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Review Article

The effects of whole-body vibration training for chronic low back pain: re-visiting the evidence through an analysis of clinical studies

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Abstract: Objective: This study aims to identify the potential benefits of whole-body vibration training (WBVT) to treat chronic low back pain (CLBP) patients through an analysis of clinical studies. Methods: Randomized controlled trials published from December 1, 1999 to July 1, 2019 (RCTs) about WBVT's effects on CLBP were searched in PubMed, Web of Science, The Cochrane Library, Springer Link, Science Direct, Embase and AMED. Two reviewers independently assessed the bias risk of the included literature and extracted the data. The data analysis was conducted using Revman 5.3 and Stata 12.0. Results: Six RCTs with 384 patients were included in this analysis. The results revealed that, compared with the control group, WBVT showed better improvement in the visual analog scale (VAS) scores [WMD = -0.52, 95% CI (-0.92, -0.13), P = 0.010], the Oswestry disability index (ODI) [WMD = -4.75, 95% CI (-6.90, -2.59), P < 0.0001], the Roland-Morris disability questionnaire (RMDQ) scores [WMD = -1.73, 95% CI (-3.23, -0.24), P = 0.02], the SF-36 Physical health summary scores [WMD = 3.87, 95% CI (1.68, 6.05), P = 0.0005], and the SF-36 Mental health summary scores [WMD = 4.74, 95% CI (1.99, 7.50), P = 0.0007], with significant statistical differences. None of the included studies reported any adverse events. Conclusion: The current evidence suggests possible improvements in pain intensity, lumbar dysfunction, and quality of life of patients with CLBP through WBVT. However, a detailed analysis of quality RCTs is needed for identifying the optimum parameters and establishing WBVT as effective treatment modality for CLBP.

Keywords: Whole-body vibration training, chronic low back pain, randomized controlled trials, systematic review, meta-analysis

Introduction

Low back pain (LBP) is a major global public health problem, and its incidence is increasing each year, especially in adults over 30 years old [1]. Epidemiological studies indicate that the incidence of LBP is as high as 80%, with an associated disability rate of about 10% [2]. In addition, 2-7% of patients with acute LBP are expected to suffer from chronic low back pain (CLBP) when the LBP course exceeds 12 weeks [3]. It not only reduces patients' quality of life and work-related efficiency, it also increases the direct and indirect social costs and the medical burden [4, 5]. Previous studies have confirmed that exercise intervention can be effective at improving lumbar function and relieving pain in patients with CLBP [6, 7]. However, such traditional exercise training methods have been less attractive due to their exercise overload [8, 9]. Therefore, the quick and effective rehabilitation of CLBP using alternative exercise therapies has always been an interesting area of research for clinicians.

In recent years, whole body vibration training (WBVT) has become increasingly popular as a new type of muscle strength training [10]. WBVT generates preset sinusoidal vibration through the vibration platform. When the vibration stimulation is transmitted to the adjacent muscle groups through the limbs, the muscle length changes rapidly, thus resulting in the tonic vibration reflex. This in turn increases the activation level of the active muscle and the frequency of the motor evoked potential, improving the excitability of the neuromuscular system [11]. Currently, WBVT is being applied intermittently for the treatment of LBP. Some studies have shown that WBVT can alleviate pain and improve proprioception [12, 13]. However, other studies have shown that WBVT cannot improve CLBP [14], and may even aggravate the disease [15].

In response to the disparate research results, this study used the meta-analysis method to systematically evaluate the impact of WBVT on CLBP and to provide reliable, evidence-based medical evidence for clinicians.

Methods

Search strategy

PubMed, Web of Science, The Cochrane Library, Springer Link, Science Direct, Embase and AMED were searched online for RCTs for the effects of WBVT on CLBP. We searched for articles published from December 1, 1999 to July 1, 2019, and the language was limited to English.

The retrieval strategy was based on a combination of subject words and free text words. Taking PubMed as an example, the retrieval strategy was as follows: (whole body vibration OR body vibration OR vibration) AND (low back pain OR low back OR nonspecific low back pain OR low lumbar).

