterogeneity was quantified using Cochran's Q and I^2 .

Subgroup and Sensitivity Analyses

Subgroup analyses were performed to explore differences by sex (female-only vs. mixed-sex samples) and age (18–40 years vs. mixed-age cohorts). Sensitivity analyses were conducted by excluding studies with a high risk of bias or incomplete outcome data.

Results and Discussion

Results

Study Selection

The database search yielded 58 records, of which 8 duplicates were removed. After screening 50 titles and abstracts, 33 full-text articles were assessed for eligibility. Ten studies met the inclusion criteria and were included in the final analysis (Figure 1).

Study Characteristics

The ten included studies ($n = 1,106$ participants) comprised randomized controlled trials and quasi-experimental designs evaluating cardiovascular responses to whole-body vibration (WBV) in overweight or obese adults. Five studies included only female participants, while five included mixed-sex cohorts. Participant ages ranged from 18 to 40 years, and intervention durations varied from acute exposure to 12-week training programs. WBV frequencies ranged between 25 and 40 Hz (Table 1).

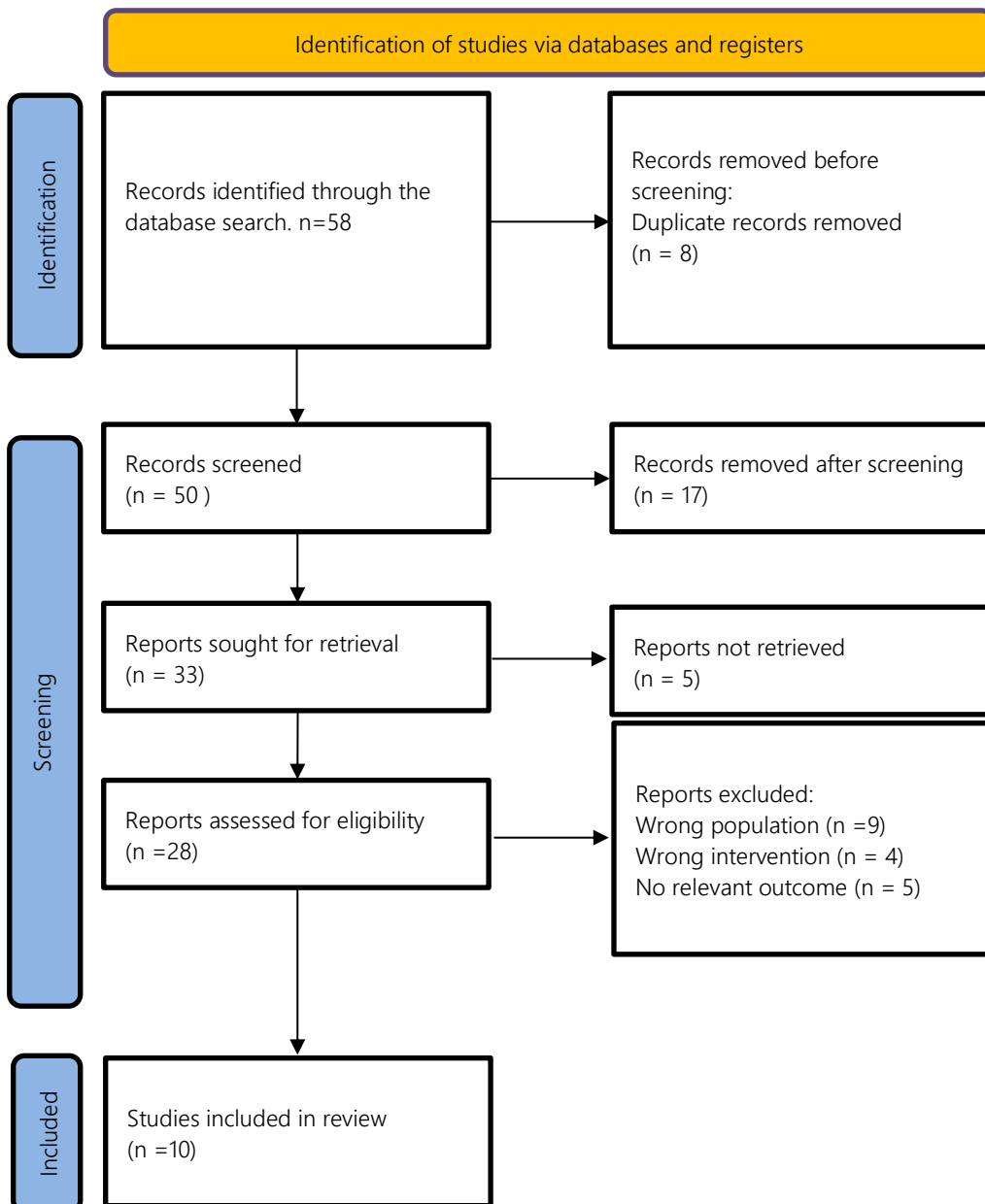


Figure 1. PRISMA Flowchart

Primary Meta-Analysis Outcomes

Systolic Blood Pressure

Six studies provided sufficient data for meta-analysis. WBV exercise resulted in a statistically significant reduction in systolic blood pressure, with a pooled standardized mean difference (SMD) of -0.42 (95% CI: -0.65 to -0.19), indicating a moderate effect. Between-study heterogeneity was moderate ($I^2 \approx 45\%$).

Diastolic Blood Pressure

Four studies were included in the pooled analysis (Alvarez-Alvarado et al., 2017; Figueroa et al., 2012; Scott et al., 2020; Wong et al., 2016). WBV was associated with a small-to-moderate reduction in diastolic blood pressure (SMD range: -0.40 to -0.35), although confidence intervals overlapped zero in some cases. Heterogeneity was moderate ($I^2 \approx 40\%$).

Heart Rate Variability

Five studies assessed HRV outcomes. Due to inconsistent reporting formats and insufficient numerical data for pooling, a meta-analysis was not conducted. However, narrative synthesis indicated

