European Review for Medical and Pharmacological Sciences 2023; 27: 6985-6995

Meta-analysis of the effect of whole-body vibration training on the improvement of limb function in patients with Parkinson's disease

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Abstract. – OBJECTIVE: This study aimed to systematically evaluate the effect of whole-body vibration (WBV) training on the improvement of limb function in patients with Parkinson's disease (PD).

MATERIALS AND METHODS: An electronic search was performed on the databases, including PubMed, Web of Science, Scopus, SCI-hub, ScienceDirect, Embase, IEEE, Medline, Wiley, ClinicalKey, CNKI, Wanfang, VIP database, Chinese Medical Association, and CBM Database from inception to May 2022 to collect randomized controlled studies on whole-body vibration training for patients with Parkinson's disease. Two researchers independently screened the literature, extracted the data, and evaluated the quality of the literature, then used ReviewManager 5.4 software for quantitative statistical analysis, including heterogeneity test, sensitivity analysis, risk of bias assessment, combined outcome index effect size and effect size inspection.

RESULTS: A total of 9 studies were included in the meta-analysis, including 346 patients, 174 patients in the control group and 172 patients in the observation group. Meta-analysis results showed that, compared with conventional physical therapy or drug therapy alone, whole-body vibration reduced the Unified Parkinson's Disease Rating Scale (UPDRSIII) score and significantly improved the motor function of patients with Parkinson's disease [MD=-2.39, 95% CI (-4.41, -0.37), Z=2.14 (*p*=0.23)]. Moreover, whole-body vibration significantly improved the walking stability of Parkinson's patients [MD=-1.96, 95% CI (-2.71– -1.21), Z=1.17 (*p*=0.03)]. However, its improvement in balance ability [MD=-0.06, 95% CI (-0.77, 0.65), Z=1.07 (*p*=0.19)] and daily living ability [MD=0.03, 95% CI (-1.68, 0.74), Z=0.24 (*p*=0.87)] of patients, it was not t statistically significant.

CONCLUSIONS: Compared with conventional therapy, WBV has certain advantages in improving the balance function and gait performance of PD patients, but the effect on balance ability and daily living ability is not significant. Thus, more high-quality research is required for further verification.

Key Words:
Whole-body vibration training, Parkinson's disease, Meta-analysis.

Introduction

Parkinson's disease (PD) is a neurodegenerative disease characterized by the progressive degeneration of dopaminergic neurons and the accumulation of multiple systems. The main pathological change is degeneration and necrosis of dopaminergic neurons in the substantia nigra[1,2]. With the clinical characteristics of chronicity and high disability rate, the most affected groups are the elderly. The prevalence of PD among people over 65 years old in China is about 1.7%. Patients with Parkinson's disease suffer a high incidence of falling and related accidents due to resting tremors, muscle stiffness, and slow movement, resulting in seriously compromised daily living ability of patients[3-5]. Levodopa is currently the drug of choice for the treatment of Parkinson's disease, as it can significantly delay the progression of the disease. However, long-term administration of Levodopa is associated with drug resistance and adverse events, and symptoms such as dysfunction and abnormal posture of patients cannot be adequately mitigated.

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At present, relaxation and breathing training, head and neck training, treadmill training, progressive resistance training, limb linkage training, compulsory exercise therapy, water exercise therapy, Tai Chi, singing, dancing, rehabilitation robot training, virtual rehabilitation treatment methods such as realistic technology and training of activities of daily living have been introduced for the intervention of PD patients[6]. Because of the difference in dysfunction severity in PD patients, comprehensive exercise therapy is thus adopted to improve the motor dysfunction of PD patients. Studies[6,7] have shown that whole-body vibration training can relieve motor symptoms of PD patients to varying degrees. Whole-body vibration training is a rehabilitation therapy that improves neuromuscular function by stimulating systemic muscle oscillations and changes in the central nervous system through mechanical vibration and resistive loads[7]. However, controversy exists about the effect of whole-body vibration training on PD patients. Therefore, this paper conducted a meta-analysis research to evaluate the effect of WBV training on the improvement of limb function and quality of life in PD patients, in order to provide an evidence-based basis for WBV intervention clinical practice.