Inclusion criteria

(1) Types of studies: The included studies were RCTs published in English. (2) Types of participants: The included patients met the CLBP diagnostic criteria established by the American College of Physicians and the American Pain Society [16] and were in the age range of 18-70 years irrespective of gender and had CLBP persisting for approximately 12 weeks or longer. They had good consciousness and cognitive function. Moreover, they had signed informed consents and showed high compliance towards the recommended interventions. (3)Types of interventions: The patients in the experimental group (EG) only received WBVT treatment with a vibration frequency of ≤ 30 Hz, and the amplitude and intensity were not restricted. The patients in the control group (CG) only received traditional rehabilitation training, such as strength training and stretching exercises. (4) Types of outcome measures: 1) pain evaluation: Visual analogue scale (VAS), 2) disability evaluation: Oswestry disability index (ODI), Roland-Morris disability questionnaire (RMDQ), 3) health related quality of life assessment: the MOS 36-item short form health survey (SF-36) was used. It consists of 8 dimensions totaling 36 items. According to the standard scoring method, the total physical health (contains 4 dimensions of general health, physical function, role physical, and bodily pain) and mental health (contains 4 dimensions of vitality, social function, role emotional, and mental health) scores were calculated. The total physical health and mental health scores were calculated according to the standard scoring method [4]. 4) adverse events (such as worsening of pain, vomiting, dizziness, etc.).

Exclusion criteria

(1) CLBP caused by a tumor, a spinal infection, lumbar disc herniation, a fracture, visceral disease, etc., (2) Patients also suffering from severe cardiovascular, cerebrovascular, nervous system, or metabolic diseases, (3) Duplicate publications, (4) Lack of relevant indicators, and (5) Non-randomized controlled trials.

Study selection and data extraction

The imported bibliographic records were entered into Endnote 7.0 software. Two reviewers (Y.-J.L. and L.J.) independently screened the articles according to our inclusion and exclusion criteria, and they extracted and reviewed the data. The extracted information included: the study publication details (author, year of publication), the sample size, sex, age, WBVT frequency, the interventions, the duration of the intervention, the country, and the main outcomes.

Quality assessment

Two reviewers independently evaluated the methodological quality of the included literature using the physiotherapy evidence database (PEDro) scale. The PEDro scale is widely used to assess the methodological quality of clinical research and to accurately rate internal

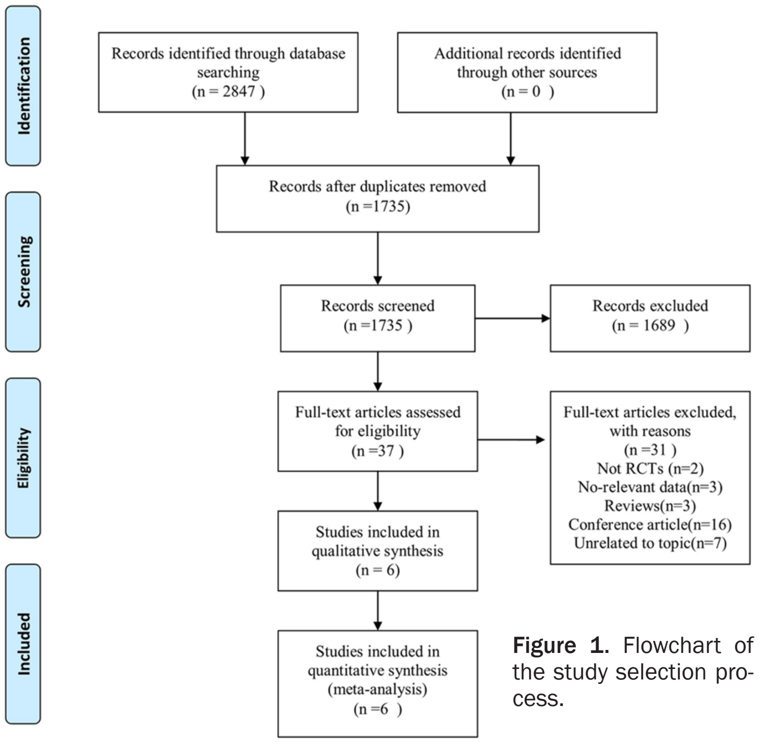

Figure 1. Flowchart of the study selection process.

study validity [17, 18]. It contains 11 items with a total possible score of 10 points (The item "eligibility criteria" is not included in the final score). Studies with a PEDro score ≥6 points are deemed to be of high methodological quality [19]. No studies were excluded based on poor methodological quality [19]. At the end of the evaluation, the two reviewers exchanged and compared the results of their evaluations. If there was any disagreement, the research group discussed and resolved it with a mutual consensus.

