ARTICLE IN PRESS

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2019;■:■■■-■■■

REVIEW ARTICLE (META-ANALYSIS)

Whole Body Vibration Exercise for Chronic Musculoskeletal Pain: a Systematic Review and Meta-analysis of Randomized Controlled Trials

Yulin Dong, MS,[a] Wu Wang, BS,[a] Jiejiao Zheng, BS,[b] Su Chen, BS,[a] Jun Qiao, MS,[a,*] Xueqiang Wang, PhD[c,*]

From the [a]Department of Treatment, The Second Rehabilitation Hospital of Shanghai, Shanghai; [b]Rehabilitation Medical Department, Hua Dong Hospital, Shanghai; and the [c]Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai, China.
[*]Qiao and Wang contributed equally to this work.

Abstract

Objective: This study systematically reviews previous work on the effects of whole body vibration exercise (WBVE) on pain associated with chronic musculoskeletal disorders.

Data Sources: Seven electronic databases (PubMed, Embase, CINAHL, Web of Science, Cochrane, Physiotherapy Evidence Database [PEDro], and the China National Knowledge Infrastructure) were searched for articles published between January 1980 and September 2018.

Study Selection: Randomized controlled trials involving adults with chronic low back pain (CLBP), osteoarthritis (OA), or fibromyalgia were included. Participants in the WBVE intervention group were compared with those in the nontreatment and non-WBVE control groups.

Data Extraction: Data were independently extracted using a standardized form. Methodological quality was assessed using PEDro.

Data Synthesis: Suitable data from 16 studies were pooled for meta-analysis. A random effects model was used to calculate between-groups mean differences at 95% confidence interval (CI). The data were analyzed depending on the duration of the follow-up, common disorders, and different control interventions.

Results: Alleviation of pain was observed at medium term (standardized mean difference [SMD], -0.67; 95% CI, -1.14 to -0.21; I^2, 80%) and long term (SMD, -0.31; 95% CI, -0.59 to -0.02; I^2, 0%). Pain was alleviated in osteoarthritis (OA) (SMD, -0.37; 95% CI, -0.64 to -0.10; $P<.05$; I^2, 22%) and CLBP (SMD, -0.44; 95% CI, -0.75 to -0.13; $P<.05$; I^2, 12%). Long-term WBVE could relieve chronic musculoskeletal pain conditions of OA (SMD, -0.46; 95% CI, -0.80 to -0.13; $P<.05$; I^2, 0%). WBVE improved chronic musculoskeletal pain compared with the treatment "X" control (SMD, -0.37; 95% CI, -0.61 to -0.12; $P<.05$; I^2, 26%), traditional treatment control (SMD, -1.02; 95% CI, -2.44 to 0.4; $P>.05$; I^2, 94%) and no treatment control (SMD, -1; 95% CI, -1.76 to -0.24; $P<.05$; I^2, 75%).

Conclusions: Evidence suggests positive effects of WBVE on chronic musculoskeletal pain, and long durations of WBVE could be especially beneficial. However, WBVE does not significantly relieve chronic musculoskeletal pain compared with the traditional treatment. Further work is required to identify which parameters of WBVE are ideal for patients with chronic musculoskeletal pain.

Archives of Physical Medicine and Rehabilitation 2019;■:■■■-■■■

Chronic musculoskeletal pain that last for ≥3 months is a common public health problem.[1] People with chronic musculoskeletal pain suffer from functional disability.[1,2] Nearly half of all patients who visit general practitioners report symptoms of pain,[3] which can affect one's long-term overall quality of life.[4] Chronic musculoskeletal pain is the leading type of chronic pain reported.[5] The most common types of chronic musculoskeletal disorders are chronic low back pain (CLBP), osteoarthritis (OA), and fibromyalgia syndrome.[6] The lifetime prevalence of low back pain is

Supported by the National Natural Science Foundation of China (grant no. 81501956, 81871844), Fok Ying-Tong Education Foundation of China (grant no. 161092), Shanghai Municipal Commission of Health and Family Planning (grant no. 201840346), Shuguang Program supported by Shanghai Education Development Foundation and Shanghai Municipal Education Commission (grant no. 18SG48), and Shanghai Key Lab of Human Performance (Shanghai University of Sport) (grant no. 11DZ2261100).

Clinical Trial Registration No.: CRD42017080546

Disclosures: none.

0003-9993/19/$36 - see front matter © 2019 by the American Congress of Rehabilitation Medicine

https://doi.org/10.1016/j.apmr.2019.03.011

about 84%, and 23% all low back pain cases involve CLBP.[7] OA affects 13.9% of all young adults and 33.6% of the elderly.[8] In European populations, the estimated overall prevalence of fibromyalgia syndrome is between 2.9% and 4.7%. The prevalence of chronic musculoskeletal disorders and mental illnesses is estimated to result in continued losses worth $47 trillion by 2030.[9] Therefore, low-cost and easily accessible treatments with minimal side effects must be developed to address chronic musculoskeletal pain.

Exercise therapy is one of the main methods of various nonpharmacologic treatments.[10] According to the clinical guidelines, exercise therapy is recommended as an effective treatment for reducing pain and improving disability among patients with chronic musculoskeletal disorders.[7,11-13] Whole body vibration exercise (WBVE) is a new type of treatment to cure patients with chronic musculoskeletal pain, which has been used in recent years.[14,15] WBVE can affect central mechanisms, cortical reorganization,[16] and second-order nociceptive activities,[17] thereby reducing pain. A number of randomized collation experiments have concluded that WBVE could reduce pain in patients with chronic musculoskeletal disorders, including women with fibromyalgia syndrome[13] and elderly patients with knee OA.[18] However, previous systematic reviews of knee OA demonstrate that WBVE does not significantly reduce pain, despite findings of pain intensity reduction in the included trials.[19,20] Indeed, the merits of WBVE when used as a treatment for patients with chronic musculoskeletal pain remain debated. Further research must be conducted to confirm the effectiveness of WBVE in patients with chronic musculoskeletal disorders.

In terms of a systematic review of WBVE, previous studies focused on only 1 type of chronic musculoskeletal disorder, such as fibromyalgia[21] and knee OA.[20] To date, only 1 literature review explored the use of WBVE for chronic disorders using 26 papers, 7 of which focused on musculoskeletal conditions; the results indicated that pain seemed to decline in the physiotherapy plus vibration group.[22] Any qualitative reviews may not be valid, because they are more subjective than quantitative meta-analyses.[23] Also, there was no meta-analysis to collect data on all chronic musculoskeletal disorders and examine the effectiveness of WBVE as a treatment for chronic musculoskeletal pain.

Thus, the objective of this systematic review is to evaluate the evidence on the effectiveness of WBVE in reducing pain in patients with chronic musculoskeletal pain conditions and to explore whether WBVE is a viable intervention for chronic musculoskeletal pain. In this review, we first examined whether the required information has been gathered and whether the conclusions obtained are reliable. Next, we conducted the subgroup analyses of the chronic musculoskeletal conditions, control interventions, and durations of WBVE.

List of abbreviations:

CI	**confidence interval**
CLBP	**chronic low back pain**
OA	**osteoarthritis**
PEDro	**Physiotherapy Evidence Database**
RCT	**randomized controlled trial**
SMD	**standardized mean difference**
VAS	**visual analog scale**
WBV	**whole body vibration**
WBVE	**whole body vibration exercise**

Methods

The methods followed in this systematic review are aligned with the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[24]

Inclusion criteria

Seven electronic databases, namely, PubMed, Embase, CINAHL, Web of Science, Cochrane, Physiotherapy Evidence Database (PEDro), and the China National Knowledge Infrastructure were searched for articles published between January 1980 and September 2018. The detailed search strategy for each database is presented in supplemental appendix S1 (available online only at http://www.archives-pmr.org/).

In this study, only studies involving randomized controlled trials (RCTs) were included. The review included full English or Chinese articles with evaluation data, including means and standardized mean difference (SMD). Reviews, systematic reviews, protocols, studies involving animal research, and those without RCTs or clinical research were excluded.

