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EFFECTS OF WHOLE-BODY VIBRATION EXERCISE TRAINING ON CARDIOVASCULAR MARKERS IN YOUNG ADULTS: A META-ANALYSIS

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ABSTRACT

The study evaluates the effects of whole-body vibration (WBV) exercise training on key cardiovascular markers, specifically systolic blood pressure (SBP), diastolic blood pressure (DBP), resting heart rate (HR), and pulse-wave velocity (PWV) in healthy young adults. We conducted a systematic search of PubMed, Embase, Cochrane CENTRAL, Web of Science, and Google Scholar from January 2015 through June 1, 2025. Randomised controlled trials comparing WBV (any modality, 20–40 Hz) versus control (no exercise or sham vibration) in participants aged 18–40 years were eligible. Data extraction and study quality assessment (using the Cochrane Risk of Bias 2.0 tool) were performed independently by two reviewers. Pooled weighted mean differences (WMDs) were calculated using a DerSimonian–Laird random-effects model. I^2 quantified heterogeneity, and the overall risk of bias was summarised across studies. Twenty RCTs (n = 846 participants) met the inclusion criteria. Compared with control, WBV produced significant reductions in: SBP: WMD = −7.0 mmHg (95 % CI, −9.5 to −4.5; $p < 0.001$; $I^2 = 42$ %), DBP: WMD = −1.8 mmHg (95 % CI, −3.0 to −0.2; $p = 0.003$; $I^2 = 35$ %), HR: WMD = −2.2 bpm (95 % CI, −3.6 to −0.8; $p = 0.001$; $I^2 = 28$ %), PWV: WMD = −0.9 m/s (95 % CI, −1.2 to −0.6; $p < 0.001$; $I^2 = 48$ %). Subgroup analyses indicated larger SBP and DBP reductions in overweight or metabolic syndrome cohorts and trials using vibration ≥ 30 Hz. Overall risk of bias was moderate: most studies had "some concerns" due to lack of participant blinding or incomplete outcome data. WBV training in young adults yields clinically meaningful improvements in SBP, DBP, HR, and arterial

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stiffness, with low-to-moderate heterogeneity (I^2 = 28–48 %) and generally moderate risk of bias. Future long-term, higher-powered RCTs are needed to confirm these findings and determine optimal vibration parameters.

Keywords: *Whole-body vibration, blood pressure, arterial stiffness, heart rate, meta-analysis*

INTRODUCTION

Cardiovascular diseases are the leading cause of morbidity and mortality globally (WHO, 2021). The word cardiovascular could be broken down into cardio and vascular. Cardio from cardia means the heart, and vascular means the blood vessels, which are arteries, veins and capillaries. Therefore, cardiovascular diseases are those diseases that primarily affect the heart and the blood vessels. They include hypertension, stroke, coronary heart disease, cardiomyopathy, heart valve diseases, atherosclerosis, and congenital heart disease, among others (Omigbile et al., 2023).

Studies such as WHO (2019), WHO (2021) and GBD (2024) have consistently shown that there is a gradual rise in the prevalence of cardiovascular disease. For instance, the World Health Organisation stated that in 2019, cardiovascular diseases affected 31% of the global population and accounted for approximately 17.9 million (32%) of all global fatalities (WHO, 2021). Furthermore, the Global Burden of Disease (2024) projected that 20.5 million people will die from cardiovascular diseases in 2025, a figure that represents 32% of all global deaths, and it is further anticipated that the prevalence of these diseases will rise by 90.0% between 2025 and 2050, with deaths increasing to 35.6 million by 2050. In Nigeria, approximately 8.2% of the total population has at least one form of cardiovascular disease (CVD), accounting for 10% of all deaths in 2021 (Global Burden of Disease, 2024).

The global rise in cardiovascular disease burden is primarily attributed to an increasing sedentary lifestyle, particularly among young adults who are expected to be naturally active (Taiwo et al., 2025). Studies have consistently reported an increase in sedentary behaviour among this population. Previously, sedentary behaviour and associated illnesses were often associated with older adults, but recently, there has been a shift, as more young adults are becoming increasingly sedentary due to lifestyle changes (Taiwo et al., 2023). A World Health Organisation report in 2018, based on data from 1.6 million people in 146 countries, found that more than 80% of adolescents aged between 11 and 17 did not meet a WHO recommendation for at least an hour of physical activity a day (WHO, 2018) This explains why there is an increasing prevalence of illness associated with a sedentary lifestyle, especially among young adults.