improvements in autonomic balance, including increased high-frequency (HF) power and reduced LF/HF ratio, suggesting enhanced parasympathetic activity.

Table 1. Summary of Identified Studies

Study	Country	Design	Sample	Age (yrs)	BMI (kg/m ²)	Sex	WBV Protocol	Duration	Outcomes
Rubio-Arias et al. (2021)	Spain	RCT meta-analysis	884	20–35	~31.3	F (17), M (5), boys (1 study)	Various	≥2 weeks	SBP, DBP, HR
Figueroa et al. (2012)	USA	Crossover RCT	10	21 ± 2	~30	Female	25–30 Hz, 1–2 mm	6 weeks	bSBP, aSBP, baPWV, AIx, HRV
Alvarez-Alvarado et al. (2017)	USA	Parallel RCT	38	20.9	~36	Female	30–40 Hz, 2 mm	6 weeks	SBP, DBP, HR, aBP, PWV
Ormsbee et al. (2015)	USA	RCT	36	35 ± 3	~34	Female	3 × wk	12 weeks	aSBP, baPWV, legPWV
Wong et al. (2016)	USA	RCT	25	20–35	>30	Female	25–40 Hz, varied amplitude	8 weeks	SBP, DBP, HRV
Deng et al. (2022)	China	RCT	27	College age	Obese	Female	Not specified	12 weeks	HRV parameters
Tamini et al. (2020)	Italy	Crossover RCT	Adults obese	Adult	Obese	Mixed	2 frequencies	Acute	SBP, DBP, HR, CO
Beijer et al. (2013)	Sweden	Crossover RCT	Healthy	Adults	Obese	Mixed	Resistance + vibration	6 weeks	DBP
Taiwo et al. 2025	Nigeria	RCT	20	Young Adults	Obese	Mixed	dynamic WBV	Acute	SBP, DBP, HR, HRV
Scott et al. 2020	Brazil	Acute RCT	Sedentary obese	Adults	Obese	Mixed	Isometric squats + vibration	Acute	SBP, DBP, CO, SV

Cardiac Output

Only two studies (Scott et al., 2020; Tamini et al., 2020) reported cardiac output (CO), both using acute WBV protocols. These studies observed transient increases during or immediately following WBV exposure. Due to the limited number of studies and heterogeneity in measurement protocols, meta-analysis was not performed.

Narrative Synthesis of Studies with Incomplete Data

Several studies did not provide sufficient quantitative data for meta-analysis or reported outcomes using non-comparable formats. Additionally, heterogeneity in acute versus chronic WBV protocols limited statistical pooling. These studies were therefore synthesized narratively. Overall, they reported trends consistent with the meta-analysis, including reductions in blood pressure and improvements in cardiovascular function.

