Systematic Review and Meta-Analysis

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Whole-body vibration provides additional benefits to patients with patellofemoral pain

A protocol for systematic review and meta analysis of randomized controlled trials

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Abstract

Background: The efficacy of the whole-body vibration (WBV) training for patients with patellofemoral pain (PFP) remains controversial. For this reason, we applied a meta-analysis of randomized controlled trials (RCTs) to evaluate the efficacy of WBV training in patients with PFP.

Methods: Relevant studies found within PubMed, EMBASE, the Cochrane Library and Web of Science were examined from January 1, 1990 to December 30, 2021. Two evaluators independently screened the literatures, extracted relevant data and assessed the methodological quality of respective studies. Meta-analysis was conducted using RevMan 5.4 software.

Results: A total of 5 RCTs with 174 patients were included. When comparing with exercise alone, WBV training in combination with exercise provided better reduction of pain assessed by visual analogue scale score ($P = .04$). There were no differences regarding changes of Kujala patellofemoral score, the physical component summary score for physical health, and the mental component summary score for mental health ($P = .08$, 0.76, 0.65 respectively) between patients with WBV training and those without WBV training.

Conclusions: Compared to the sole performance of exercise, WBV training in combination with exercise showed better pain reduction, but no superior improvement in function and on quality of life.

Abbreviations: CI = confidence interval, KPS = kujala patellofemoral score, MCS = mental component summary, NPRS = numeric pain rating scale, PCS = physical component summary, PFP = patellofemoral pain, RCTs = randomized controlled trials, SF-36 = 36-itemized Short Form Health Survey, VAS = visual analogue scale, WBV = whole-body vibration, WMD = weighted mean difference.

Keywords: analysis, meta, patellofemoral pain, whole-body vibration

1. Introduction

Patellofemoral pain (PFP) is a common pain disorder found in the joint of the knee that affects close to 30% of young adults.[1] There is a higher prevalence in athletes, particularly among jumpers and long-distance runners[2] whose patellofemoral joints sustain overload stress.[2,3] Patellofemoral pain is described as an aggravated pain when performing joint activities, usually accompanied with functional deficits. The diagnosis of PFP is primarily based on its clinical history, because its etiology and the source of pain remains unknown. Physical examination and imaging also play an important role during diagnosis.[2,4]

The conservative management of PFP generally includes activity modification, use of anti-inflammatory drugs and establishment of an individualized rehabilitation program.[2,4] Recently, whole-body vibration (WBV) training, which is emerging as a new rehabilitation method, has been applied to various chronic musculoskeletal disorders.[5,6] It is believed that WBV training is able to enhance neuromuscular performance, and modulate pain. Several studies had successfully reported that WBV training in combination with exercise improved knee function and reduced pain in knee osteoarthritis.[7–9] A positive effect on pain reduction in patients with chronic low back pain was also discovered recently.[10,11] Various theories may explain how WBV provide benefit to patients with chronic pain. With a newly developed concept of translational medicine,[12] we want to fill the gap between the basic theory and the clinical practice in this field.

However, there is a lack of evidence demonstrating its efficacy in patients with PFP. Some studies suggested that WBV training

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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can effectively reduce pain and improve lower limb functionality in some patients, while other authors showed conflicting results.[13–17] The efficacy of WBV training for patients with PFP remains controversial. Consequently, we applied a meta-analysis of randomized controlled trials (RCTs) comparing WBV training in combination with exercise and another solely with exercise alone, to evaluate the efficacy of WBV training in patients with PFP.

2. Methods

2.1. Search strategy

This study was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.[18] The literature search was considered in line with ethical principles for medical research involving human subjects. No approval was needed for the present review. PubMed, EMBASE, the Cochrane Library and Web of Science were independently searched by 2 authors to identify potentially eligible literature from January 1, 1990 to December 30, 2021 with the following search terms: "whole body vibration," "WBV," "whole body vibration training," "WBVT," "whole-body vibration," "patellofemoral pain," "PFP," "Patellofemoral pain syndrome," and "PFPS." All eligible studies which showed practicable data were manually retrieved in relevant publications.

2.2. Study selection

The titles and abstracts of studies identified were screened by 2 authors independently. The full texts of potentially relevant articles were acquired for subsequent assessment. Any disagreement was resolved by a third opinion.