Statistical analysis

RevMan 5.3 software (*Review Manager 5.3*, Cochrane Collaboration) and Stata 12.0 were used for the data analysis. The outcome indicators of this study were continuous data. If the outcome indicators were quantified using different measurement tools or scales, the standard mean difference (SMD) with a 95% confidence interval (CI) was used for the meta-analysis. If the outcome indicators were quantified using the same measurement tools or scales, the weighted mean difference (WMD) with a 95% confidence interval (CI) was used for the meta-analysis [18]. We took into account the potential heterogeneity factors (sample sizes of the study populations, durations of the interventions, vibration frequencies, etc.) among the studies that affected the final results, so the random-effects model was chosen for the meta-analysis [17]. Tests for heterogeneity among the included studies were carried out using the I^2 statistic. Heterogeneity was interpreted as low ($I^2 \leq 25\%$), moderate ($25\% < I^2 \leq 50\%$), high ($50\% < I^2 \leq 75\%$), or considerable ($I^2 > 75\%$). We used a subgroup analysis to investigate the factors that may lead to heterogeneity [17]. If the source of the heterogeneity was unknown or the included article could not be quantitatively combined, a descriptive analysis was performed. The stability of the results was verified using a sensitivity analysis. Begg and Egger tests were conducted to evaluate the publication bias using the Stata 12.0 software.

Results

Search results

A flowchart of the study selection process is shown in **Figure 1**. 2,847 studies were retrieved by searching PubMed and the other databases according to the predefined search strategy. After removing 1,112 duplicates, 1,689 studies were excluded after we read the titles and abstracts and 31 articles were excluded after we read the full text. In the end, 6 RCTs [20-25] were included in our analysis.

Study characteristics

The basic characteristics of the included studies are presented in **Table 1**. These RCTs were published between 2002 and 2019. Their sample sizes ranged from 20 to 125, for a total size of 384 (219 males and 165 females). The patients' average ages ranged from 21.6 to 59.5 years. The included studies were conducted in Germany [22, 24], Spain [25], the United States [23], China [21] and Korea [20]. Among these studies, all the experimental groups used

Table 1. Study characteristics

Study (author/year)	Sample size	Sex	age	WBVT Frequency (Hz)	Interventions	Duration of intervention	Country	Main outcomes
	EG/CG	M/F	EG/CG		EG/CG			
Kaeding 2017	21/20	13/28	46.4±9.3/44.6±9.1	10-30 Hz	WBVT/Traditional rehabilitation	12 weeks	Germany	ODI, RMDQ, SF-36 Physical health and Mental health summary score
Maddalozzo 2016	70/55	75/50	55.1±18.8/50.1±11.3	20-30 Hz	WBVT/Traditional rehabilitation	12 weeks	USA	ODI
Pozo-Cruz 2011	25/24	28/21	58.7±4.6/59.5±5.5	20 Hz	WBVT/Traditional rehabilitation	12 weeks	Spain	VAS, ODI, RMDQ
Rittweger 2002	30/30	26/34	54.1±3.4/49.8±6.6	18 Hz	WBVT/Traditional rehabilitation	12 weeks	Germany	VAS
Wang 2019	45/44	65/24	21.6±3.0/22.0±4.6	18 Hz	WBVT/Traditional rehabilitation	12 weeks	China	VAS, ODI, SF-36 Physical health and Mental health summary score
Yang 2015	10/10	12/8	32.8/31.0	18 Hz	WBVT/Traditional rehabilitation	6 weeks	Korea	VAS, ODI

EG: experimental group; CG: control group; M: male; F: female; ODI: Oswestry disability index; VAS: Visual analogue scale; RMDQ: Roland-Morris disability questionnaire; SF-36: the MOS 36-item short from health survey.