The patients included in the study should have reported chronic musculoskeletal pain lasting for at least 3 months. The condition was defined broadly as pain that affects muscles, tendons, ligaments, and bones. Musculoskeletal disorders included CLBP, OA, rheumatoid arthritis, ankylosing spondylitis, fascia pain, fibromyalgia, and so on. Exclusion criteria for participants were as follows: (1) pregnancy; (2) pain without musculoskeletal disorders; and (3) duration of pain of less than 3 months. WBVE was the only intervention considered. The included studies were required to have 1 primary outcome that focused on pain, such as the visual analog scale (VAS), numeric rating scale, Western Ontario and McMaster Universities Osteoarthritis Index, and facial expression scale score.

Methodological quality

Two authors independently selected full articles based on their titles and abstracts. If the data could not be checked from the original article directly, we contacted the primary authors. If differences were noted between the 2 reviewers, a third author was asked to resolve the issue. We evaluated the methodological quality of the studies using the PEDro scale, which contained 11 items. The PEDro scale is a reliable assessment tool for systematic reviews of physical therapy studies, especially RCTs.[25] The 2 authors performed quality assessment independently.

Data extraction, selection and coding

We collected the baseline of the studies that include the first author, primary report, sample size, mean age, duration of symptoms, main pain outcome assessments, experimental group intervention, control group intervention, and duration of intervention (in weeks). To identify the effects of WBVE on chronic musculoskeletal pain, this meta-analysis compared mean values for pain between WBVE intervention and control groups. Subgroup analyses were then performed. First, this systematic review included various common chronic musculoskeletal diseases, such as OA, CLBP, and other chronic musculoskeletal diseases. Therefore, the subgroup analysis was performed based on different musculoskeletal diseases. Second, the ranges of control interventions were classified as no treatment, traditional treatment, and treatment “X.” Subgroup analysis was conducted based on different control interventions as follows: (1) WBVE plus treatment X vs WBVE; (2) WBVE vs traditional treatment; and (3) WBVE vs no treatment. Third, the subgroup analysis was performed according to the durations of WBVE. The intervention time of all the included studies was ranked from low to high and divided into 3 equal parts, namely, short term (≤4 weeks from randomization), medium term (>4 and ≤12wk) and long term (>12wk).

The final continuous data were presented by SMD and 95% confidence interval (CI), because the scales of the outcome measurements were not the same. We used Review Manager version 5.0[a] to analyze the continuous data through a random effect model. The conclusion was a conservative evaluation of the influence of WBVE training on musculoskeletal disorders. Heterogeneity was assessed using the Cochran Q statistic with a cut-off point of ≥50%. The chi-square test was defined according to the degree of significance; publication bias was assessed using Egger test. A value of $P<.05$ was considered to be statistically significant. Sensitivity analysis was used to assess the results in a consistent and high-quality manner by individually removing each study. The subgroup analysis was conducted on the basis of the different durations of WBVE, as described previously. If 2 or more control groups were involved, we combined the original data according to the calculation formula of the meta-analysis. All data were analyzed using Stata/MP[b] statistical software.

Results

Study selection

A total of 2146 potentially eligible articles were included through our search strategy. A total of 2024 studies were in English, and 122 studies were in Chinese. After excluding the duplicates, we retained 1430 studies. A total of 1367 records were removed because of the following reasons: not related to whole body vibration (WBV) (n=984); not related to musculoskeletal disorders (n=289); not RCTs (n=8); not clinical studies (n=11); not preferred outcomes (n=8); systematic reviews (n=20); reviews (n=27); animal studies (n=14); and protocols (n=6). After assessing 63 full-text articles for eligibility, we identified 44 full-text articles that failed to meet the inclusion criteria. In such

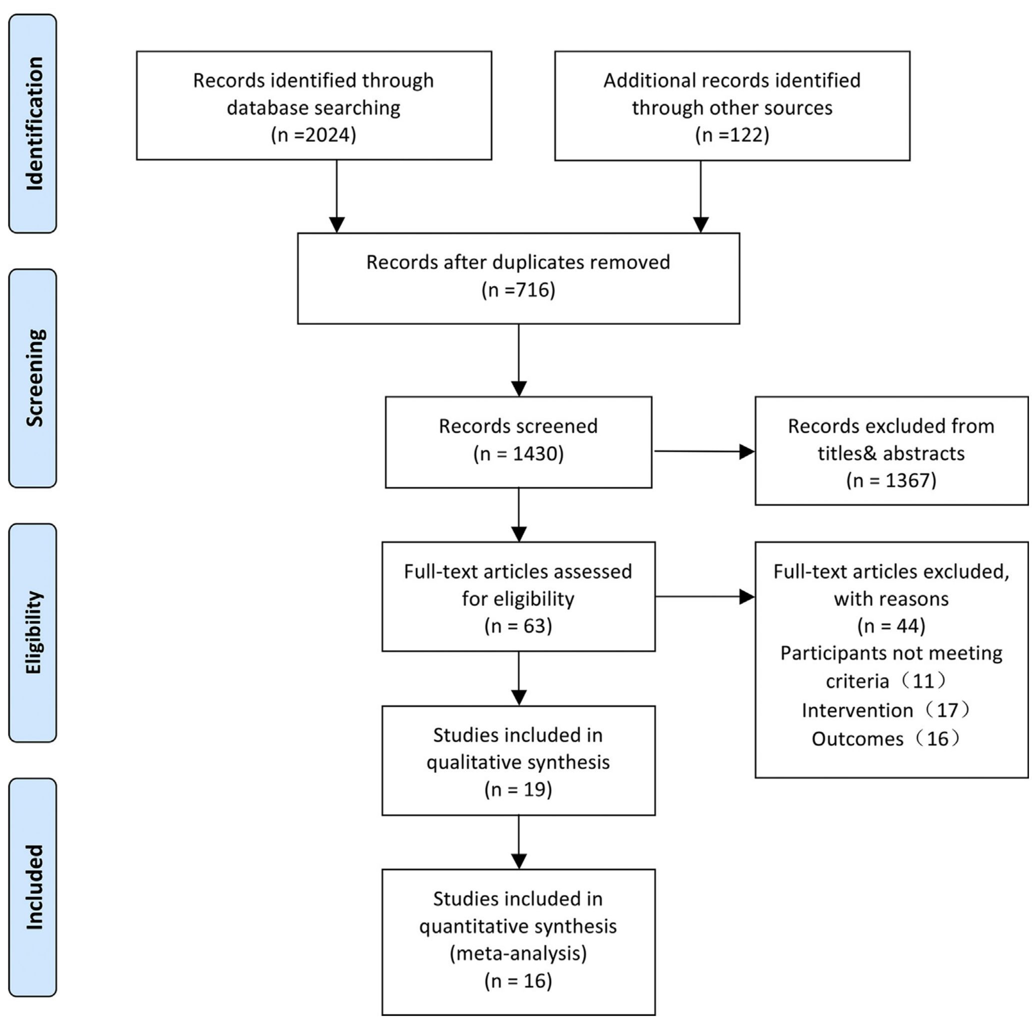


Fig 1 Flow diagram of study selection.