2.3. Inclusion and exclusion criteria

Studies meeting the following criteria were included: performing under an RCT framework; focuses on participants with firmly diagnosed PFP; WBV training patients in combination with home exercise or conventional exercise in the intervention group and comparator group with home exercise or conventional exercise alone; includes a measured pain intensity, function or life quality, and reported complications or adverse effects in outcomes.

For exclusion, the following criteria were employed: article not written in English; data collected was inadequate or unavailable.

2.4. Data collection and management

Data collection was independently accomplished by 2 evaluators, and for any disagreement, a consensus was reached after further discussion. The extracted data included the title of the paper, name of first author, patient characteristics, sample size, details of intervention and follow-up period. The pooled outcomes were changes (Δ) of function score, pain score and quality of life after vibration training. Function score was measured by the Kujala patellofemoral score (KPS). Pain was assessed either with visual analogue scale (VAS) score, or Numeric Pain Rating Scale (NPRS). Quality of life was evaluated by the 36-itemized Short Form Health Survey (SF-36), which consisted of 2 aspects: the physical component summary (PCS) score for physical health, and the mental component summary (MCS) score for mental health.

2.5. Risk of bias

To assess the methodological quality of eligible studies, the risk of bias of enrolled trials was evaluated with domain-based evaluation according to the Cochrane risk of bias tool. Sequence generation and allocation ambiguity (selection bias), randomization and blinding of participants and personnel (performance bias), randomization and blinding of outcome assessors (detection bias), forgo selective reporting (reporting bias), removal of incomplete outcome data (attrition bias) and identification of any other bias which were evaluated to be unclear, or has either a high or low risk as determined by 2 separate reviewers. Any disagreements were settled by further discussion.

2.6. Statistical analysis

Statistical analyses were performed with Review Manager V.5.4 (The Cochrane Collaboration, Software Update, Oxford. We analyzed the outcomes by calculating the weighted mean difference (WMD) and pooled odds ratio with corresponding 95% confidence intervals (CIs). A P value < 0.05 was considered to be statistically significant. Statistical heterogeneity between studies was assessed using I^2 value, where < 50% was considered to be within the acceptable range of heterogeneity and the fixed effect model was applied. Otherwise, the random effect model was adopted. Publication bias was not assessed because the number of studies included in each study area was < 10; therefore, the statistical power was low. Sensitivity analyses were conducted to confirm the robustness of pooled outcomes by sequentially removing included studies 1-by-1.

3. Results

3.1. Studies characteristics

In total, 914 studies were retrieved from the initial database and additional sources. Among them, 5 RCTs[13–17] with 174 patients were enrolled after full assessment. The flow diagram is presented in Figure 1.

Table 1 shows the detailed characteristics of included studies.

3.2. Risk of bias across the included studies

Figure 2 shows the summarized risk of bias for the eligible studies.

3.3. Outcomes of changes (δ) of VAS after vibration training

All 5 studies focused on pain intensity, 4[13,14,16,17] of them reported VAS score and the 1[15] other reported NPRS score. After converting NPRS value to VAS, data from 5 articles were pooled together. WBV training in combination with exercise was found to be significantly more effective in reducing pain than exercise therapy alone (WMD,1.43; 95% CI, 0.09 to 2.77; I^2 = 92%; P = .04).

After conducting the sensitivity analysis, a single trial (Alvares 2020[17]) was removed for having unclear risks of bias in randomization and blinding, the conclusion remained consistent (WMD, 0.76; 95% CI, 0.44 to 1.09; I^2 = 42%; P < .00001) (Fig. 3A).

3.4. Outcomes of changes (δ) of KPS after vibration training

In regard to Δ KPS, there was no significant difference between WBV training in combination with exercise and exercise alone (WMD, 2.31; 95% CI, -0.67 to 11.13; I^2 = 79%; P = .08).

After the sensitivity analysis conducted by removing the trial (Alvares 2020[17]) for unclear risks of bias in randomization and blinding, the conclusion remained consistent, which indicated that WBV training did not provide additional function improvement (WMD, 1.64; 95% CI, -0.20 to 3.49; I^2 = 0%; P = .08) (Fig. 3B).