Materials and Methods

Research Object

An electronic search was performed on the databases, including PubMed, Web of Science, Scopus, SCI-hub, ScienceDirect, Embase, IEEE, Medline, Wiley, ClinicalKey, CNKI, Wanfang, VIP database, Chinese Medical Association, and CBM Database from inception to May 2022 to collect randomized controlled studies on whole-body vibration training for patients with Parkinson's disease. The retrieval method follows the population, intervention, comparison, and outcomes (PICO) principle, and the Chinese retrieval terms include Parkinson's disease, idiopathic Parkinson's disease, Parkinson's syndrome, parkinsonism, whole body vibration training, vibration training, and limb function improvement. The English search terms are idiopathic Parkinson's disease, PD, Parkinson, paralysis agitans, shaking palsy, Whole Body Vibration, WBV, and vibration training. The flowchart of retrieval result processing is shown in Figure 1.

Literature inclusion criteria: (1) controlled clinical trials of whole body vibration training in the treatment of patients with Parkinson's dis-

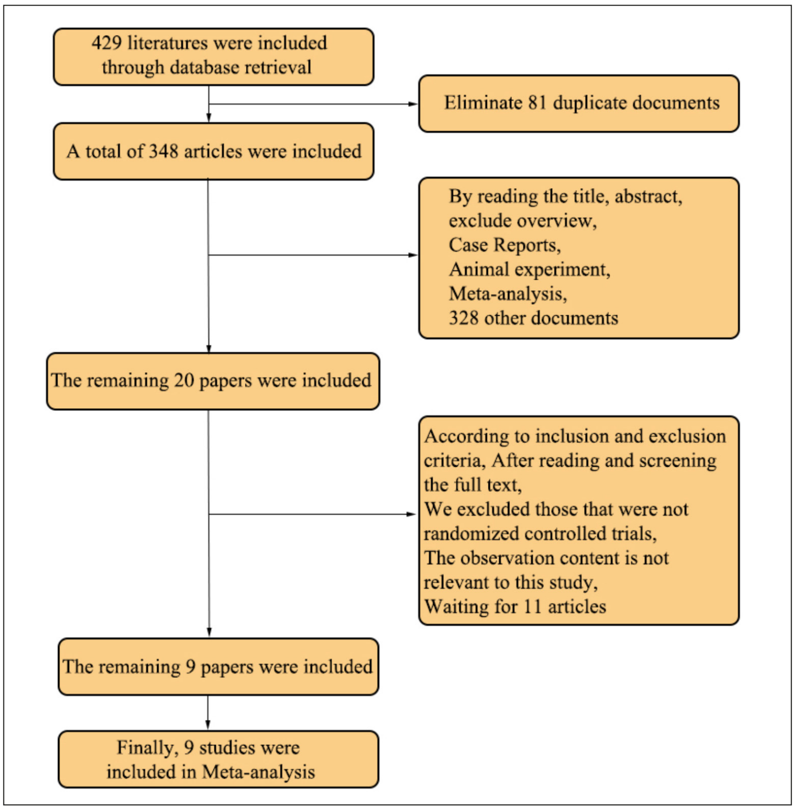

Figure 1. Document retrieval flow chart.

ease; (2) both the control group and the experimental group met the clinical diagnosis criteria of PD of the International Movement Disorder Society (MDS) and had typical symptoms and signs of PD; (3) main observation includes improvement of limb function; (4) randomized controlled trials.

Literature exclusion criteria: (1) reviews, case reports, animal experiments, or meta-analysis; (2) repeatedly published literature; (3) documents whose full text cannot be obtained; (4) low-quality literature.

The manuscript was prepared and revised according to the **PRISMA 2020 Checklist.**

Interventions

The control group received conventional exercise therapy, conventional rehabilitation training, or conventional anti-PD drugs combined with basic rehabilitation treatment, and the experimental group received whole-body vibration training.

Outcome Indicators

1) Motor function: Unified Parkinson's Comprehensive Rating Scale [unified Parkinson's disease rating Chapter 3 (UPDRS-III) of scale] was used to evaluate the patient's motor function. The evaluation items include 14 items, such as limb movements and gait, with a total score of 56 points. The higher the score, the worse the motor function.
2) Balance ability: Berg Balance Scale (BBS) was used as a screening and assessment tool for the balance ability of PD patients. The assessment items include 14 items, such as sitting balance, sit-stand transfer, and standing, with a total score of 56 points.
3) Stability of walking: Timed up-go test (TUGT) was adopted to record the time for the patient to stand up independently from the seat, walk 3 m, turn around and return, and then turn around and sit down. The timing started when the spine left the seat back and ended when the patients returned to the same position and sat down. The test was performed thrice with an interval of 1-2 min, and the average value was used for analysis.
4) Activities of daily living: the modified Barthel index (MBI) scale was employed to assess the activities of daily living of patients. The evaluation items include eating, dressing, going to the toilet, transferring, etc. The total score is 100 points, and the higher the score, the stronger ability of daily living (ADL).