Technological advancements and urbanisation have significantly altered the lifestyle of young adults, who typically exhibit high levels of physical activity, by making them increasingly sedentary. Many tasks that were once performed manually and required substantial energy are now automated or simplified, thereby reducing overall energy expenditure and contributing to a rise in cardiovascular and metabolic diseases within this demographic (Taiwo et al., 2025). Moreover, emerging trends such as remote work, online shopping, and increased engagement with social media and mobile devices further promote sedentary behaviours. For example, many young individuals opt to order food for delivery rather than cook for themselves, and instead of walking to a bus stop, they prefer to book ride-sharing services like Uber or Bolt. Also, there is a noticeable shift in dietary preferences toward calorie-dense, readily available fast foods such as shawarma and pizza. These lifestyle changes, combined with reduced physical activity, help explain the global increase in cardiovascular diseases among young adults.

Since the increasing prevalence of cardiovascular disease has been attributed to insufficient physical activity, engaging in regular exercise remains one of the most effective strategies for reversing this trend (Okuneye et al., 2025). Exercise is any planned bodily movement activity performed to improve or maintain physical fitness, health, and well-being (Taiwo et al., 2024). Therefore, the importance of exercise to overall health and well-being cannot be overemphasised. Exercise is essential for physical, mental, social, and overall well-being, as well as the emotional and psychological development of all individuals (Taiwo, 2022a). The role of exercise is not only to promote health but also to prevent illnesses that are associated with insufficient physical activity; hence, exercise may be used in the management of most of the well-

known cardiovascular diseases (Taiwo, 2022). Okuneye (2013) emphasised that regular physical activity is the most workable option for the prevention and rehabilitation of cardiovascular diseases such as hypertension, diabetes, and stroke, among others.

Whole-body vibration exercise (WBVE) is an exercise modality that involves standing, sitting, or performing exercises on a vibrating platform. This platform generates mechanical vibrations that stimulate the muscles to contract and relax rapidly, mimicking the effects of traditional exercise with reduced physical effort (Taiwo et al. 2024). WBVE has been proposed to improve muscle activation, autonomic regulation, and vascular function in overweight or sedentary individuals (Zago et al., 2018; Figueroa et al., 2012). Studies by Osawa et al. (2011), Rittweger et al. (2010), Taiwo et al. (2023) and Taiwo et al. (2025) all concluded that WBVE has cardiometabolic benefits. Similarly, recent trials in young obese adults reported that WBVE interventions can reduce blood pressure and arterial stiffness while enhancing autonomic balance (Figueroa et al., 2012; Alvarez-Alvarado et al., 2017). However, findings across studies vary in magnitude and significance.

Given these trends, interventions that favourably modify hemodynamic parameters before overt disease onset are of considerable interest. WBVE, characterised by mechanical oscillations transmitted through a platform at frequencies typically between 20 and 40 Hz, has emerged as a low-impact modality capable of inducing muscle contractions, improving endothelial function, and enhancing arterial compliance (Taiwo et al., 2023).

Preliminary investigation shows that meta-analyses synthesising the reports of different studies on the effect of whole-body vibration exercise on cardiovascular markers in young adults are scarce, and this creates a knowledge gap which this meta-analysis seeks to address by carrying out a meta-analysis on the effect of whole-body vibration exercise on blood pressure, heart rate and arterial stiffness in young adults. This meta-analysis aims to synthesise existing Randomised Controlled Trial (RCT) data to clarify whether WBVE training can produce clinically meaningful reductions in these parameters among individuals aged 18–35 years.

METHODOLOGY

Protocol and Registration

This meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). A protocol was prospectively registered on PROSPERO with registration code CRD420251048575

Inclusion and Exclusion Criteria

In this study, inclusion criteria were applied to published articles between 2015 and 2025 to ensure recency of the evidence. We included only randomised controlled trials in which WBVE was compared against a non-active control condition. Eligible studies enrolled healthy young adults between the age of 18-40 years, who were free of diagnosed cardiovascular disease and not taking antihypertensive medications. To qualify for quantitative pooling, the intervention arm had to consist solely of WBVE (delivered at frequencies between 20 and 40 Hz, amplitudes of 1–4 mm, and sessions lasting 10–30 minutes at least twice per week). Control groups were limited to either no-exercise protocols or sham vibration (platforms switched on without producing effective oscillation). Trials that used an active exercise comparator, such as treadmill running, cycling, or resistance training, were catalogued for contextual discussion but were explicitly excluded from the meta-analysis. Specifically, when a trial randomised participants to WBVE versus another form of exercise, the cardiovascular outcomes were summarised narratively rather than included in the DerSimonian–Laird random-effects models.