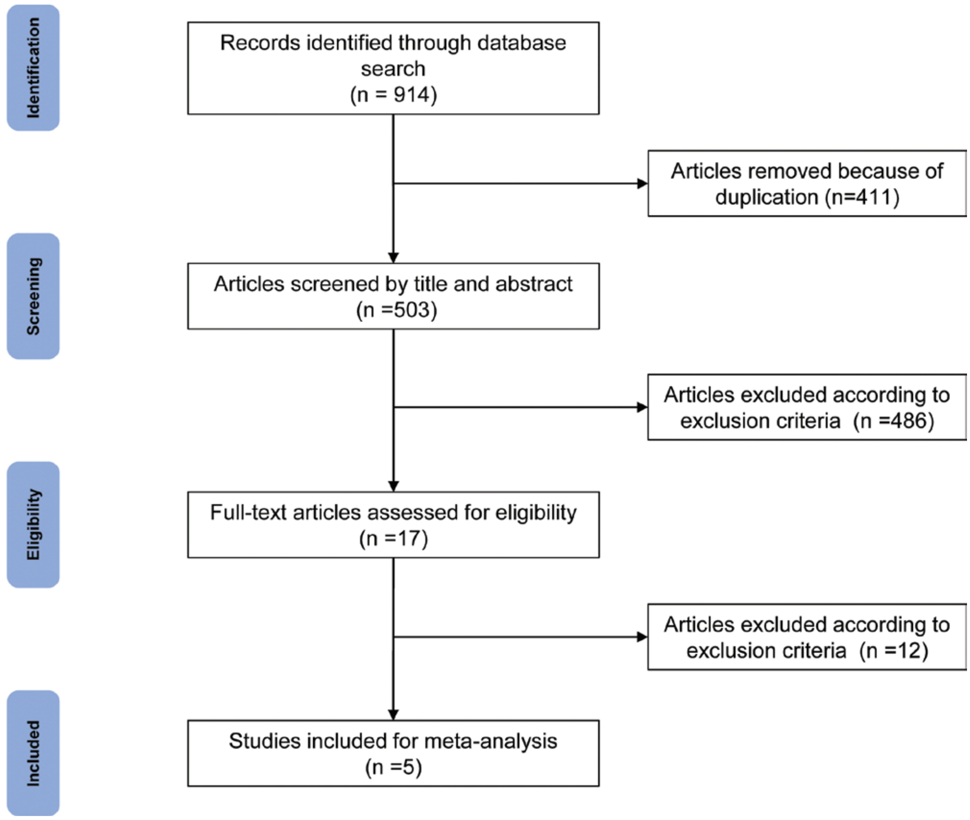

Figure 1. PRISMA flow chart of literature retrieval.

Table 1

Characteristics of the included studies.

Author, year	Study design	Country	Groups	Mean age (yr)	Gender (male/female)	Durations	WBVT parameters
Corum, 2018	RCT	Turkey	WBVT + exercise (n = 18) Control: exercise only (n = 16)	WBVT: 32.7 ± 7.3 Control: 33.7 ± 7.7	WBVT: 0/18 Control: 0/16	3 times/wk for 8 wk	Time: 20–30 min Frequency: 35 Hz Amplitude: 2 mm in the first 4 wk and 4 mm in the second 4 wk Acceleration: –
Rasti, 2020	RCT	Iran	WBVT + exercise (n = 12) Control: exercise only (n = 12)	WBVT: 25.9 ± 5.16 Control: 24.1 ± 5.12	WBVT: 12/0 Control: 12/0	3 times/wk for 4 wk	Time: 60 s Frequency: 50 Hz Amplitude: 4 mm Acceleration: –
Álvarez, 2020	RCT	Spain	WBVT + exercise(n = 25) Control: exercise only(n = 25)	WBVT: 48 ± 13.0 Control: 52 ± 10.7	WBVT: 11/14 Control: 13/12	3 times/wk for 4 wk	Time: 20 min Frequency: 40 Hz Amplitude: 2 mm in the first 2 wk and 4 mm in the second 2 wk Acceleration: 3.2–6.4 g
Shadloo, 2021	RCT	Iran	WBVT + exercise (n = 15) Control: exercise only (n = 15)	WBVT: 28.2 ± 2.34 Control: 26.6 ± 2.69	WBVT: 9/6 Control: 8/7	3 times/wk for 4 wk	Time: 10 min Frequency: 30 Hz Amplitude: 3 mm Acceleration: –
Wu, 2021	RCT	China	WBVT + exercise (n = 18) Control: exercise only (n = 18)	WBVT: 27.3 Control: 27.5	WBVT: 10/8 Control: 9/9	3 times/wk for 6 wk	Time: 40–60 s Frequency: 26 Hz Amplitude: level grade 2–4 Acceleration: –

RCT = randomized clinical trail, WBVT = whole-body vibration training.