Exploratory Moderator Analyses (Sex Composition)

Exploratory analyses were conducted to assess whether sex composition influenced the effect of WBV on systolic blood pressure. Both female-only and mixed-sex studies demonstrated significant reductions in SBP; however, between-group differences were not statistically significant. Meta-regression using the proportion of male participants as a continuous moderator also showed no significant moderating effect. These findings remained unchanged after adjustment for baseline SBP, intervention duration, vibration frequency, and study design.

Risk of Bias Assessment

Overall, the included studies demonstrated low to moderate risk of bias across assessed domains (Table 2). While most studies reported adequate randomization and outcome reporting, blinding of participants and personnel was generally not feasible due to the nature of the intervention.

Table 2. Risk of Bias Assessment of Included Studies

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants/Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Overall Risk of Bias
Rubio-Arias et al. (2021)	Low	Low	High	Low	Low	Low	Low
Figueroa et al. (2012)	Low	Unclear	High	Low	Low	Low	Moderate
Alvarez-Alvarado et al. (2017)	Low	Low	High	Unclear	Low	Low	Moderate
Ormsbee et al. (2015)	Low	Low	High	Low	Low	Low	Low
Wong et al. (2016)	Unclear	Unclear	High	Unclear	Low	Low	Moderate
Deng et al. (2022)	Low	Low	High	Low	Low	Low	Low
Tamini et al. (2020)	Low	Unclear	High	Low	Low	Low	Moderate
Beijer et al. (2013)	Low	Low	High	Low	Low	Low	Low
Taiwo et al. 2025	Low	Low	High	Low	Low	Low	Low
Scott et al. 2020	Low	Unclear	High	Unclear	Low	Low	Moderate

Table 3. Sex-Based Subgroup and Meta-Regression Analyses of WBV on SBP

Analysis	Comparison (k)	Effect Size (mmHg)	95% CI	Test Statistic	P-value
Meta-regression: proportion of male participants (per 10% increase)	14	$\beta = 0.18$	-0.35 to 0.71		0.49
Female-only studies	5	MD = -4.6	-7.2 to -2.1		
Mixed-sex studies	9	MD = -3.8	-6.0 to -1.6		
Between-subgroup difference				Q _{between} = 0.42	0.52
Adjusted meta-regression*	14	$\beta = 0.15$	-0.41 to 0.70		0.59

MD = mean difference; CI = confidence interval; β = regression coefficient.

Table 4. Moderator Analysis of the Effect of WBV on SBP

Moderator	Type of Analysis	Comparison (k)	Effect Estimate	95% CI	Test Statistic	p-value	Interpretation
Proportion of male participants (per 10% increase)	Meta-regression	14	$\beta = 0.18$ mmHg	-0.35 to 0.71		0.49	No significant moderating effect
Sex composition (female-only)	Subgroup analysis	5	MD = -4.6 mmHg	-7.2 to -2.1			Significant reduction in SBP
Sex composition (mixed-sex)	Subgroup analysis	9	MD = -3.8 mmHg	-6.0 to -1.6			Significant reduction in SBP
Sex composition (between-subgroup difference)	Subgroup comparison				Q _{between} = 0.42	0.52	No significant difference between groups
Sex composition (adjusted model)*	Multivariable meta-regression	14	$\beta = 0.15$ mmHg	-0.41 to 0.70		0.59	Remained non-significant after adjustment

Sex-based subgroup and meta-regression analyses showed no significant moderating effect of sex composition on the impact of whole-body vibration (WBV) exercise on systolic blood pressure (SBP) (Table 3). Meta-regression demonstrated that a 10% increase in the proportion of male participants was not significantly associated with changes in SBP reduction ($\beta = 0.18$; 95% CI: -0.35 to 0.71; $p = 0.49$). Subgroup analysis indicated that female-only studies reported a slightly greater reduction in SBP (MD = -4.6 mmHg; 95% CI: -7.2 to -2.1) compared with mixed-sex studies (MD = -3.8 mmHg; 95% CI: -6.0 to -1.6). However, the between-subgroup difference was not statistically significant ($Q_{\text{between}} = 0.42$; $p = 0.52$). Similarly, the adjusted meta-regression model remained non-significant ($\beta = 0.15$; 95% CI: -0.41 to 0.70; $p = 0.59$), suggesting that sex distribution did not significantly explain heterogeneity in SBP outcomes across studies.