Table 2. Physiotherapy evidence database (PEDro) scores of the included studies

study	Eligibility criteria	Randomized allocation	Blinded allocation	Group Homogeneity	Blinded subjects	Blinded Therapists	Blinded assessor	Drop Out < 15%	Intention to-treat analysis	Between group comparison	Point estimates And variability	PEDro score
Kaeding 2017	●	●	●	●	○	●	●	●	○	●	●	8
Maddalozzo 2016	●	●	○	●	○	○	○	○	●	●	●	5
Pozo-Cruz 2011	●	●	○	●	○	○	○	●	●	●	●	6
Rittweger 2002	●	●	○	●	○	○	○	●	●	●	●	6
Wang 2019	●	●	●	●	○	○	●	●	○	●	●	7
Yang 2015	●	●	○	●	○	○	○	●	●	●	●	6

● adds a point on the score, ○ adds no point on the score. The item "eligibility criteria" is not included in the final score.

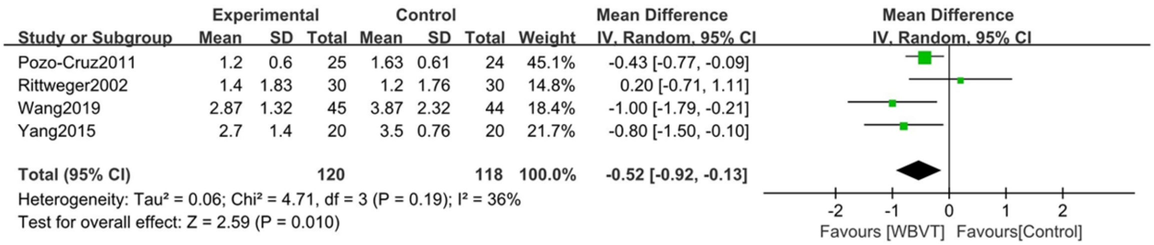

Figure 2. Forest plot for the WBVT effects on the VAS.

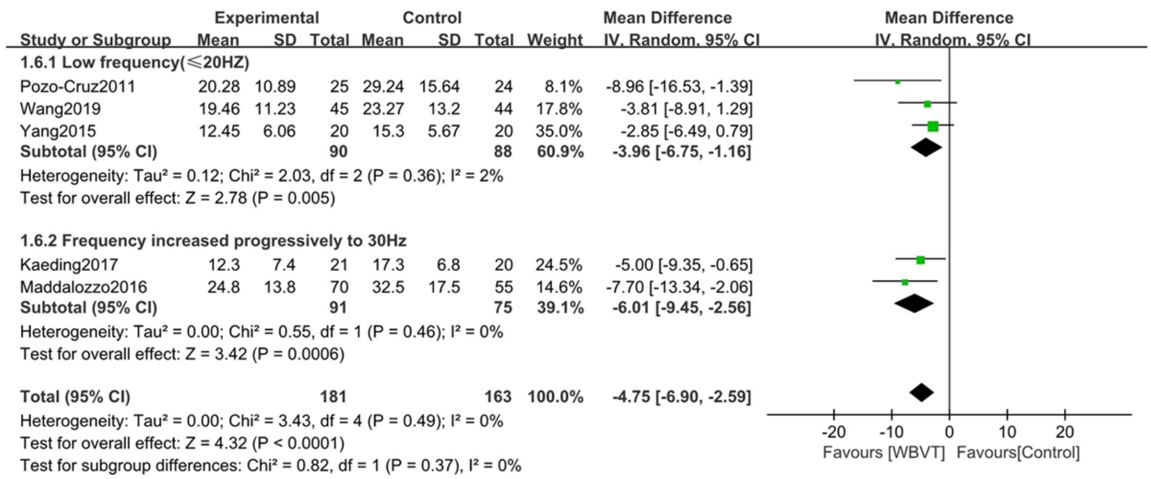

Figure 3. Forest plot for the WBVT effects on the ODI.

WBVT, and the vibration frequency was between 18 and 30 Hz. Moreover, the durations of the intervention were mostly 12 weeks, except for one study [20] that employed a WBVT intervention for 6 weeks.

Quality assessment

The specific quality assessment of the included studies is shown in **Table 2**. The total scores of the PEDro scale of the included studies ranged from 5 to 8. Five studies [20-22, 24, 25] were assessed as high-quality and one study [23] as low-quality. None of the studies blinded the patients with CLBP, one study [24] blinded the therapists, two studies [21, 24] blinded the assessor, and four studies [20, 22, 23, 25] reported an intention-to-treat analysis.