Table 1 Characteristics of included studies

	Primary Report	Sample Size	Mean Age ± SD (y)	Duration of Symptoms ± SD (y)	Main Pain Outcome Assessments	Experimental Group Intervention	Control Group Intervention	Duration of Intervention (wk)
Alentorn-Geli et al[13]	Fibromyalgia	33	55.97±1.55	EVG: 10.1±0.7 EG: 9.8±0.8	VAS	Traditional exercise with WBV: 2/wk	Traditional exercise: 2/wk	6
Avelar et al[18]	Knee OA	21	VG: 75±5 EG: 71±4	NR	WOMAC (self-reported pain)	Squatting exercise with WBV: 3/wk	Squatting exercise: 3/wk	12
Bokaeian et al[28]	Knee OA	28	ST+WBV: 51.8±8.3 ST: 54.0±3.9	NR	VAS	Strength training with WBV: 3/wk	Strength training: 3/wk	8
del Pozo-Cruz et al[15]	Chronic low back pain	49	WBV group: 58.71±4.59 control group: 59.53±5.47	≥0.5	VAS	Standing position with WBV: 2/wk	Normal pattern of daily activity	12
Horstmann et al[38]	Chronic Achilles Tendinopathy	54	46	NR	VAS	Knee slightly bending position with WBV: 3/wk	1. Eccentric training: 3/wk 2. Wait and see	12
Iwamoto et al[37]	Osteoporosis	52	ALN: 70.6±8.7 ALN+EX: 71.9±8.1	NR	Face scale score	one taking alendronate (5 mg daily) with WBV (1/wk)	One taking alendronate; 5 mg daily	12
Park et al[11]	Knee OA	22	WBV with home-based exercise: 60.0±5.7 home-based exercise only: 62.5±6.2	≥0.5	NRS	Home-based exercise with WBV: 3/wk	Home-based exercise	8
Rittweger et al[35]	Chronic Lower Back Pain	60	51.7	≥0.125 (continuously) or ≥2 (intermittently)	VAS	WBVE: 2/wk	Isodynamic lumbar extension: 2/wk	12
Simao et al[33]	Knee OA	31	Control group: 71±5.3 squat group: 69±3.7 platform group: 75±7.4	NR	WOMAC (self-reported pain)	Squatting exercise with WBV: 3/wk	1. Squatting exercise: 3/wk 2. Daily life	12
Tsuji et al[39]	Knee pain	38	WBVE group: 62.1±5.5 control group: 60.9±4.6	NR	VAS	Strength and flexibility training with WBV: 3/wk	Strength and flexibility training with WBV: 3/wk	8
Wang et al[29]	Knee OA	39	WBVE+QSE: 61.1±7.1 QSE: 61.5±7.3	NR	VAS	WBVE+QSE: 5/wk	QSE: 5/wk	12
Wang et al[30]	Knee OA	99	WBVE+QSE: 61.2±9.6 QSE: 61.5±9.1	NR	VAS	WBVE+QSE: 5/wk	QSE: 5/wk	24

(*continued on next page*)

Table 1 (*continued*)

	Primary Report	Sample Size	Mean Age ± SD (y)	Duration of Symptoms ± SD (y)	Main Pain Outcome Assessments	Experimental Group Intervention	Control Group Intervention	Duration of Intervention (wk)
Yang et al[34]	Chronic low back pain	40	lumbar stability training with WBV: 32.80, lumbar stability training: 30.95	≥0.25	VAS	Lumbar stability training with WBV: 3/wk	Lumbar stability training: 3/wk	6
Ke et al[32]	Knee OA	40	57.35±2.98	≥0.5	VAS	Traditional therapy with WBV: 3/wk	Traditional therapy: 3/wk	4
Zhongmiao et al[31]	knee OA	42	47∼78	NR	VAS	WBVE training: 5/wk	Normal pattern of daily activity	3
Binglin et al[36]	Chronic low back pain	46	Exercise therapy with WBV: 25.24±2.22: Exercise therapy: 24.76±1.96	≥0.25	VAS	Exercise therapy with WBV: 3/wk	Exercise therapy: 3/wk	12

NOTE. Intervention/dose: number of intervention time/number of sessions.
Abbreviations: ALN, taking alendronate; EG, exercise group; EVG, exercise and vibration group; EX, exercise; NR, not reported; NRS, numeric rating scale; QSE, quadriceps strengthening exercise; ST, strength training; VG, vibration group; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 2 PEDro scale of quality for included trials

Study	Random Allocation	Concealed Allocation	Similar at Baseline	Subjects Blinded	Therapists Blinded	Assessors Blinded	<15% Dropouts	Intention to Treat	Between-Group Comparisons
Alentorn-Geli et al[13]	Yes	No	Yes	No	No	Yes	Yes	No	Yes
Avelar et al[18]	Yes	No	Yes	No	No	No	Yes	No	Yes
Bokaeian et al[28]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
del Pozo-Cruz et al[15]	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes
Horstmann et al[38]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Iwamoto et al[37]	Yes	No	Yes	No	No	No	No	No	Yes
Park et al[11]	Yes	No	Yes	No	No	No	No	No	Yes
Rittweger et al[35]	Yes	No	Yes	No	No	No	No	Unclear	Yes
Simao et al[33]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Tsuji et al[39]	Yes	Yes	Yes	No	No	No	Yes	No	Yes
Wang et al[29]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Wang et al[30]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes
Yang et al[34]	Yes	No	Yes	No	No	No	Yes	No	Yes
Ke et al[32]	Yes	Yes	Yes	No	No	No	Yes	No	Yes
Zhongmiao et al[31]	Yes	Unclear	Yes	No	No	Yes	No	No	Yes
Binglin et al[36]	Yes	Unclear	Yes	No	No	Yes	Yes	No	Yes

studies, the participants did not report any chronic pain for at least 3 months, the intervention was not WBVE, and the outcome was not a pain scale. According to the response, we excluded 2 studies[12,26] because of data loss. Moreover, we excluded 1 study[27] because it had no clear intervention time. Finally, 16 records (13 trials in English and 3 trials in Chinese) were included in our meta-analysis. The details of the selection process are presented in figure 1.

Characteristics of included studies

The characteristics of the 16 included studies comprise a total of 680 patients who reported chronic musculoskeletal disorders, such as fibromyalgia,[13] knee OA,[11,18,28-33] CLBP,[15,34-36] osteoporosis,[37] and chronic Achilles tendinopathy.[38] These characteristics are summarized in table 1. The main outcome measure was pain intensity, whereas others used the VAS, numeric rating scale, and the Western Ontario and McMaster Universities Osteoarthritis Index (pain). The duration of the included studies ranging from 3 weeks to 24 weeks. The follow-up time ranged from 3 weeks to 12 months. Sixteen studies were RCTs. In most of the interventions, WBVE involved combination of exercises. Examples include traditional exercise with WBV,[13] squatting exercise with WBV,[18] exercise therapy with WBV, and so on.[36] A range of controls was used, including home-based exercise,[11] normal pattern of daily activity[31] and some other exercise.

The methodological quality of all the included articles was assessed, as shown in table 2. If “yes” was 1 point and “no or unclear” was 0 points, the mean method methodological quality of included studies was 4.875. Across all trials, the subjects and therapists were not blinded to the treatments, and 4 trials had a dropout rate of more than 15%.[11,31,35,37] In addition, unclear allocation concealments were observed in 9 trials because of the absence of details.[11,13,15,18,31,33-37,39] The baseline, random allocation, between-group comparisons and point measures and variability data met the criteria in all of the trials. Only 2 of the 16 trials performed an intention-to-treat analysis.[15,29] Nine trials reported that the right assessors were blinded,[13,15,28-31,33,36,38] whereas the remaining 7 trials did not report this setting clearly.

As demonstrated in the Methods section, the reported outcomes for the experimental and the control groups were compared.

WBVE for chronic musculoskeletal pain

Data from 16 of the included studies were suitable for meta-analysis. The total number of participants in the WBVE groups was 328, whereas that in the control groups was 342. Although the fixed effects model did not show effect on the results, we analyzed the data with a relatively conservative random effects model. The total result demonstrated that WBVE achieved better gains than the control in terms of relieving chronic musculoskeletal pain (SMD, -0.48; 95% CI, -0.81 to -0.16; P<.05; I^2, 74%) noted in figure 2.

Short-term effects of WBVE on chronic musculoskeletal pain

The subgroup analysis was performed on the basis of the different durations of WBVE for chronic musculoskeletal pain. In terms of WBVE as an intervention to reduce pain, no more than 4 weeks were considered short-term duration. These subgroups included 4 cases of knee OA[11,30-32,35] and 1 case of CLBP.[35] The results indicated that WBV did not significantly relieve chronic musculoskeletal pain (SMD, -0.09; 95% CI, -0.61 to 0.43; P>.05; I^2, 72%) noted in figure 3.