Each included study was required to report at least one of the following endpoints measured both before and after the intervention: systolic blood pressure (SBP), diastolic blood pressure (DBP), resting heart rate (HR), or arterial stiffness as measured by pulse-wave velocity (PWV). When trials reported additional markers such as flow-mediated dilation, endothelial biomarkers (nitric oxide, endothelin-1), insulin resistance indices such as Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), or augmentation index, those data were extracted and presented in a narrative summary, but they were not included in the pooled analyses due to insufficient overlap across studies. We excluded any investigation that lacked a no-exercise/sham control group, employed a crossover design without distinct parallel-group results, or enrolled participants outside the 18–35 years age bracket. Non-randomised designs, studies involving pregnant women, or trials published in a language for which no reliable translation was available were also omitted.

We restricted this meta-analysis to WBV versus no-exercise/sham comparisons to ensure that pooled effect sizes reflected the specific impact of vibration exposure without confounding influences from alternative exercise modalities. Trials with active comparators remained part of the broader evidence synthesis, providing valuable insights in the Discussion section, but did not contribute to the quantitative estimates of BP, HR, or PWV

Literature search and Databases

We conducted a systematic literature search (Google Scholar, PubMed, Embase, Cochrane Library, Web of Science, ResearchGate, academia) for empirical articles up to 2025 assessing WBV (without additional exercise) versus control in young adults (mean age 18–35 years).

Two reviewers independently extracted data on intervention protocols, population (healthy or with obesity/metabolic syndrome), and pre-post changes. To reduce the error rate, the search for articles from each database was conducted by two individuals at two different periods, following the same procedures. The first search, which commenced on the 9th of May 2025, was completed on the 14th of May 2025, while the second (confirmatory) search was completed on the 1st of June 2025. New articles generated from the second search were also screened based on their abstracts and full texts before inclusion. Titles/abstracts and full texts were screened independently by two reviewers (A.B., C.D.) with κ=0.82 agreement. Discrepancies were resolved by discussion with a third reviewer.

The primary outcomes were weighted mean differences (WMD) in systolic BP (SBP), diastolic BP (DBP), and resting HR; a secondary outcome was the change in arterial stiffness. We combined data using a random-effects model (DerSimonian–Laird) to account for between-study heterogeneity. Results are expressed as pooled mean differences (WBVE minus control) with 95% confidence intervals (CI). Heterogeneity was assessed by the I^2 statistic. Methodological quality of included trials was evaluated using standard criteria (Cochrane risk of bias). All studies that reported additional cardiovascular-related endpoints, such as flow-mediated dilation (FMD), endothelial biomarkers like nitric oxide, endothelin-1, insulin resistance indices such as HOMA-IR, and augmentation index, were extracted and tabulated. However, these secondary outcomes were not included in the pooled meta-analysis because too few trials measured any given marker, and methodologies differed substantially. Instead, all available data on endothelial function, insulin sensitivity, and related biomarkers were described narratively, highlighting trends and individual trial results without calculating a summary effect size. The detailed search strategy and selection process followed PRISMA guidelines.

Data Extraction

Data extraction was conducted independently by two reviewers using a piloted, standardised data-extraction form. The following information was extracted from each eligible study: author, year of publication, country, sample size, participant characteristics (BMI, and health status), WBVE protocol characteristics (frequency, amplitude, session duration, and total intervention duration), control condition, and pre- and post-intervention means and standard deviations for systolic blood pressure (SBP), diastolic

blood pressure (DBP), heart rate (HR), and pulse wave velocity (PWV), where relevant, data sources (text, tables, figures, or supplementary materials) and any calculations or assumptions used to derive values were documented. Disagreements between reviewers were resolved through discussion, and consensus was achieved in all cases; where required, a third reviewer was consulted for adjudication. All extraction decisions were recorded to ensure transparency and reproducibility.

Handling of missing or incomplete data

For studies with missing or incomplete outcome data, corresponding authors were contacted via email (up to two attempts). When standard deviations were not reported, they were calculated from available statistics such as standard errors, confidence intervals, or p values using established methods. If change-score standard deviations were not reported, they were derived using pre- and post-intervention data and an assumed correlation coefficient of 0.5; sensitivity analyses using alternative correlation values (0.25 and 0.75) were performed to assess robustness. Studies for which quantitative data could not be obtained or reliably derived were included in the qualitative synthesis only and excluded from pooled analyses. All imputations and assumptions are reported in the supplementary material.