Meta-analysis findings

VAS: A total of 238 patients were included in the four RCTS [20-22, 25]. The heterogeneity test showed that there was moderate statistical heterogeneity among the studies (P = 0.19, I^2 = 36%). The results showed that WBVT improved the pain intensity of the CLBP patients in the EG as compared to the CG, as indicated by a significant statistical difference [WMD = -0.52, 95% CI (-0.92, -0.13), P = 0.010] (**Figure 2**). In the included studies, only Yang's [20] intervention lasted for 6 weeks. When this study was excluded, we found that there was no significant statistical difference between the EG and the CG [WMD = -0.44, 95% CI (-0.96, 0.08), P = 0.09, I^2 = 48%], indicating that the results were not stable. In addition, it should be noted that the largest weighting was 45.1% among the studies for VAS, giving the impression that the synthesis largely reflects the results of the study of Pozo-Cruz, et al.

ODI: A total of 344 patients were included in the five RCTS [20, 21, 23-25]. The heterogeneity test showed that there was a low statistical heterogeneity among the studies (P = 0.49, I^2 = 0%). The analyses showed that WBVT had significantly improved the lumbar function in patients in the EG compared to the patients in the CG [WMD = -4.75, 95% CI (-6.90, -2.59), P < 0.0001] (**Figure 3**).

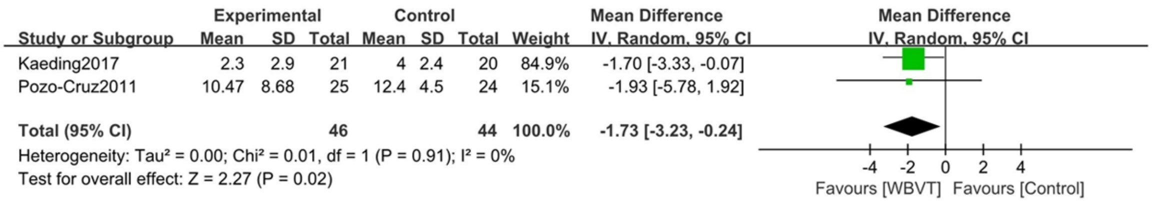

Figure 4. Forest plot for the WBVT effects on the RMDQ.

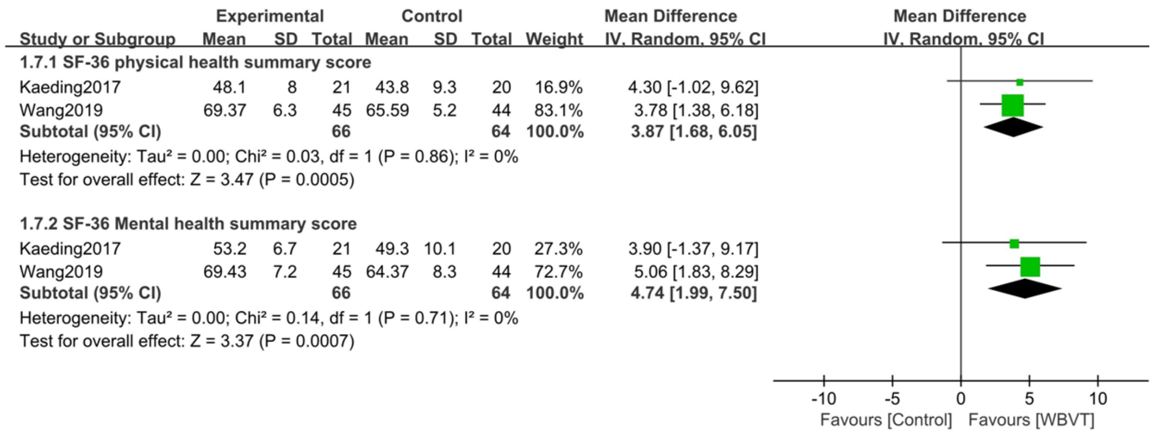

Figure 5. Forest plot for the WBVT effects on the SF-36 health related quality of life summary scores.