Literature Quality Evaluation

The quality of each article was assessed by 2 independent researchers, including independent evaluation and cross-checking using the Cochrane risk of a bias assessment tool, mainly from selection (including random sequence generation and blinding), measurement (blinded evaluation of research outcomes), follow-up (completeness of outcome data), reporting (selective reporting of research results) and others (other sources of bias); a total of 7 items were used to evaluate the risk of bias. The judgment results of "low risk of bias", "high risk of bias" and "unclear" were made for each item. The modified Jadad scale was used to score each included literature. The specific content is as follows. Random scoring method: (1) explain random and describe the generation of random order (2 points); (2) only explain random (1 point); (3) not random or unclear (0 points). Scoring methods for blinding: (1) adequate description (2 points); (2) only explanation of blinding (1 point); (3) no blinding or unclear (0 points). Scoring methods for withdrawal and loss to follow-up: (1) describe the number and reasons for withdrawal and loss to follow-up (1 point); (2) insufficient description (0 point). Improved Jadad quality scoring method: 1-3 points are low-quality documents, and 4-7 points are high-quality documents. Any discrepancies found were resolved through discussion, and a third evaluator was consulted if necessary. After reaching a consensus, the quality evaluation of the final literature was formed, which was entered into the RevMan 5.3 software (developed by the International Cochrane Network) to generate the final risk of bias assessment map.

Statistical Analysis

The meta-analysis was performed using RevMan 5.3 software. Firstly, the heterogeneity test is carried out, and $I^2>50\%$, $p\leq0.05$ indicates the existence of large heterogeneity, and the random effect model is used for analysis; if $I^2\leq50\%$, $p>0.05$ indicates small heterogeneity of multiple similar studies, and thus a fixed-effects model was employed for analysis. The enumeration data adopts the relative risk (RR), and the measurement data adopt mean difference (MD) or standardized mean difference (SMD). Both use 95% confidence intervals (95% CI). When more than 10 studies reported outcome indicators, funnel plot analysis was used to judge whether there was publication bias.

Results

Literature Screening Process and Results

After searching the database, a total of 429 documents were obtained. First, 81 duplicate documents were eliminated through the preliminary screening of NoteExpress. 328 studies, including literature reviews, case reports, animal experiments, or meta-analyses, were excluded by reading titles and abstracts. The remaining 20 articles were read and screened in full text according to the inclusion and exclusion criteria, and finally, 9 articles[8-16] were included for meta-analysis. A total of 346 patients were involved, including 174 patients in the control group and 172 patients in the observation group (Figure 1 and Table I).

Included in the RCT Process and Baseline Characteristics

Basic information and quality evaluation results of included literature

The quality of the 9 included studies was evaluated by the RevMan5.4 software. All the documents showed that the random method was used for grouping. Only 3 studies[10,13,14] used double-blind, 1 study[12] used single-blind, and 4 studies[8,9,11,15] used numerical randomization method; no studies dropped out of clinical trials, and 7 studies reported complete outcome data. The baseline levels of the included studies were all comparable (Figures 2-3).

Motor Function

Among the included studies, 5 articles[9,10,11,14,15] reported the change in UPDRSIII score. The heterogeneity test results were p=0.61, I^2=0%, indicating that the heterogeneity among the included studies was small, and the fixed effect model was adopted. The results of the meta-analysis showed that MD=-2.39, 95% CI (-4.41, -0.37), Z=2.14 (p=0.23). It indicated that the whole body vibration had a significant effect on reducing the UPDRSIII score. The whole-body vibration had a significant effect on improving the motor function of patients (Figure 4).

Balance Ability

Among the included studies, 4 studies[8,9,13,16] reported a change in BBS scores. The heterogeneity test results were p=0.19, I^2=0%, indicating that the heterogeneity among the included studies was small, and the fixed effect model was adopted. Meta-analysis results showed that MD=-0.06, 95% CI (-0.77, 0.65), Z=1.07 (p=0.19). There was no statistically significant difference in balance between the two groups (Figure 5).