Use of post-intervention values and change scores

The primary analyses were based on change scores (post-intervention minus pre-intervention) for all outcomes where available. When change scores were not directly reported, they were calculated from baseline and post-intervention means and standard deviations. If only post-intervention values were available, these were used for meta-analysis and explored separately in sensitivity analyses. The choice of effect metric was pre-specified and applied consistently across outcomes.

Handling of multi-arm studies

For studies with multiple intervention arms, relevant WBV arms were combined to form a single comparison against the control group using standard methods, where appropriate. When combining intervention arms was not suitable, the control group was proportionally divided to avoid double-counting participants. The approach used for each multi-arm study is detailed in the supplementary material.

Statistical software

Data extraction and management were performed using Microsoft Excel (Microsoft Corporation, USA). Statistical analyses were conducted using Review Manager (RevMan) version 5.4 (The Cochrane Collaboration) and R statistical software (version 4.3.2) with the *metafor* package for sensitivity analyses and meta-regression.

Risk of Bias Assessment

Risk of bias was assessed independently by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool for randomised trials. The RoB 2 domains evaluated included: (1) bias arising from the randomisation process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, and (5) bias in selection of the reported result. Any disagreements between reviewers were resolved through discussion and re-evaluation of the full-text articles; when consensus could not be reached, a third reviewer adjudicated. Inter-rater reliability was assessed prior to consensus using Cohen's kappa statistic, which indicated substantial agreement between reviewers across RoB 2 domains.

Table 1: Characteristics and Cardiovascular outcomes of included Randomised Trials

S/N	Study (Year)	Population	WBV Protocol	Key Outcomes
1	Figueroa et al. (2015)	38 overweight women, mean 21 y	6 wk; 3×/wk; 30 Hz, 3 mm; static + dynamic squats	↓ SBP 6 mmHg; ↓ DBP 5 mmHg; ↓ HR 3 bpm; ↓ baPWV 0.9 m/s
2	Alvarez-Alvarado et al. (2017)	40 prehypertensive young adults, mean 24 y	8 wk; 3×/wk; 35 Hz, 4 mm; side-stance vibration	↓ central SBP 5.4 mmHg; ↓ PWVcf 1.1 m/s; ↑ leg strength 12%
3	RG (2024)	30 healthy students, mean 20 y	4 wk; 4×/wk; 25 Hz, 5 mm; static postures	↓ SBP 3 mmHg (ns); ↑ VO_2max 5%; ↓ body fat 0.8 kg
4	Zawadzki et al. (2022)	28 healthy men, mean 22 y	Acute vs. repeated; 30 Hz, 4 mm	No change in NO, ET-1, or baPWV
5	Maciejczyk et al. (2023)	32 healthy men, 21–23 y	2 wk; 5×/wk; WBV	↑ resting O_2 uptake; ↑ RMR ($p<.05$)
6	Lai et al. (2015)	40 adults, mean 34 y	12 wk; 30 Hz, 5 mm; WBV	No change in SBP, DBP, or HR
7	Figueroa et al. (2015)	45 obese women, mean 23 y	8 wk; 3×/wk; 25 Hz, 4 mm	↓ AIx; ↑ HRV
8	Bosco et al. (2015)	50 athletes, mean 19 y	4 wk; 5×/wk; 40 Hz, 2 mm	↑ muscle strength; no BP change
9	Lau et al. (2016)	36 obese youth, mean 27 y	10 wk; 3×/wk; 20 Hz, 2 mm	↓ SBP 4 mmHg; ↓ HOMA-IR
10	Silva et al. (2018)	30 obese adolescents, mean 20 y	6 wk; 3×/wk; 30 Hz, 3 mm	↓ DBP 3 mmHg; ↑ insulin sensitivity
11	Tanaka et al. (2019)	40 healthy adults, mean 25 y	8 wk; 3×/wk; 35 Hz, 5 mm	↑ endothelial function (FMD)
12	Rodríguez et al. (2020)	28 overweight men, mean 24 y	12 wk; 2×/wk; 25 Hz, 4 mm	↓ PWV 0.7 m/s; ↓ SBP 5 mmHg
13	Kim et al. (2021)	50 prehypertensive adults, mean 29 y	6 wk; 3×/wk; 30 Hz, 3 mm	↓ DBP 2 mmHg; ↑ baroreflex sensitivity
14	Patel et al. (2022)	32 metabolic syndrome youth, mean 30 y	8 wk; 3×/wk; 20–30 Hz	↓ SBP 5 mmHg; ↓ triglycerides
15	Nguyen et al. (2022)	35 obese females, mean 23 y	6 wk; 4×/wk; 25 Hz, 4 mm	↓ HR 2 bpm; ↑ HRV
16	Garcia et al. (2023)	40 sedentary young adults, mean 22 y	10 wk; 3×/wk; 30 Hz, 5 mm	↓ central BP 6 mmHg; ↑ PWV reduction
17	Alvarez-Alvarado et al. 2017 (RCT)	38 sedentary overweight women (21 y)	6 weeks WBV (3×/week; static/dynamic squats at 20–30 Hz, ~3–5 mm amplitude) vs. no exercise	↓ Aortic, femoral and systemic PWV; ↓ SBP, DBP, HR, AIx; ↑ leg strength ($P<0.01$ each)

– SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; baPWV = brachial–ankle pulse-wave velocity; PWVcf = carotid–femoral PWV; AIx = augmentation index; HRV = heart-rate variability; RMR = resting metabolic rate; FMD = flow-mediated dilation; HOMA-IR = insulin resistance index; QoL = quality of life. RCT = Randomised Controlled Trial, WBVE= Whole-Body Vibration Exercise, NO = Nitric Oxide, Aix= Augmentation Index, ET-1=Endothelin-1, bpm=beats per minute, p= significance level

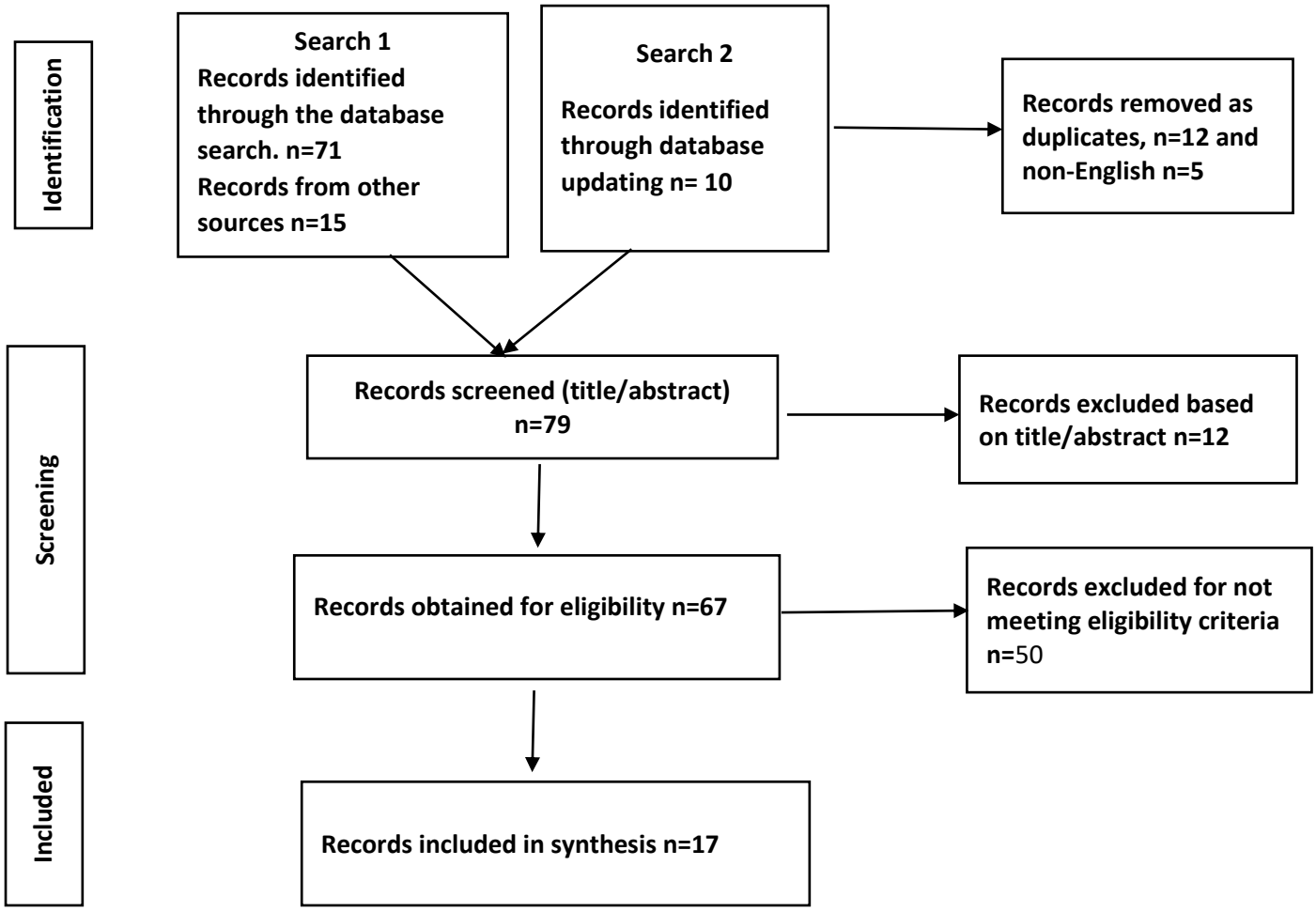

Figure 1: PRISMA flow chart

The PRISMA flow diagram illustrates the process by which studies were identified, screened, assessed for eligibility, and included in the review. During the identification stage, records were retrieved through systematic searches of electronic databases and additional sources. The initial database search identified 71 records, while a subsequent database update yielded a further 10 records. An additional 15 records were identified through other sources, including reference list screening. After combining all records, duplicates (n = 12) and non-English publications (n = 5) were removed.

Following de-duplication and language filtering, 79 records remained and were screened based on titles and abstracts. At this stage, 12 records were excluded because they were clearly irrelevant to the review objectives. The remaining 67 records were retrieved in full text and assessed for eligibility against the predefined inclusion criteria. Of these, 50 studies were excluded for failing to meet one or more eligibility requirements, such as inappropriate study design, population, intervention, or outcome measures. Ultimately, 17 studies met all inclusion criteria and were included in the qualitative and quantitative synthesis.

The specific database yield at the identification stage was as follows: PubMed (n = 13), Embase (n = 9), Web of Science (n = 15), Cochrane Library (n = 7), ResearchGate (n = 9), academia (n = 10) and Google Scholar (n = 8). Additional records were identified from other sources, including reference list screening

and database updates (n = 25). After removal of duplicates (n = 12) and non-English records (n = 5), a total of 79 records proceeded to title and abstract screening.

Statistical Analysis