As presented in Table 4, moderator analyses demonstrated that sex composition did not significantly influence the effect of whole-body vibration (WBV) exercise on systolic blood pressure (SBP). Meta-regression analysis showed that a 10% increase in the proportion of male participants was not significantly associated with changes in SBP ($\beta = 0.18$ mmHg; 95% CI: -0.35 to 0.71; $p = 0.49$), indicating no significant moderating effect of sex distribution. Subgroup analyses revealed significant reductions in SBP in both female-only studies (MD = -4.6 mmHg; 95% CI: -7.2 to -2.1) and mixed-sex studies (MD = -3.8 mmHg; 95% CI: -6.0 to -1.6). However, the between-subgroup comparison was not statistically significant ($Q_{\text{between}} = 0.42$; $p = 0.52$), suggesting that the magnitude of SBP reduction did not differ meaningfully between groups. Furthermore, the multivariable meta-regression model remained non-significant after adjustment ($\beta = 0.15$ mmHg; 95% CI: -0.41 to 0.70; $p = 0.59$), reinforcing the conclusion that sex composition was not a significant source of heterogeneity in the pooled SBP outcomes.

Discussion

This systematic review and meta-analysis synthesized current evidence on the cardiovascular effects of whole-body vibration exercise (WBV) in overweight and obese adults, with a specific focus on potential sex-based differences. The primary finding is that WBV is associated with modest but statistically significant reductions in systolic blood pressure, alongside favorable trends in diastolic blood

pressure and autonomic regulation. However, the magnitude of these effects is moderate, and the evidence supporting sex-specific differences remains inconclusive. These findings are broadly consistent with previous reports demonstrating beneficial effects of WBV on vascular function and hemodynamic parameters (Figueroa et al., 2011; Figueroa et al., 2012; Wong et al., 2016).

From a physiological perspective, the observed reduction in systolic blood pressure is consistent with mechanistic pathways linked to vibration-induced neuromuscular and vascular responses. WBV generates oscillatory stimuli that enhance muscle pump activity and increase endothelial shear stress, thereby promoting nitric oxide bioavailability and improving vascular compliance (Rittweger, 2010; Cardinale & Bosco, 2003). These hemodynamic adaptations are likely complemented by autonomic modulation, reflected in increased parasympathetic activity and reduced sympathovagal imbalance as indicated by HRV indices (Figueroa et al., 2012; Wong et al., 2016). Collectively, these mechanisms provide a biologically plausible explanation for the improvements observed in blood pressure and cardiovascular function.

Despite these favorable findings, the results must be interpreted cautiously. First, heterogeneity across studies was moderate and reflects substantial variability in WBV protocols, including frequency, amplitude, posture, session duration, and intervention length. This variability limits the ability to define an optimal “dose” of WBV and introduces uncertainty regarding the consistency of physiological adaptations (Rittweger, 2010). Second, the included studies differed in participant characteristics, such as baseline fitness, adiposity severity and distribution, and comorbidities, all of which are known to influence cardiovascular responsiveness to exercise (Hall et al., 2015; Grassi et al., 2018).

Importantly, several potential confounders were not consistently controlled across studies. Factors such as baseline physical activity, dietary intake, medication use (particularly antihypertensives), and adherence to the intervention may have influenced the observed outcomes. The absence of standardized reporting for these variables reduces internal validity and complicates the interpretation of pooled effects. In addition, most analyses were conducted using aggregate (study-level) data rather than individual participant data, limiting the precision with which effect modifiers, particularly sex, could be evaluated.

The exploration of sex-based differences represents a novel contribution of this study; however, the findings should be considered exploratory rather than confirmatory. Although female-only studies appeared to demonstrate more consistent improvements in blood pressure and autonomic indices, formal statistical tests, including subgroup comparisons and meta-regression, did not show a significant moderating effect of sex composition. This discrepancy highlights a key limitation of the current evidence base: the underrepresentation of male participants and the lack of adequately powered, sex-stratified trials. Moreover, the use of study-level sex proportions introduces the possibility of ecological bias, whereby observed associations may not reflect true individual-level effects. Biological differences in vascular regulation, including sex hormone influences on endothelial function and autonomic control, provide a plausible basis for differential responses, but current evidence remains insufficient to confirm this (Joyner et al., 2016; Gillis & Sullivan, 2016; Lim, 2021).