Medium-term effects of WBVE on chronic musculoskeletal pain

For medium term (>4 and ≤12 weeks), the WBVE group showed improvements in chronic musculoskeletal pain (SMD, -0.67; 95% CI, -1.14 to -0.21; P<.05; I^2, 80%) (see fig 3). These groups included 1 case of fibromyalgia,[13] 5 cases of knee OA,[11,18,28,29,33] 4 cases of CLBP,[15,34-36] 1 case of chronic Achilles tendinopathy,[38] and 1 case of knee pain.[39]

Long-term effects of WBVE on chronic musculoskeletal pain

For long-term effects (>12 weeks), the whole body vibration group showed improvements in chronic musculoskeletal pain (SMD, -0.31; 95% CI, -0.59 to -0.02; P<.05; I^2, 0%) (see fig 3).[29,30,37] Three trials reported long-term effects of WBVE on chronic musculoskeletal pain, including 2 cases of knee OA[29,30] and 1 case of osteoporosis.[37] Two RCTs on knee OA assessed

Study or Subgroup	WBV Mean	WBV SD	WBV Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
5.2.1 OA								
Avelar 2011	-109	33.5	11	-95	36.78	10	5.4%	-0.38 [-1.25, 0.48]
Bokaeian 2016	-3.6	2.89	15	-4.4	3	11	5.9%	0.26 [-0.52, 1.05]
Ke Liu,2015	-0.93	1.65	20	-0.32	1.79	20	6.7%	-0.35 [-0.97, 0.28]
Park 2013	-1.45	1.73	11	-0.63	2.33	11	5.5%	-0.38 [-1.23, 0.46]
Simao, NLM	-137.5	162	10	-62.5	51.61	11	5.4%	-0.61 [-1.49, 0.27]
Wang 2016	-4.8	1.11	19	-4.2	1.18	20	6.6%	-0.51 [-1.15, 0.13]
Wang 2016a	-12.73	2.3	49	-12.42	2.32	50	7.9%	-0.13 [-0.53, 0.26]
Zhong miao, 2005	-1.42	1.83	33	0.89	1.89	9	5.8%	-1.23 [-2.02, -0.44]
Subtotal (95% CI)			**168**			**142**	**49.2%**	**-0.37 [-0.64, -0.10]**
Heterogeneity: Tau² = 0.03; Chi² = 8.93, df = 7 (P = 0.26); I² = 22%								
Test for overall effect: Z = 2.65 (P = 0.008)								
5.2.2 CLBP								
Binlin 2016	-1.78	0.91	23	-1.31	0.73	23	6.9%	-0.56 [-1.15, 0.03]
del 2011	-9.36	15.99	25	0.14	15.4	24	7.0%	-0.60 [-1.17, -0.02]
Rittweger 2002	-2.4	1.76	25	-2.4	2	25	7.1%	0.00 [-0.55, 0.55]
Yang 2015	-2.9	1.59	20	-1.75	1.7	20	6.6%	-0.68 [-1.32, -0.05]
Subtotal (95% CI)			**93**			**92**	**27.5%**	**-0.44 [-0.75, -0.13]**
Heterogeneity: Tau² = 0.01; Chi² = 3.42, df = 3 (P = 0.33); I² = 12%								
Test for overall effect: Z = 2.76 (P = 0.006)								
5.2.3 other chronic musculoskeletal diseases								
Alentorn-Geli 2008	-27	3.03	11	-3.62	5.04	22	3.1%	-5.08 [-6.57, -3.59]
Horstmann 2013	-20.9	34.88	22	-28.04	32.8	32	7.1%	0.21 [-0.34, 0.75]
Iwamoto 2005	-2.2	1.21	25	-1.7	1.1	25	7.0%	-0.43 [-0.99, 0.14]
Tsuji 2014	-0.7	20.5	9	-4.9	20.3	29	6.0%	0.20 [-0.55, 0.95]
Subtotal (95% CI)			**67**			**108**	**23.3%**	**-1.08 [-2.47, 0.32]**
Heterogeneity: Tau² = 1.82; Chi² = 44.64, df = 3 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 1.51 (P = 0.13)								
Total (95% CI)			**328**			**342**	**100.0%**	**-0.48 [-0.81, -0.16]**
Heterogeneity: Tau² = 0.31; Chi² = 57.44, df = 15 (P < 0.00001); I² = 74%								
Test for overall effect: Z = 2.92 (P = 0.003)								
Test for subgroup differences: Chi² = 1.00, df = 2 (P = 0.61), I² = 0%								

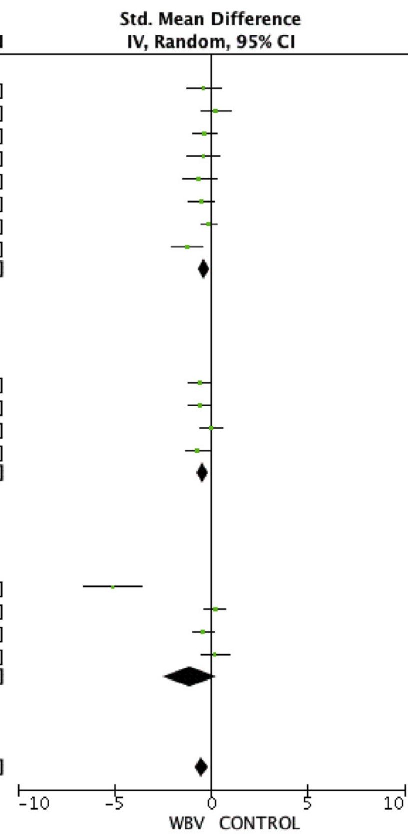


Fig 2 Forest plot of the subgroup analyses of WBVE for chronic musculoskeletal pain based on different diseases after intervention. SMD (95% CI) was calculated from 8 studies for OA, 4 studies for CLBP, and 4 studies for other chronic musculoskeletal diseases.

the long-term effects of WBVE after 16 weeks of follow-up[29] and 24 weeks of follow-up[30]; both RCTs reported that WBVE showed positive effects on pain. The same results were obtained in trials on osteoporosis.[37]

WBVE for chronic musculoskeletal pain in different diseases

The subgroup analysis was based on WBVE for chronic musculoskeletal pain in common disorders such as OA,[11,18,28-33,37] CLBP,[15,34-36] and other chronic musculoskeletal diseases.[13,38,39] The aggregated results of 16 RCTs indicated that WBVE alleviated the condition of patients with OA (SMD, -0.37; 95% CI, -0.64 to -0.10; $P<.05$; I^2, 22%) (see fig 2). In addition, significant differences were observed in WBVE for pain in patients with CLBP[15,34-36] (SMD, -0.44; 95% CI, -0.75 to -0.13; $P<.05$; I^2, 12%) (see fig 2). Furthermore, no significant differences were observed in WBVE for pain in patients suffering from other chronic musculoskeletal diseases (SMD, -1.08; 95% CI, -2.47 to 0.32; $P>.05$; I^2, 93%) (see fig 2).

Different durations of WBVE for OA

The subgroup analyses of WBVE for chronic musculoskeletal pain conditions of OA based on different durations of WBVE. In the short-term (≤4wk; SMD, -0.47; 95% CI, -1.1 to 0.16; $P>.05$; I^2, 71%) (fig 4) and medium-term (>4 and≤12wk; SMD, -0.31; 95% CI, -0.65 to 0.04; $P>.05$; I^2, 0%) (see fig 4) periods, WBVE did not significantly reduce pain in patients with OA. The results were same to the medium term. However, the WBVE group experienced improvements in pain for the long term (>12wk; SMD, -0.46; 95% CI, -0.80 to -0.13; $P<.05$; I^2, 0%) (see fig 4).

WBVE for chronic musculoskeletal pain in different control interventions

The subgroup analysis was performed on the basis of various control interventions. Squatting exercise,[18] strength training,[28,39] home-based exercise,[11,39] lumbar stability training,[34,35] and quadriceps strengthening exercise[29,30] were included in the treatment X. Treatments involving alendronate,[37] eccentric training,[37] traditional exercise,[13,32] and isodynamic lumbar extension[35] were included in the traditional treatment group. Normal pattern of daily activity,[15,31] wait and see,[37,38] and daily life[33] were included in no treatment group. The results indicated that WBVE plus treatment X compared with the treatment X alone (SMD, -0.37; 95% CI, -0.61 to -0.12; $P<.05$; I^2, 26%) (fig 5), WBVE compared with traditional treatment (SMD, -1.02; 95% CI, -2.44 to 0.40; $P>.05$; I^2, 94%) (see fig 5) and no treatment (SMD, -1; 95% CI, -1.76 to -0.24; $P<.05$; I^2, 75%) (see fig 5).

Publication bias

The Egger test for all the trials included in the meta-analyses was evaluated for publication bias. The value of the Egger test showed evidence of publication bias ($P=.008$; 95% CI, -0.48 to -1.50).