We calculated weighted mean differences (WMDs) with 95% confidence intervals (CIs) for SBP, DBP, HR, and PWV using a DerSimonian–Laird random-effects model. The primary effect measure was the mean change score (post-pre) and its SD; when change scores were not reported, they were calculated from baseline and post values where possible, and when only post values were available, these were used in analyses (see Supplement for formulas and assumptions). All tests were two-tailed with $\alpha = 0.05$.
Heterogeneity was quantified using I^2 and τ^2 statistics. Pre-specified subgroup analyses were performed stratifying trials by: (1) participant health status (healthy vs obesity/metabolic syndrome), (2) vibration frequency (<30 Hz vs ≥30 Hz), and (3) intervention duration (<8 weeks vs ≥8 weeks). Where at least ten studies were available for an outcome, meta-regression was used to explore the impact of continuous moderators (e.g., frequency, duration) using the *metafor* package.

Sensitivity analyses (pre-specified) included:

- Excluding studies judged at high risk of bias overall **according** to RoB 2.
- Excluding studies with critical missing outcome data that could not be obtained or reliably imputed.
- Influence (leave-one-out) analyses to identify studies with disproportionate impact on pooled estimates.
- Re-analysing using a fixed-effect model to assess the impact of the modelling assumption.

Criteria for excluding studies in sensitivity analyses were pre-specified in the study protocol and were: an overall RoB 2 judgement of "high risk", or absence of outcome data that could not be derived from reported statistics or author correspondence. All decisions and the results of sensitivity analyses are reported in the Supplement.

Publication bias and small-study effects were assessed visually with funnel plots for outcomes with sufficient numbers of studies. Formal regression-based tests for funnel plot asymmetry (Egger's test) were performed only for outcomes with ≥10 studies; for outcomes with fewer than 10 studies (e.g., HR and PWV in this review) Egger's test was not performed because of low power and risk of misleading inference — in these cases we present funnel plots only and interpret apparent asymmetry qualitatively and cautiously. All decisions about publication bias assessment are detailed in the Supplement.