3.5. Outcomes of changes (δ) of SF-36 after vibration training

A total of 2 studies[13,16] investigated life quality, both of them reported PCS and MCS of SF-36. In term of ΔPCS, WBV training in combination with exercise did not provide a significant improvement in physical health than having done exercise alone (WMD, 0.29; 95% CI, -1.59 to 2.18; $I^2 = 0\%$; $P = .76$)

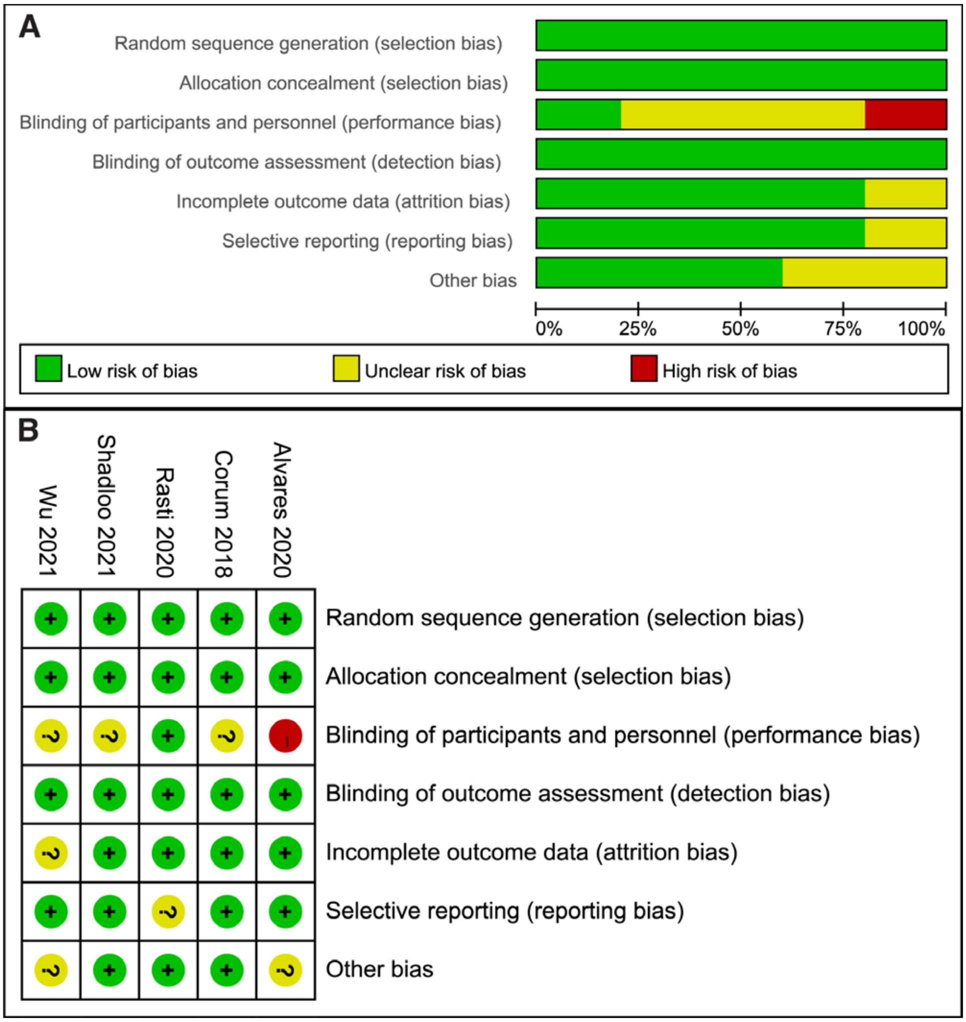

Figure 2. Risk of bias graph (A) graph of the risk of bias for the included RCTs; (B) graph of the risk of bias summary for the included RCTs. RCT = randomized clinical trail.

(Fig. 3C). As for ΔMCS, there were also no significant differences between the 2 groups for mental health improvement (WMD, 0.77; 95% CI, -2.53 to 4.07; $I^2 = 0\%$; $P = .65$) (Fig. 3D).

3.6. Complications and adverse events

There were no adverse events or treatment-related local or systemic complications reported in all enrolled trials.