Adverse events

Four studies included a statement of related adverse events.[13,15,28,35] One patient felt anxious during WBVE at first, but the patient ultimately completed the intervention. Three subjects did not show up on testing day.[13] Fourteen participants did

Study or Subgroup	[WBV]Experimental Mean	SD	Total	[CONTROL]Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
6.1.1 short term								
Park 2013	−0.27	1.81	11	−0.73	1.92	11	4.5%	0.24 [−0.60, 1.08]
Zhong miao, 2005	−1.42	1.83	33	0.89	1.89	9	4.7%	−1.23 [−2.02, −0.44]
Ke Liu,2015	−0.93	1.65	20	−0.32	1.79	20	5.3%	−0.35 [−0.97, 0.28]
Rittweger 2002	−1.5	1.74	25	−2.3	2.1	25	5.5%	0.41 [−0.15, 0.97]
Wang 2016a	−8.8	2.46	49	−9.42	2.31	50	6.1%	0.26 [−0.14, 0.65]
Subtotal (95% CI)			**138**			**115**	**26.0%**	**−0.09 [−0.61, 0.43]**
Heterogeneity: Tau² = 0.25; Chi² = 14.51, df = 4 (P = 0.006); I² = 72%								
Test for overall effect: Z = 0.35 (P = 0.73)								
6.1.2 medium term								
Alentorn-Geli 2008	−27	3.03	11	−3.62	5.04	22	2.6%	−5.08 [−6.57, −3.59]
Simao, NLM	−137.5	162	10	−62.5	51.61	11	4.3%	−0.61 [−1.49, 0.27]
Avelar 2011	−109	33.5	11	−95	36.78	10	4.4%	−0.38 [−1.25, 0.48]
Park 2013	−1.45	1.73	11	−0.63	2.33	11	4.4%	−0.38 [−1.23, 0.46]
Bokaeian 2016	−3.6	2.89	15	−4.4	3	11	4.7%	0.26 [−0.52, 1.05]
Tsuji 2014	−0.7	20.5	9	−4.9	20.3	29	4.8%	0.20 [−0.55, 0.95]
Yang 2015	−2.9	1.59	20	−1.75	1.7	20	5.2%	−0.68 [−1.32, −0.05]
Wang 2016	−4.8	1.11	19	−4.2	1.18	20	5.2%	−0.51 [−1.15, 0.13]
Horstmann 2013	−20.9	34.88	22	28.04	32.8	32	5.3%	−1.43 [−2.04, −0.82]
Binlin 2016	−1.78	0.91	23	−1.31	0.73	23	5.4%	−0.56 [−1.15, 0.03]
del 2011	−9.36	15.99	25	0.14	15.4	24	5.5%	−0.60 [−1.17, −0.02]
Rittweger 2002	−2.4	1.76	25	−2.4	2	25	5.5%	0.00 [−0.55, 0.55]
Subtotal (95% CI)			**201**			**238**	**57.2%**	**−0.67 [−1.14, −0.21]**
Heterogeneity: Tau² = 0.52; Chi² = 55.70, df = 11 (P < 0.00001); I² = 80%								
Test for overall effect: Z = 2.83 (P = 0.005)								
6.1.3 long term								
Wang 2016	−4	1.11	19	−3.2	1.43	20	5.2%	−0.61 [−1.25, 0.03]
Iwamoto 2005	−2.2	1.21	25	−1.7	1.1	25	5.5%	−0.43 [−0.99, 0.14]
Wang 2016a	−12.73	2.3	49	−12.42	2.32	50	6.1%	−0.13 [−0.53, 0.26]
Subtotal (95% CI)			**93**			**95**	**16.8%**	**−0.31 [−0.59, −0.02]**
Heterogeneity: Tau² = 0.00; Chi² = 1.77, df = 2 (P = 0.41); I² = 0%								
Test for overall effect: Z = 2.08 (P = 0.04)								
Total (95% CI)			**432**			**448**	**100.0%**	**−0.46 [−0.76, −0.16]**
Heterogeneity: Tau² = 0.35; Chi² = 83.94, df = 19 (P < 0.00001); I² = 77%								
Test for overall effect: Z = 2.98 (P = 0.003)								
Test for subgroup differences: Chi² = 2.86, df = 2 (P = 0.24), I² = 30.1%								

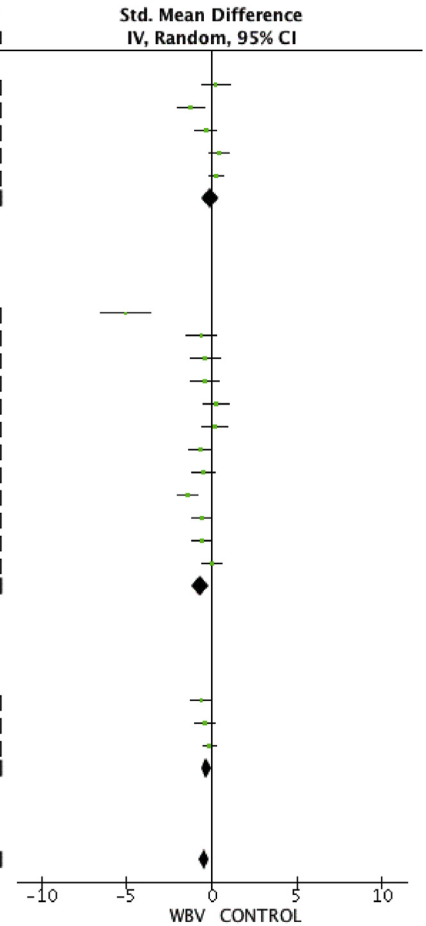


Fig 3 Forest plot of the subgroup analyses of WBVE for chronic musculoskeletal pain based on different durations of WBVE. SMD (95% CI) was calculated from 7 studies for short term, 12 studies for medium term, and 3 studies for long term.

Study or Subgroup	WBV Mean	SD	Total	CONTROL Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.2.1 short term for OA								
Ke Liu,2015	−0.93	1.65	20	−0.32	1.79	20	32.5%	−0.35 [−0.97, 0.28]
Wang 2016a	−10.24	2.37	49	−10.12	2.33	50	40.1%	−0.05 [−0.44, 0.34]
Zhong miao, 2005	−1.42	1.83	33	0.89	1.89	9	27.4%	−1.23 [−2.02, −0.44]
Subtotal (95% CI)			**102**			**79**	**100.0%**	**−0.47 [−1.10, 0.16]**
Heterogeneity: Tau² = 0.22; Chi² = 6.93, df = 2 (P = 0.03); I² = 71%								
Test for overall effect: Z = 1.46 (P = 0.15)								
1.2.2 medium term for OA								
Avelar 2011	−109	33.5	11	−95	36.78	10	15.6%	−0.38 [−1.25, 0.48]
Bokaeian 2016	−3.6	2.89	15	−4.4	3	11	19.2%	0.26 [−0.52, 1.05]
Park 2013	−1.45	1.73	11	−0.63	2.33	11	16.4%	−0.38 [−1.23, 0.46]
Simao, NLM	−137.5	162	10	−59.52	181.9	21	20.2%	−0.43 [−1.19, 0.33]
Wang 2016	−4.8	1.11	19	−4.2	1.18	20	28.7%	−0.51 [−1.15, 0.13]
Subtotal (95% CI)			**66**			**73**	**100.0%**	**−0.31 [−0.65, 0.04]**
Heterogeneity: Tau² = 0.00; Chi² = 2.61, df = 4 (P = 0.63); I² = 0%								
Test for overall effect: Z = 1.75 (P = 0.08)								
1.2.3 long term for OA								
Wang 2016	−4	1.11	19	−3.2	1.43	20	27.7%	−0.61 [−1.25, 0.03]
Wang 2016a	−11.67	2.36	49	−10.7	2.35	50	72.3%	−0.41 [−0.81, −0.01]
Subtotal (95% CI)			**68**			**70**	**100.0%**	**−0.46 [−0.80, −0.13]**
Heterogeneity: Tau² = 0.00; Chi² = 0.27, df = 1 (P = 0.60); I² = 0%								
Test for overall effect: Z = 2.69 (P = 0.007)								
Test for subgroup differences: Chi² = 0.47, df = 2 (P = 0.79), I² = 0%								