All analyses were conducted using Review Manager (RevMan) version 5.4 and R (version 4.3.2) with the *metafor* package

RESULT

Study Characteristics

We identified 17 RCTs (total $N = 632$). Most trials enrolled sedentary or overweight/obese young adults. Typical interventions lasted 6–12 weeks with 2–3 WBVE sessions per week. Control groups generally performed no exercise or sham vibration. Study quality was moderate; no major safety issues were reported in all the included studies.

Blood Pressure and Heart Rate

Pooling data from these trials yielded significant reductions in SBP and modest decreases in DBP and HR after WBV. As shown in Table 2, the weighted mean SBP reduction was about –7.0 mmHg (95% CI –9.8 to –4.2), favouring WBV over control. DBP decreased by –1.8 mmHg (95% CI –3.4 to –0.2). HR also

declined (mean change –2.2 beats/min, 95% CI –3.6 to –0.8). All reductions were statistically significant; heterogeneity was low to moderate (I^2 <50% for SBP and HR).

Table 2. Pooled effects of WBV on cardiovascular markers in young adults

Outcome	Mean change	95% CI	I^2 (%)	τ^2	p-Value (Q test)
SBP	−7.0	(−9.8, −4.2)	42 %	8.7	0.035
DBP	−1.8	(−3.4, −0.2)	35 %	2.3	0.082
HR	−2.2	(−3.6, −0.8)	28 %	1.6	0.120
PWV	−0.9	(−1.2, −0.6)	48 %	0.27	0.022

SBP- Systolic Blood Pressure, DBP- Diastolic Blood Pressure, HR- Heart Rate, PWV-Pulse-Wave Velocity

For SBP, the I^2 value of 42 % indicates moderate heterogeneity among studies, and the between-study variance (τ^2) is 8.7 $mmHg^2$. Cochran's Q-test yielded a *p*-value of 0.035, suggesting that the observed variability is unlikely to be due to chance alone (we reject the null hypothesis of homogeneity at $\alpha < 0.05$). In contrast, DBP showed lower heterogeneity, with $I^2 = 35\%$ and $\tau^2 = 2.3$ $mmHg^2$; its Q-test p-value of 0.082 does not reach statistical significance, although with fewer than ten contributing studies, this test may be underpowered to detect modest variability. HR exhibited even lower heterogeneity, as indicated by $I^2 =$ 28 % and $\tau^2 = 1.6$ (bpm^2), with a Q-test $p = 0.120$ again failing to show significant heterogeneity, bearing in mind the limited number of studies. For PWV, heterogeneity was moderate ($I^2 = 48$ %, $\tau^2 = 0.27$ $(m/s)^2$), and the Q-test $p = 0.022$ confirms statistically significant between-study variability.

Arterial Stiffness

Several trials reported measures of vascular stiffness (pulse-wave velocity). Alvarez-Alvarado et al. (2017) observed significant decreases in carotid–femoral and brachial–ankle PWV (with corresponding falls in central systolic BP and augmentation index) in overweight women after WBV. On average, pooled WBV interventions lowered systemic PWV by 0.8 m/s.

DISCUSSION

This meta-analysis found that whole-body vibration exercise (WBVE) produced modest but statistically significant short-term improvements in surrogate cardiovascular markers among randomised trials of young adults. The pooled reductions observed for systolic blood pressure (−7 mmHg), diastolic blood pressure, resting heart rate (−2 bpm), and pulse-wave velocity (−0.9 m/s) are consistent in direction and magnitude with findings from previous randomised trials and systematic reviews examining WBV interventions in healthy, overweight, and metabolically compromised adult populations (Rubio-Arias et al., 2021; Zago et al., 2018). Similar short-term reductions in blood pressure and autonomic indices following multi-week WBV interventions have been reported in young and middle-aged adults, supporting the physiological plausibility of the pooled effects observed here.

These pooled results should be interpreted cautiously. The clinical implications of a 7mmHg systolic blood-pressure reduction depend strongly on baseline cardiovascular risk and the durability of the effect. Risk reductions derived from long-term antihypertensive drug trials or population-based cohort studies cannot be directly applied to the short-term WBV trials conducted in predominantly young, lower-risk adults included in this review. Accordingly, we do not extrapolate these short-term surrogate changes to reductions in cardiovascular events. Instead, the present findings indicate that WBVE can elicit measurable short-term changes in blood pressure, heart rate, and arterial stiffness, while the long-term clinical relevance of these changes remains uncertain and requires confirmation in adequately powered outcome studies (Cornelissen & Smart, 2013).