Walking Stability

Timed up and go test (TUGT) is a routine way to assess the walking stability of PD patients. Figure 6 shows that a total of 4 studies[8,10,11,12] were included, and the heterogeneity test results: p=0.86, I^2 =0%, indicating that the heterogeneity among the included studies was small, and the fixed effect model was adopted. Meta-analysis results showed that MD=-1.96, 95% CI (-2.71~-1.21), Z=1.17 (p=0.03). It shows that whole-body vibration has a significant positive effect on the walking stability of PD patients.

Abilities of Daily Living

In the included studies, 2 articles[8,9] evaluated the ability of daily living after the intervention and reported a change in MBI score. The heterogeneity test results were p=0.46, I^2=0%, indicating that the heterogeneity among the included studies was relatively large, and a fixed-effects model was used. The meta-analysis results showed that MD=0.03, 95% CI (-1.68, 0.74), Z=0.24 (p=0.87). It shows that there is no statistically significant difference between the observation group and the control group in improving the daily living ability of PD patients (Figure 7).

Discussion

The course of PD is protracted, and the condition is progressively exacerbated. Motor dysfunction is the main factor leading to the loss of self-care ability and social adaptation ability of patients, especially PD patients with balance disorders[17]. At present, there is no standardized treatment for PD. Drug therapy is the main strategy to improve motor symptoms, but its clinical symptoms are highly heterogeneous, and differences exist in the response of different symptoms to dopamine drugs[18]. Among the core symptoms of PD, postural instability (PI) is one of the symptoms that affect the quality of life of patients the most. Alam et al[19] found that the risk of falling due to PI in PD patients is about 2 times that of healthy elderly people. Arenales Arauz et al[20] developed the vibrating chair at the

Table I. Basic characteristics of included studies.

Author	Year of publication	Sample size	Age	Intervention program		Follow-up time	Observation indicators
		Study/ comparison	Study/ comparison	Research	Control		
Lei et al[8]	2021	40/40	58.3 ± 5.5/ 56.8 ± 3.4	Whole body vibration training: vibration frequency (6-11 Hz), 10 min/time, 1 time/d, 6 times/week. Limb linkage training: 30 min/time, 1 time/d, 6 times/week.	Routine Medication and Routine Rehabilitation	2 months	②③④
Zeng et al[9]	2020	11/11	63.27 ± 4.54/ 63.72 ± 3.37	Whole body vibration training, vibration frequency 6 Hz, amplitude 3 mm, 15 min each time, 2 consecutive times, total 30 min/d, 5 d a week, 6 weeks in total.	Multi-sport strategies were used for training, 30 minutes eachtime, once a day, 5 days a week, for 6 weeks in total.	6 weeks	①②④
Kaut et al[10]	2016	30/26	67.92 ± 8.78/ 66.10 ± 8.28	4 series of vibrations over 8 days, each series consisting of 6 stimulation sequences of 60-second duration, using randomized whole-body vibration	Fake treatment	12 months	①
Gaßner et al[11]	2014	8/9	71.4 ± 4.4/ 68.2 ± 4.9	In the experimental group, five groups of stimulations lasting 60 s and 6 Hz (±1 Hz noise, amplitude 3 mm) were performed. Rest between sets is set to 60 seconds	Vibration simulation	5 weeks	①
Li et al[12]	2021	13/16	61.15 ± 3.72/ 60.06 ± 3.38	The vibration frequency and amplitude settings were 6 Hz and 3 mm, and in this case the respectively, feet were mainly stimulated by the vibration. Each treatment session consists of 5 vibrations for 1 minute and 1 rest	Participants t underwen 10 minutes of postural control and Conventional Treatment for Functional Walking		①③

Continued

Table I ***(Continued).*** Basic characteristics of included studies.

Author	Year of publication	Sample size	Age	Intervention program		Follow-up time	Observation indicators
		Study/ comparison	Study/ comparison	Research	Control		
Jin et al[13]	2014	35/35	55.0 ± 4.8/ 55.0 ± 4.7	Whole body vibration mode, frequency 20 Hz, amplitude 3 mm, 1 group of vibration therapy; 1 group of vibration therapy for lower extremity on the opposite side. Each group of vibrations lasts for 45 s and rests for 1 min. All the above treatments were given once a day, 5 days a week, for a total of 6 weeks.	Routine rehabilitation +ower body weight ltraining	6 weeks	②
Arias et al[14]	2009	10/10		Vibration therapy	Placebo	6 weeks	①
Ebersbach and Storch[15]	2009	11/10	74.7 ± 10.3/ 73.8 ± 9.7	Whole body vibration subjects were randomly assigned to receive 30 sessions (twice daily, 15 min each, 5 days per week) of WBV on a vibrating platform or conventional balance training including exercises on an inclined board	Conventional physical therapy	4 weeks	①
Guadarrama-Molina et al[16]	2020	14/17		Whole body vibration	Conventional physical therapy		②

Evaluation criteria: ① Unified Parkinson's Disease Rating Scale (UPDRSIII); ② Berg Balance Scale (BBS); ③ Timed Up and Gotest (TUGT); ④ Modified Barthel Rating (MBI).