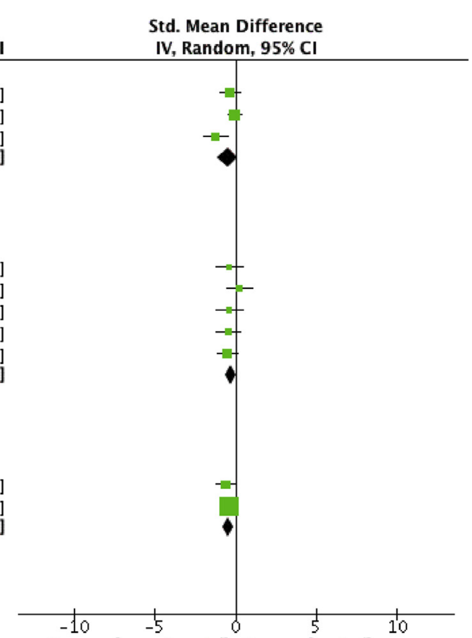
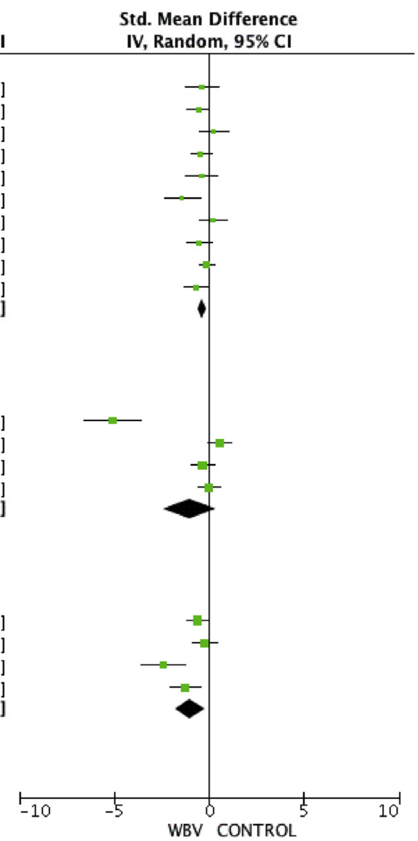


Fig 4 Forest plot of the subgroup analyses of WBVE for chronic musculoskeletal pain conditions of OA based on different durations of WBVE. SMD (95% CI) was calculated from 3 studies for short term, 4 studies for medium term, and 2 studies for long term.

Study or Subgroup	[WBV]Experimental Mean	SD	Total	[CONTROL]Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
7.1.1 WBV + X vs X								
Avelar 2011	−109	33.5	11	−95	36.78	10	6.6%	−0.38 [−1.25, 0.48]
Binlin 2016	−1.78	0.91	23	−1.31	0.73	23	11.8%	−0.56 [−1.15, 0.03]
Bokaeian 2016	−3.6	2.89	15	−4.4	3	11	7.8%	0.26 [−0.52, 1.05]
Iwamoto 2005	−2.2	1.21	25	−1.7	1.1	25	12.7%	−0.43 [−0.99, 0.14]
Park 2013	−1.45	1.73	11	−0.63	2.33	11	6.8%	−0.38 [−1.23, 0.46]
Simao, NLM	−137.5	50.2	10	−62.5	51.61	12	5.5%	−1.42 [−2.37, −0.46]
Tsuji 2014	−0.7	20.5	9	−4.9	20.3	29	8.3%	0.20 [−0.55, 0.95]
Wang 2016	−4.8	1.11	19	−4.2	1.18	20	10.6%	−0.51 [−1.15, 0.13]
Wang 2016a	−12.73	2.3	49	−12.42	2.32	50	19.3%	−0.13 [−0.53, 0.26]
Yang 2015	−2.9	1.59	20	−1.75	1.7	20	10.6%	−0.68 [−1.32, −0.05]
Subtotal (95% CI)			**192**			**211**	**100.0%**	**−0.37 [−0.61, −0.12]**
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 12.23$, df = 9 (P = 0.20); $I^2 = 26\%$								
Test for overall effect: Z = 2.94 (P = 0.003)								
7.1.2 WBV vs Traditional treatment								
Alentorn-Geli 2008	−27.03	3.03	11	−3.62	5.04	22	21.1%	−5.09 [−6.58, −3.59]
Horstmann 2013	−20.9	34.88	22	−39.9	30.13	19	26.2%	0.57 [−0.06, 1.20]
Ke Liu,2015	−0.93	1.65	20	−0.32	1.79	20	26.2%	−0.35 [−0.97, 0.28]
Rittweger 2002	−2.7	1.78	25	−2.7	1.78	25	26.5%	0.00 [−0.55, 0.55]
Subtotal (95% CI)			**78**			**86**	**100.0%**	**−1.02 [−2.44, 0.40]**
Heterogeneity: $Tau^2 = 1.90$; $Chi^2 = 47.53$, df = 3 (P < 0.00001); $I^2 = 94\%$								
Test for overall effect: Z = 1.40 (P = 0.16)								
7.1.3 WBV vs No treatment								
del 2011	−9.36	15.99	25	0.14	15.4	24	28.6%	−0.60 [−1.17, −0.02]
Horstmann 2013	−20.9	34.88	22	−12.8	35.82	16	27.4%	−0.22 [−0.87, 0.42]
Simao, NLM	−137.5	50.2	10	10	65.25	12	19.1%	−2.41 [−3.56, −1.26]
Zhong miao, 2005	−1.42	1.83	33	0.89	1.89	9	25.0%	−1.23 [−2.02, −0.44]
Subtotal (95% CI)			**90**			**61**	**100.0%**	**−1.00 [−1.76, −0.24]**
Heterogeneity: $Tau^2 = 0.44$; $Chi^2 = 12.19$, df = 3 (P = 0.007); $I^2 = 75\%$								
Test for overall effect: Z = 2.59 (P = 0.010)								



Test for subgroup differences: $Chi^2 = 3.09$, df = 2 (P = 0.21), $I^2 = 35.2\%$

Fig 5 Forest plot of the subgroup analyses of WBVE for chronic musculoskeletal pain based on different interventions in control groups after intervention. SMD (95% CI) was calculated from 10 studies for "WBVE+treatment X" vs "treatment X alone," 4 studies for "WBVE vs traditional treatment," and 4 studies for "WBVE vs no treatment."

not complete the experiments. Three participants did not have sufficient time or interest to attend the training.[15,28] One study included 9 participants with CLBP who dropped out of the experiment because of unspecified causes.[35]

Discussion

In this meta-analysis, we searched for a certain number of studies and gathered evidence to evaluate the effects of WBVE on chronic musculoskeletal pain. The overall findings showed that WBVE is related to significant improvements in pain from chronic musculoskeletal disease. Subgroup analysis demonstrated that short-term WBVE did not significantly alleviate chronic musculoskeletal pain. By contrast, long-term WBVE presented improvements in patients with chronic musculoskeletal pain. Therefore, the long durations of WBVE for chronic musculoskeletal pain are more beneficial than short durations.

WBVE is a type of mechanical vibration that is transmitted through the body via different musculoskeletal structures, such as muscles, bones, cartilage, and joints. The tonic vibration reflexes and spinal and supraspinal neurophysiological mechanisms were considered to be the underlying reasons explaining the positive effects of WBVE on musculoskeletal structures and neuromuscular responses.[40] In addition, given that WBVE is a clinical intervention, the appropriate duration of treatment is required. Acute WBVE may affect microscopic changes in musculoskeletal structures, such as the degree of muscle activity[41] and the properties of the intramuscular connective tissue.[42] Short-term WBVE is unable to relieve chronic musculoskeletal pain. In a previous clinical study, the WBVE was conducted for 20 weeks to improve muscle function[43] and 12 weeks to improve quality of life[44] and decrease pain.[15] Long-term WBVE could sufficiently enable the adjustment of the musculoskeletal system, such that chronic musculoskeletal pain could be effectively treated.