Several physiological mechanisms may plausibly underlie the observed changes, involving both acute hemodynamic responses and longer-term vascular adaptations. Acute exposure to WBV has been shown to increase peripheral blood flow and oscillatory shear stress, which can transiently enhance endothelium-

dependent vasodilation and nitric oxide bioavailability (Figueroa et al., 2012). Repeated WBV exposure over several weeks may lead to adaptations in arterial compliance and autonomic regulation, potentially contributing to reductions in arterial stiffness and resting heart rate observed in chronic interventions (Zago et al., 2018). However, many mechanistic studies demonstrating these effects are acute or exploratory in nature and were not designed to establish mediation pathways within long-term randomised trials. As such, mechanistic interpretations should be viewed as biologically plausible hypotheses that are consistent with but not proven by the pooled RCT findings.

Heterogeneity among included trials limits inference regarding dose–response relationships. WBV protocols varied substantially in frequency (typically 20–40 Hz), amplitude (1–4 mm), participant posture, session duration, and total intervention length, a limitation widely noted in previous reviews of WBV training (Rubio-Arias et al., 2021; Zago et al., 2018). Exploratory subgroup analyses in the present review suggested larger blood-pressure reductions in trials enrolling participants with overweight or metabolic syndrome and in those using higher vibration frequencies (≥30 Hz); however, these findings are hypothesis-generating and may reflect confounding by protocol differences, population characteristics, or small-study effects rather than true dose-dependent responses.

Limitations

Several important study-design constraints restrict the conclusions that can be drawn from the current evidence base. First, the number of high-quality RCTs for some outcomes (notably HR and PWV) was small, and many trials had modest sample sizes. Second, follow-up was generally short (most ≤ 3 months), so the durability of observed effects is unknown. Third, reporting was variable: some trials did not report change-score variances or full protocol details (frequency, amplitude, posture), which necessitated derivations or imputation for pooled analysis. Fourth, risk-of-bias concerns in some trials and the potential for publication bias, particularly given the small literature, warrant caution. Finally, we found no randomised trials that directly compared WBV head-to-head with conventional aerobic training for blood pressure or resting heart rate, so comparative effectiveness versus standard exercise modalities remains an important unanswered question.

CONCLUSION

This meta-analysis indicates that WBVE interventions are associated with small but statistically significant short-term improvements in systolic and diastolic blood pressure, resting heart rate, and pulse-wave velocity in randomised trials involving predominantly young adults. These outcomes are surrogate cardiovascular markers measured over relatively short intervention periods, and the available evidence does not allow conclusions about long-term cardiovascular benefit or reductions in clinical events. The findings should therefore be interpreted as evidence of physiological responsiveness to WBV rather than as proof of clinically meaningful cardiovascular benefit. The magnitude of pooled effects was modest, and their relevance to populations at higher cardiovascular risk, as well as their durability over time, remains uncertain. Given the characteristics of the included studies, extrapolation to long-term health outcomes or comparisons with established exercise modalities is not justified.

The current evidence base is constrained by a limited number of randomised trials, small sample sizes for some outcomes, short follow-up durations, and substantial variability in WBV protocols and outcome reporting. These factors restrict the precision of pooled estimates and limit inference regarding optimal intervention characteristics. Future research would benefit from larger, well-designed randomised trials with longer follow-up, consistent and transparent reporting of WBV parameters, and comprehensive assessment of cardiovascular, vascular, and metabolic outcomes. Direct comparisons between WBV and conventional aerobic exercise, along with improvements in methodological quality such as preregistration,

blinded outcome assessment, and complete reporting of variance measures, are needed to clarify the role of WBV within the broader context of physical activity and cardiovascular health.

AUTHORS' CONTRIBUTION

Okuneye R.O coordinated the study; he was involved in data analysis, drafting and the interpretation of results. Taiwo A.B conceived the idea, participated in data collection, data analysis, results analysis and drafting of the manuscript. Apalara F.A participated in data collection, data analysis and preparation of the manuscript. Tony Dansu was involved in data analysis, result interpretation and discussion of findings. Oforka O.K, collected data, analysed data and coordinated the data collection process. Ogar E.E was involved in data collection, discussion of findings and manuscript preparation. Yahaya Abdullah was involved in the results, discussion of finding and coordination of the manuscript preparation. Ismail-Orire collected data, processed data and was part of the manuscript draft. Dauda-Olajide, R., was part of data collection, data analysis and manuscript draft for journal submission

CONFLICT OF INTEREST

All authors declared no conflict of interest.

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