We considered that different vibration frequencies may have different effects on the ODI results. Therefore, according to the vibration frequencies of the included studies, we divided the studies into two subgroups: low frequency (< 20 Hz) and frequency increased progressively to 30 Hz. The subgroup results of low frequency (< 20 Hz) showed that the WBVT in the EG was superior to the CG at improving lumbar function [WMD = -3.96, 95% CI (-6.75, -1.16), P = 0.005, I^2 = 2%]. When Yang 2015 [20] was excluded due to the intervention time of 6 weeks, the low frequency WBVT was still better at improving lumbar function in the EG compared to the CG [WMD = -5.59, 95% CI (-10.39, -0.79), P = 0.02, I^2 = 18%], indicating the stability of the results. The subgroup results of frequency increased progressively to 30 Hz showed that the WBVT in the EG was better than it was in the CG at improving lumbar function [WMD = -6.01, 95% CI (-9.45, -2.56), P = 0.0006, I^2 = 0%]. In addition, based on current evidence, there was no significant statistical difference between the two subgroups (P = 0.37).

RMDQ: A total of 90 patients were included in the two RCTS [21, 24]. The heterogeneity test showed that there was a low significant statistical heterogeneity among the studies (P = 0.91, I^2 = 0%). The results showed that the WBVT in the EG was better than it was in the CG at improving lumbar function as indicated by the significant statistical difference [WMD = -1.73, 95% CI (-3.23, -0.24), P = 0.02] (**Figure 4**).

SF-36 health related quality of life summary score

A total of 130 patients were included in the two RCTS [21, 24]. The heterogeneity test showed that there was low significant statistical heterogeneity among the studies (P = 0.86, I^2 = 0%). When compared with the CG, the analysis showed that the WBVT had significantly improved the physical health of the patients in the EG [WMD = 3.87, 95% CI (1.68, 6.05), P = 0.0005] (**Figure 5**).

The effects of the WBVT on the mental health of the CLBP patients were analyzed in the 130 patients recruited in the same two studies [21, 24] used for the analysis of the patients' health-related quality of life. The heterogeneity test showed that there was a low significant statisti-

Table 3. Publication bias test of VAS and ODI

Main outcomes	Begg test		Egger test	
	Z value	*P* value	T value	*P* value
VAS	-0.340	1.000	-0.170	0.881
ODI	1.710	0.086	-3.130	0.052

cal heterogeneity among the studies ($P = 0.71$, $I^2 = 0\%$). When compared with the CG, the analysis showed that WBVT had significantly improved the mental health of the patients in the EG [WMD = 4.74, 95% CI (1.99, 7.50), $P = 0.0007$] (**Figure 5**).

Adverse events

None of the included studies reported any adverse events.

Publication bias

Both the Begg and Egger tests were conducted to assess the publication bias of VAS and ODI, and they indicated no significant publication bias among all the included studies (**Table 3**).

Discussion

To the best of our knowledge, this is the first analysis evaluating the effects of WBVT on CLBP. RCTs on the effects of WBVT on CLBP have been reported in multiple sources. Six studies that included 384 patients were identified. We chose a random effects model rather than a fixed effects model after considering the heterogeneity of multi-studies. The results of our analysis showed that WBVT can possibly relieve pain intensity, improve lumbar function, and improve quality of life.

One of the most-common clinical symptoms, chronic pain not only brings unpleasant subjective feelings and emotional experiences to patients, it also causes physiological disorders [26]. VAS has always been widely used worldwide as a e highly reliable and valid pain evaluation scale [27]. Therefore, we used VAS as an tool for assessing the pain of the patients with CLBP. The results of our analysis showed that WBVT is superior to traditional rehabilitation at improving pain, which is consistent with the findings of Zheng [28] and Lee [29]. The reason for the improvement may be that regular low-frequency vibration can activate the large nerve fibers (A-beta fibers) and excite the glial cells (SG cells) in the dorsal horn of the spinal cord, and then promote the SG cells to release inhibitory transmitters to the brain transfer cells (T cells), thus preventing the small nerve fibers (C fibers) from transmitting pain signals to the central nervous system, and finally relieving the pain [30]. In this VAS study, the vibration frequencies of the included studies were all within 20 Hz, which is a low-frequency vibration [28]. Therefore, based on the current evidence, we might conclude that low-frequency WBVT can effectively alleviate the pain of patients with CLBP. Rittweger [31] also explained that a vibration frequency lower than 20 Hz can promote muscle relaxation and reduce lumbar pain caused by paraspinal muscle spasms, which is consistent with our results. In the included studies, only Yang's [20] intervention lasted for 6 weeks. When the study was removed, we found that there was no significant statistical difference between the EG and the CG, and the heterogeneity was also enhanced to varying degrees, indicating that the results were not stable. This further indicates that the results of the study need to be treated with caution.