According to the subgroup analysis, the aggregated results indicated that WBVE is more effective for treating chronic musculoskeletal pain than no treatment and treatment X alone. This finding reveals that WBVE could be an effective complementary intervention to cure chronic musculoskeletal disorders.[13,22,29,30,45] However, WBV did not significantly relieve chronic musculoskeletal pain compared with the traditional treatment. Traditional treatments harness the knowledge, skills, and practices based on the theories, beliefs, and experiences of different cultures.[46] In the current meta-analysis, traditional treatments included exercise therapies, such as eccentric training,[38] isodynamic lumbar extension,[35] and other traditional exercises.[13,32] Traditional exercise, as a form of nondrug therapy, provides patients with benefits related to chronic musculoskeletal pain.[6]

This systematic review assessed the effects of WBVE on chronic musculoskeletal pain associated with various common diseases. The results of subgroup analysis demonstrated that WBVE shows good effects in improving chronic musculoskeletal pain caused by OA and CLBP. Furthermore, the long-term WBVE could relieve pain in patients with OA. Previous systematic reviews report that WBVE does not reduce pain in patients with knee OA.[19,20,47] Differences in the results may be the result of differences in the eligible studies and the duration of WBVE. In addition, the different parameters of WBVE (duration, exercises or vibration frequencies) may have different effects on chronic musculoskeletal pain.[48-50] Thus, further work is required to identify which parameters of WBVE are ideal for patients with chronic musculoskeletal pain.

We used the chi-square test and I-square statistic to evaluate heterogeneity among the studies. The quality and consistency of the results were tested by sensitivity analysis that could solve the issue of heterogeneity. Moreover, we conducted sensitivity analysis by removing each study individually. In this review, the overall result was stable when the sensitivity analysis was performed. Only 1 study[13] indicated an effect on the degree of heterogeneity (from $I^2=75\%$ to $I^2=35\%$). This study[13] reported on WBVE for chronic musculoskeletal pain in patients with fibromyalgia. The main reason for the high sensitivity could mainly be due to fact that the disease was different from others. Moreover, heterogeneity appears to be influenced by various factors, such as different control groups, effective or ineffective results, and so on.[51] In future investigations, we need additional moderator analyses or subanalyses to identify the various sources of heterogeneity and minimize heterogeneity as much as possible. Even though the study showed influence on the degree of heterogeneity, the overall effect size was still not affected ($P<.05$). According to the stable P value, we concluded that these results were reliable and stable.

Strengths and study limitations

We gathered the selected articles from a wild range of electronic databases, such as PubMed, Cochrane Library CINAHL (EBSCO), Web of Science, PEDro, Embase, and the China National Knowledge Infrastructure. Our results represented global studies, because the selected studies originated from Asia, Africa, Europe, and South America. Two reviewers selected the articles, extracted data, and assessed quality independently to reduce bias and transcription errors. In contrast to previous studies, our meta-analysis involved an adequate number of eligible studies to obtain reliable results.[19,20] Furthermore, detailed subgroup analyses were performed in 3 aspects (different diseases, control interventions, and durations of WBVE). We identified the effectiveness of WBVE for chronic musculoskeletal pain. Thus, this meta-analysis could serve as a sufficient reference for clinical practice.

However, our review has several limitations. First, even though we used a rigorous search strategy in the review, we had to exclude a number of good studies because of language restrictions.[52] We could not identify the languages, except for Chinese and English. Therefore, we easily ignored clinical studies that failed to meet the inclusion criteria. Second, we were not able to access all the available data that could be applied to our meta-analysis, because the data were limited or excessive and were provided in a different manner, thereby preventing us from obtaining data for our meta-analysis.[12,26] This characteristic could be considered a limitation of this review, because we did not know whether the final results were influenced by data loss. Third, although all of the included studies were RCTs, only 7 studies (44%) reported how other studies concealed patient allocation. Considering the principle of intention to treat, only 2 studies involved intention-to-treat analysis that considered potential risk biases and detection biases.[53] Finding patients and therapists for WBVE studies is challenging, but blinded assessors and concealed allocations can remedy the limitations.[23] Fourth, few eligible RCTs for long term, daily life, and CLBP were noted in the subgroup analysis, which would reliably influence the subresults. Fifth, the only outcome was pain intensity (VAS), which was described by SMD and random effects in this meta-analysis. Our review indicated various outcome measures to affect conclusions potentially. Sixth, few adverse events happened in WBVE studies. However, we were unable to confirm whether WBVE was completely safe for patients. WBVE involved a low risk of injury for patients with chronic musculoskeletal diseases.

Implications for policy and practice

WBVE is a type of training method that can improve neuromuscular performance in healthy people[54] and clinical patients.[55] Considering the popularity of WBVE, many clinicians, researchers, policymakers, and other health care professionals are interested in the effectiveness, safety, and quality of WBVE. Our meta-analysis demonstrated that WBVE could relieve pain in patients with chronic musculoskeletal disorders, and a long duration of WBVE could be especially beneficial. The results identified the significance of scientific and clinical research. They also provided useful information for patients with chronic musculoskeletal conditions, clinicians, and healthcare policymakers as they view other valid treatment options.

Conclusions

Evidence suggests the positive effects of WBVE on chronic musculoskeletal pain and long durations of WBVE could be especially beneficial. WBVE showed a more positive effect compared with no treatment, and WBVE plus treatment X showed better effects than treatment X alone only in reducing pain caused by chronic musculoskeletal disorders. However, WBVE did not significantly relieve chronic musculoskeletal pain compared with the traditional treatment. Further work is required to identify which parameters of WBVE are ideal for patients with chronic musculoskeletal pain.

Suppliers

a. Review Manager, version 5.0 (RevMan 5); the Cochrane Collaboration.
b. Stata/MP 14.1; Stata Corp.

Keywords

Chronic pain; Meta-analysis; Musculoskeletal diseases; Rehabilitation; Systematic review

Corresponding author

Jun Qiao, MD, Department of Treatment, The Second Rehabilitation Hospital of Shanghai, 25 Changjiang Road, Shanghai, China. *E-mail address:* qiaojun19791117@126.com.