4. Discussion

Patellofemoral pain is a complex knee disorder with unclear pathogenesis. Therefore, the management of PFP is challenging. Although traditional exercise therapy yielded good to excellent outcomes in most patients with PFP, it had some disadvantages. For instance, the requirement for professional guidance, a possibility of developing injuries, and difficulties in keeping regular training. Based on the convenience and potential benefits on neuromuscular performance of WBV training, some authors advocated this exercise for patients with PFP.[13–17] However, the debate over its efficacy remains. To solve this dispute, this present study analyzed 5 RCTs involving 174 patients to compare the clinical outcomes of WBV training in combination with exercise and exercise alone. A significantly reduced pain outcome was found among patients in the WBV training group. However, there was no difference in the improvement in the lower limb function and physical or mental life quality between the 2 groups.

The most important finding of this present study is that, WBV provided benefits to pain reduction in patients with PFP. The association between pain and vibration was originally founded in 1950s.[19] Some doctors believed that the high incidence of low back pain in engineers was due to the exposure to vibration. While contemporary researchers hold an opposite view. Increasing studies suggests that vibration is beneficial to reducing chronic pain.[10,11,20] In addition, WBV training is now being used as an effective treatment for low back pain and fibromyalgia pain.[21] To explain the pain reduction effect of WBV training, the gate-control theory was the dominating mechanism, while Gay *et al* revealed that the supraspinal mechanism may potentially be involved too.[19,22] The theory proclaims that fast conductive somatosensory afferents can block poorly myelinated nociceptive afferents at spinal level, therefore the reduction of pain induced by vibration creates a long-term remission. In this present study, pooled outcomes regarding VAS score indicated that WBV did provide additional benefits to pain reduction in patients with PFP.

However, this study did not find any statistical difference regarding KPS score or quality of life in WBV training plus exercise and exercise alone. This outcome indicated that WBV training might not be able to improve the joint function of patients with PFP. The clinical practice guideline of PFP by the American Physical Therapy Association in 2019 suggested that hip-targeted and knee-targeted exercises are effective for early stages of