Patients with CLBP usually experience varying degrees of lumbar dysfunction. ODI and RMQ are preferred for assessing low back pain-related functional status due to their consistency and the reliability of their results. Thus, we analyzed lumbar function both terms of their ODI and RMQ scores [32, 33]. The analysis showed that WBVT was superior to traditional rehabilitation at reducing the ODI and RMQ scores, indicating that WBVT can effectively improve the lumbar function of patients with CLBP, which is consistent with the findings of Lee [29] and Arora [32]. The reason for the improvement may be related to the enhancement of trunk muscle strength. Previous studies have shown that WBVT can activate the trunk muscles and promote their contraction, and then it improves the neuromuscular recruitment ability of the trunk muscles and the coordination ability between the muscle groups, thus enhancing the stability of the lumbar vertebrae, and finally improving the lumbar function of patients with CLBP [34, 35]. According to the vibration frequency of the included studies, ODI was divided into two subgroups: low frequency (< 20 Hz) and frequency increased progressively to 30 Hz. The results show that both subgroups of

WBVT were effective at improving the lumbar function in patients with CLBP. In addition, based on the current evidence, there was no significant statistical difference between the two subgroups. Moreover, when Yang 2015 [20] was excluded due to the study's intervention time of 6 weeks, the low frequency WBVT was still superior to traditional rehabilitation at improving lumbar function, indicating that the results were stable. However, the small number of included studies may reduce the credibility of the results. Thus, further investigation with a larger number of studies is needed so this effect can be neutralized by the large population size.

CLBP has a long disease course and recurrent attacks, so it causes both physical and mental suffering in patients and seriously reduces their health-related quality of life. Therefore, assessing health-related quality of life is of great significance in determining the therapeutic efficacy of patients with CLBP. The SF-36 scale, which had good reliability and validity, has been widely used to evaluate the quality of life of all types of people [36]. In this study, health related quality of life was assessed using the SF-36 scale in terms of both physical health and mental health. The results of the analysis showed that WBVT is better than traditional rehabilitation at improving the total physical and mental health scores, indicating that WBVT can effectively improve the health-related quality of life in patients with CLBP, which is consistent with the findings of Pozo-Cruz [25]. However, our analysis of these parameters was based on the results of only two primary studies [21, 24], so its reliability might not be much higher and can be questioned in clinical settings considering WBVT as a treatment strategy for rehabilitation of CLBP. The authors conclude that more high-quality studies are needed for further validation of our findings.

In our study, we found WBVT to be safe, and this safety may be related to the shorter intervention time (7-15 minutes) and the stable vibration frequency (no random changes). However, the treatment is contraindicated for CLBP caused by certain conditions such as pregnancy, severe osteoporosis, severe cardiovascular distress, fractures, and the dislocation of lumbar joint, tumors, etc. In addition, if symptoms such as dizziness, nausea, and the worsening of pain appear during the WBVT intervention, the training should be immediately stopped.

Given the subjective and objective conditions, our study has certain limitations. First, we only included the English medical literature, so we might have a language bias. Second, due to the impact of the number of included studies, a deeper subgroup analysis could not be carried out. Third, the training form, intensity, and duration of the intervention of WBVT were not completely consistent. Fourth, our analysis did not examine any a gender-based differences. Furthermore, the results of the study were heavily influenced by one trial. These factors in turn might have a certain impact on the results of our analysis. Finally, the methodological quality of the included studies was uneven, which could lead to a bias in the results.

Conclusion

The current evidence suggests that possible improvements in pain intensity, lumbar dysfunction, and quality of life of patients with CLBP using WBVT. However, a firm recommendation to clinicians regarding the treatment of CLBP patients using WBVT cannot be made based on these findings due to certain limitations of the current meta-analysis. This necessitates further in-depth analyses of high-quality RCTs with large sample sizes and similar characteristics to establish unified and standardized intervention programs. In addition, the current evidence is insufficient to prove the safety of WBVT. Therefore, future research is needed to further investigate the potential negative effects (such as the worsening of pain, vomiting, dizziness, etc.) of WBVT.

Disclosure of conflict of interest

None.

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