References

1. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012;380:2163-96.
2. Bjornsdottir SV, Jonsson SH, Valdimarsdottir UA. Functional limitations and physical symptoms of individuals with chronic pain. Scand J Rheumatol 2013;42:59-70.
3. Mantyselka P, Kumpusalo E, Ahonen R, et al. Pain as a reason to visit the doctor: a study in Finnish primary health care. Pain 2001;89:175-80.
4. Park PW, Dryer RD, Hegeman-Dingle R, et al. Cost burden of chronic pain patients in a large integrated delivery system in the United States. Pain Pract 2016;16:1001-11.
5. Gatchel RJ. Musculoskeletal disorders: primary and secondary interventions. J Electromyogr Kinesiol 2004;14:161-70.
6. O'Connor SR, Tully MA, Ryan B, et al. Walking exercise for chronic musculoskeletal pain: systematic review and meta-analysis. Arch Phys Med Rehabil 2015;96:724-34.
7. Airaksinen O, Brox JI, Cedraschi C, et al. Chapter 4. European guidelines for the management of chronic nonspecific low back pain. Eur Spine J 2006;15:S192-300.
8. Lawrence RC, Felson DT, Helmick CG, et al. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II. Arthritis Rheum 2008;58:26-35.
9. Marrero S, Adashi EY. Noncommunicable diseases. Semin Reprod Med 2015;33:35-40.
10. Alizadeh R, Shariat A, Nakhostin Ansari N, et al. Office-based exercise therapy as a non-pharmacological treatment for discogenic low back pain among army staff. Iran J Public Health 2018;47:1969-70.
11. Park YG, Kwon BS, Park JW, et al. Therapeutic effect of whole body vibration on chronic knee osteoarthritis. Ann Rehabil Med 2013;37:505-15.
12. Trans T, Aaboe J, Henriksen M, Christensen R, Bliddal H, Lund H. Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. Knee 2009;16:256-61.
13. Alentorn-Geli E, Padilla J, Moras G, Lazaro Haro C, Fernandez-Sola J. Six weeks of whole-body vibration exercise improves pain and fatigue in women with fibromyalgia. J Altern Complement Med 2008;14:975-81.
14. Nordlund MM, Thorstensson A. Strength training effects of whole-body vibration? Scand J Med Sci Sports 2007;17:12-7.
15. del Pozo-Cruz B, Hernandez Mocholi MA, Adsuar JC, Parraca JA, Muro I, Gusi N. Effects of whole body vibration therapy on main outcome measures for chronic non-specific low back pain: a single-blind randomized controlled trial. J Rehabil Med 2011;43:689-94.
16. Gay A, Parratte S, Salazard B, et al. Proprioceptive feedback enhancement induced by vibratory stimulation in complex regional pain syndrome type I: an open comparative pilot study in 11 patients. Joint Bone Spine 2007;74:461-6.
17. Melzack R, Wall PD. Pain mechanisms: a new theory. Science 1965;150:971-9.
18. Avelar N, Simão A, Tossige-Gomes R, et al. The effect of adding whole-body vibration to squat training on the functional performance and self-report of disease status in elderly patients with knee osteoarthritis: a randomized, controlled clinical study. J Altern Complement Med 2011;17:1149-55.
19. Li X, Wang XQ, Chen BL, Huang LY, Liu Y. Whole-body vibration exercise for knee osteoarthritis: a systematic review and meta-analysis. Evid Based Complement Alternat Med 2015;2015:1-11.
20. Wang P, Yang X, Yang Y, et al. Effects of whole body vibration on pain, stiffness and physical functions in patients with knee osteoarthritis: a systematic review and meta-analysis. Clin Rehabil 2015;29:939-51.
21. Moretti E, Tenorio A, Holanda L, Campos A, Lemos A. Efficacy of the whole-body vibration for pain, fatigue and quality of life in women with fibromyalgia: a systematic review. Disabil Rehabil 2018;40:988-96.
22. Chanou K, Gerodimos V, Karatrantou K, Jamurtas A. Whole-body vibration and rehabilitation of chronic diseases: a review of the literature. J Sports Sci Med 2012;11:187-200.
23. Kong LJ, Lauche R, Klose P, et al. Tai chi for chronic pain conditions: a systematic review and meta-analysis of randomized controlled trials. Sci Rep 2016;6:25325.
24. Knobloch K, Yoon U, Vogt PM. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement and publication bias. J Craniomaxillofac Surg 2011;39:91-2.
25. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther 2003;83:713-21.
26. Alev A, Mihriban A, Bilge E, et al. Effects of whole body vibration therapy in pain, function and depression of the patients with fibromyalgia. Complementary Ther Clin Pract 2017;28:200-3.
27. Maddalozzo GF, Kuo B, Maddalozzo WA, Maddalozzo CD, Galver JW. Comparison of 2 multimodal interventions with and without whole body vibration therapy plus traction on pain and disability in patients eith nonspecific chronic low back pain. J Chiropr Med 2016;15:243-51.
28. Bokaeian HR, Bakhtiary AH, Mirmohammadkhani M, Moghimi J. The effect of adding whole body vibration training to strengthening training in the treatment of knee osteoarthritis: a randomized clinical trial. J Bodyw Mov Ther 2016;20:334-40.
29. Wang P, Yang L, Li H, et al. Effects of whole-body vibration training with quadriceps strengthening exercise on functioning and gait parameters in patients with medial compartment knee osteoarthritis: a randomised controlled preliminary study. Physiotherapy 2016;102:86-92.
30. Wang P, Yang L, Liu C, et al. Effects of whole body vibration exercise associated with quadriceps resistance exercise on functioning and quality of life in patients with knee osteoarthritis: a randomized controlled trial. Clin Rehabil 2016;30:1074-87.
31. Zhongmiao T, Yulin X, Lulin Li, et al. Clinical experimental study on the treatment of osteoarthritis by vibrotherapy. J Tradit Chin Orthop Trauma 2005;17:387-8.
32. Ke L, Guang C, Yueqiao H, et al. Effectiveness of whole body vibration therapy on knee osteoarthritis: a randomized controlled study. Biomed Eng Clin Med 2015:609-12.
33. Simao AP, Avelar NC, Tossige-Gomes R, et al. Functional performance and inflammatory cytokines after squat exercises and whole-body vibration in elderly individuals with knee osteoarthritis. Arch Phys Med Rehabil 2012;93:1692-700.
34. Yang J, Seo D. The effects of whole body vibration on static balance, spinal curvature, pain, and disability of patients with low back pain. J Phys Ther Sci 2015;27:805-8.
35. Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D. Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. Spine (Phila Pa 1976) 2002;27:1829-34.
36. Binglin C. Effect of whole body vibration for neuromuscular function in patients with chronic low back pain[D]. Shanghai universtity of sports; 2016. Available at: http://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CMFD&dbname=CMFD201701&filename=1016243333.nh&v=MTA2NDIxTHV4WVM3RGgxVDNxVHJXTTFGckNVUkxPZll1Wm5GeXptVWJ6UFZGMjZHTEc4SGRMUHJKRWJQSVI4ZVg=. Accessed May 16, 2019.
37. Iwamoto J, Takeda T, Sato Y, Uzawa M. Effect of whole-body vibration exercise on lumbar bone mineral density, bone turnover, and chronic back pain in post-menopausal osteoporotic women treated with alendronate. Aging Clin Exp Res 2005;17:157-63.
38. Horstmann T, Jud HM, Frohlich V, Mundermann A, Grau S. Whole-body vibration versus eccentric training or a wait-and-see approach for chronic Achilles tendinopathy: a randomized clinical trial. J Orthop Sports Phys Ther 2013;43:794-803.
39. Tsuji T, Yoon J, Aiba T, Kanamori A, Okura T, Tanaka K. Effects of whole-body vibration exercise on muscular strength and power, functional mobility and self-reported knee function in

middle-aged and older Japanese women with knee pain. Knee 2014;21:1088-95.
40. Zaidell LN, Mileva KN, Sumners DP, Bowtell JL. Experimental evidence of the tonic vibration reflex during whole-body vibration of the loaded and unloaded leg. PLoS One 2013;8:e85247.
41. Marin PJ, Garcia-Gutierrez MT, Da Silva-Grigoletto ME, Hazell TJ. The addition of synchronous whole-body vibration to battling rope exercise increases skeletal muscle activity. J Musculoskelet Neuronal Interact 2015;15:240-8.
42. Donahue RB, Vingren JL, Duplanty AA, Levitt DE, Luk HY, Kraemer WJ. Acute effect of whole-body vibration warm-up on footspeed quickness. J Strength Cond Res 2016;30:2286-91.
43. Högler W, Scott J, Bishop N, et al. The effect of whole body vibration training on bone and muscle function in children with osteogenesis imperfecta. J Clin Endocrinol Metab 2017;102:2734-43.
44. Chang SF, Lin PC, Yang RS, Yang RJ. The preliminary effect of whole-body vibration intervention on improving the skeletal muscle mass index, physical fitness, and quality of life among older people with sarcopenia. BMC Geriatr 2018;18:17.
45. Prusak K, Prusak K, Mahoney J. An integrated mind-body approach to arthritis: a pilot study. J Tradit Complement Med 2014;4:99-107.
46. Shankar PR. Essential medicines and health products information portal. J Pharmacol Pharmacother 2014;5:74-5.
47. Zafar H, Alghadir A, Anwer S, Al-Eisa E. Therapeutic effects of whole-body vibration training in knee osteoarthritis: a systematic review and meta-analysis. Arch Phys Med Rehabil 2015;96:1525-32.
48. Piecha M, Juras G, Krol P, Sobota G, Polak A, Bacik B. The effect of a short-term and long-term whole-body vibration in healthy men upon the postural stability. PLoS One 2014;9:e88295.
49. Dong Y, Wang H, Zheng Y, et al. Analysis of surface electromyography of lumbo- abdominal muscles in patients with chronic low back pain under different vibration conditions. Chin J Rehab Med 2018;33:297-303.
50. Wirth B, Zurfluh S, Müller R. Acute effects of whole-body vibration on trunk muscles in young healthy adults. J Electromyogr Kinesiol 2011;21:450-7.
51. Lee JH. The effects of music on pain: a meta-analysis. J Music Ther 2016;53:430-77.
52. von Stengel S, Kemmler W, Mayer S, Engelke K, Klarner A, Kalender WA. [Effect of whole body vibration exercise on osteoporotic risk factors] [German]. Dtsch Med Wochenschr 2009;134:1511-6.
53. Wang X, Pi Y, Chen B, et al. Effect of traditional Chinese exercise on the quality of life and depression for chronic diseases: a meta-analysis of randomised trials. Sci Rep 2015;5:15913.
54. Rehn B, Lidstrom J, Skoglund J, Lindstrom B. Effects on leg muscular performance from whole-body vibration exercise: a systematic review. Scand J Med Sci Sports 2007;17:2-11.
55. Pang MY. Whole body vibration therapy in fracture prevention among adults with chronic disease. World J Orthop 2010;1:20-5.