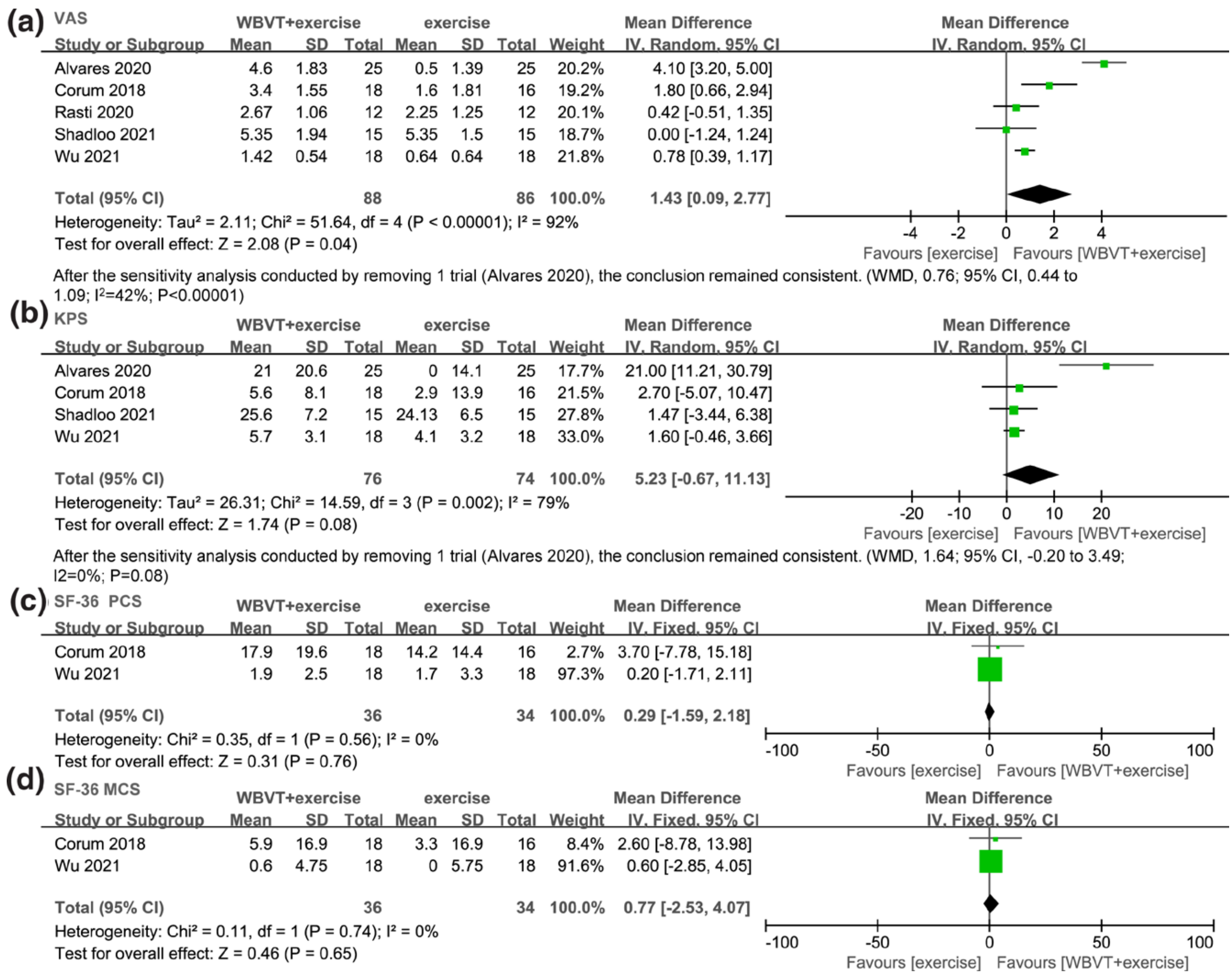

Figure 3. Meta-analysis of changes (Δ) of (A) VAS; (B) KPS; (C) SF-36 PCS; (D) SF-36 MCS. KPS = Kujala patellofemoral score, KPS = Kujala patellofemoral score, MCS = mental component summary, PCS = physical component summary, SF-36 = 36-itemized Short Form Health Survey, VAS = visual analogue scale.

PFP.[4] Sven *et al* reported that WBV training has similar effects on muscles strength of the lower limb as compared to exercise training.[23] The improvement of muscle strength and power may be explained by WBV-induced reflex muscle contractions. The vibration may affect the alpha motor neuron, and activate a number of muscle groups, possibly resulting in a better neuromuscular performance.[19,24] However, there is no consensus whether WBV training is beneficial to the functional improvement of patients with PFP, on top of this the pooled outcomes in this study did not support application of WBV training to patients with PFP.

WBV is performed on a platform which deliver a wide range of parameters. The exercise devices provide vibration to the whole body by 2 varying means: reciprocating vertical displacements on both the left and right side of the fulcrum; oscillating the plate uniformly up and down. Vibration exercise is quite a new method in sports medicine, but the consensus of several key parameters is yet to be reached. For instance, the frequencies of vibration vary from 15Hz to 60Hz, which is considered a secure range to be used on humans. As for amplitudes, most researchers believe that an effective distance range from < 1mm to 10mm. But it has been reported that an excessive frequency or amplitude may cause harm to the muscles. The acceleration delivered can reach as high as 15*g* (where 1*g* is the acceleration due to the Earth's gravitational field or 9.81 m/s^2). Taking both the safety and effectiveness into consideration, the interval of training in most studies was conducted 3 times a week. The parameters of WBV training of each included studies were restricted in a safe and effective range, limited data prevented us from an in-depth sub-group analysis to explore the best parameters setting for patients with PFP.

There are several strengths to this study. Firstly, this is the first meta-analysis that evaluate the efficacy of WBV training for patients with PFP. Secondly, the included studies of this meta-analysis were all RCTs meeting evidence criteria of level II and above. However, with a relatively small sample size of the included RCTs, as well as inconsistent parameters applied to the various studies, along with the lack of long-term outcomes are the main limitations for this study.

5. Conclusion

Compared to the performance of exercise alone, WBV training in combination with exercise showed better pain reduction, but no superior improvement in function and quality of life. According to the rudimentary evidence reviewed, WBV is able to relieve knee pain intensity in patients with PFP. However, it should not be applied in patients with PFP if only for improvement of joint function or quality of life. Further RCTs with heavier sample sizes are needed to verify this conclusion.

Author contributions

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Writing – original draft: Xinyue Yang, Guang Yang.
Writing – review & editing: Yunxia Zuo.

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