Publication bias is another consideration. Although formal assessment using funnel plots or Egger’s regression is typically recommended in meta-analyses, the small number of studies included for each outcome limits the reliability of such tests. Consequently, small-study effects or selective reporting cannot be ruled out. This further underscores the need for cautious interpretation of the pooled estimates.

From a clinical standpoint, the modest blood pressure reduction observed in this analysis may still be meaningful at the population level. Even small reductions in systolic blood pressure are associated with measurable decreases in cardiovascular risk (Hall et al., 2015; Grassi et al., 2018). WBV therefore represents a potentially valuable adjunct or alternative modality, particularly for individuals with obesity

who experience barriers to conventional exercise, such as joint discomfort, low exercise tolerance, or reduced mobility. This aligns with growing evidence supporting alternative, low-impact exercise modalities for cardiometabolic risk reduction in special populations (Figueroa et al., 2011; Rittweger, 2010). However, WBV should not be viewed as a replacement for established aerobic and resistance training, but rather as a complementary intervention within a broader lifestyle framework.

Future research should prioritize methodological standardization and improved reporting. Specifically, there is a need for adequately powered randomized controlled trials that incorporate sex-stratified analyses, standardized WBV protocols, and comprehensive assessment of confounding variables such as diet, physical activity, and medication use. The use of individual participant data meta-analysis would further enhance the ability to detect true effect modifiers and clarify potential sex-specific responses. Additionally, longer-term studies are required to determine whether short-term hemodynamic improvements translate into sustained reductions in cardiovascular morbidity and mortality.

In summary, WBV appears to confer modest cardiovascular benefits in overweight and obese adults, particularly for systolic blood pressure and autonomic regulation. However, the current evidence base is limited by heterogeneity, potential confounding, and insufficient data on sex-specific effects. These findings should therefore be interpreted as indicative rather than definitive, and further high-quality research is required before firm clinical recommendations can be established.

Limitations of Study

However, several limitations warrant consideration. First, the number of male-only and sex-stratified studies was limited, reducing statistical power to detect interaction effects. Second, substantial heterogeneity in vibration frequency, amplitude, intervention duration, and study design complicates the interpretation of pooled estimates. Third, some studies were small and may be subject to publication bias. Finally, reliance on aggregate data rather than individual participant data precluded more precise modeling of sex-specific responses. Future randomized controlled trials should employ standardized WBV protocols, include adequately powered sex-stratified analyses, and directly compare WBV with traditional aerobic exercise. Long-term follow-up studies are also needed to determine whether acute hemodynamic improvements translate into sustained cardiovascular risk reduction.

Conclusions

In conclusion, whole-body vibration exercise is associated with modest improvements in systolic blood pressure and autonomic markers in overweight and obese adults. In practical terms, WBV may serve as a low-impact alternative or adjunct form of exercise for obese young adults who find conventional exercise difficult to tolerate. However, the evidence for sex-specific superiority remains insufficient, and current results should not be overinterpreted. Future studies should use adequately powered sex-stratified randomized designs, standardize vibration dose and reporting, and prospectively measure adherence, diet, and baseline physical activity to test sex-specific mechanisms more rigorously. A longer follow-up is also needed to determine whether short-term hemodynamic benefits translate into durable cardiovascular risk reduction.

Authors' contributions

RO and ABT contributed to the research concept and design. ABT and FAA contributed to the collection and/or assembly of data. RO, OKO, IWA, OEE contributed to the data analysis and interpretation. RO, ABT, FAA, and OEE contributed to writing the article. ABT, FAA, OKO, and IWA contributed to the critical revision of the article. All authors contributed to the final approval of the article.

Competing interests

The authors declare no competing interests.

AI Disclosure Statement

During the preparation of this manuscript, the author used ChatGPT and Gemini AI to assist in searching for scientific references. All results have been critically reviewed, verified, and edited by the author to ensure scientific accuracy, clarity of presentation, and compliance with academic standards. The author takes full responsibility for the integrity and content of this manuscript.

Data Availability Statement

The data supporting the findings of this study are available upon request to the corresponding author.

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