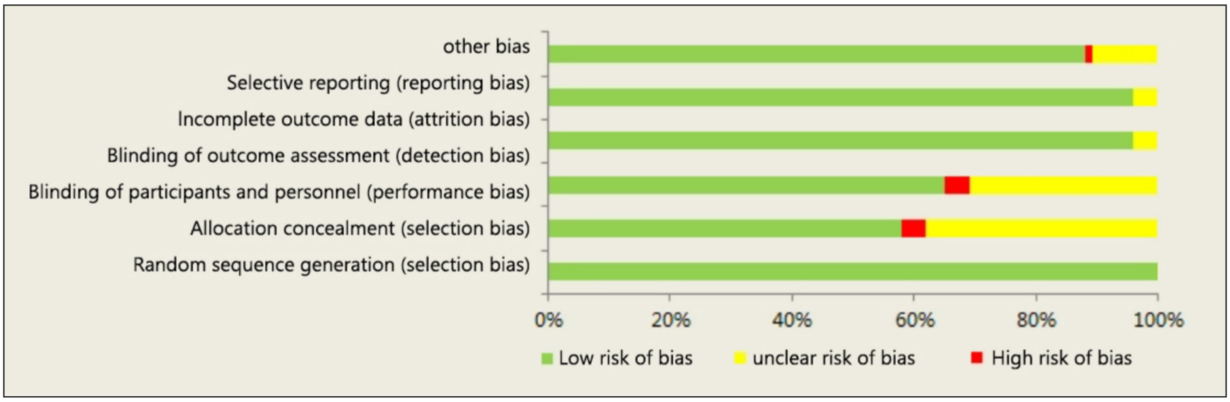

Figure 2. The ratio chart of the quality evaluation of the included literature.

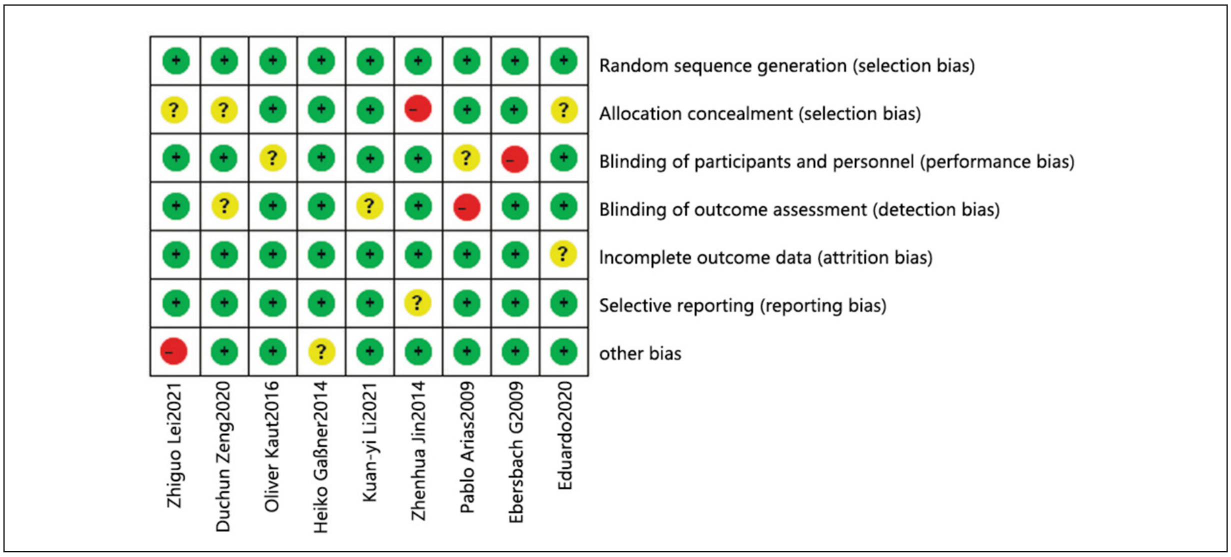

Figure 3. Judgment diagram for each cheap risk item in the included studies.

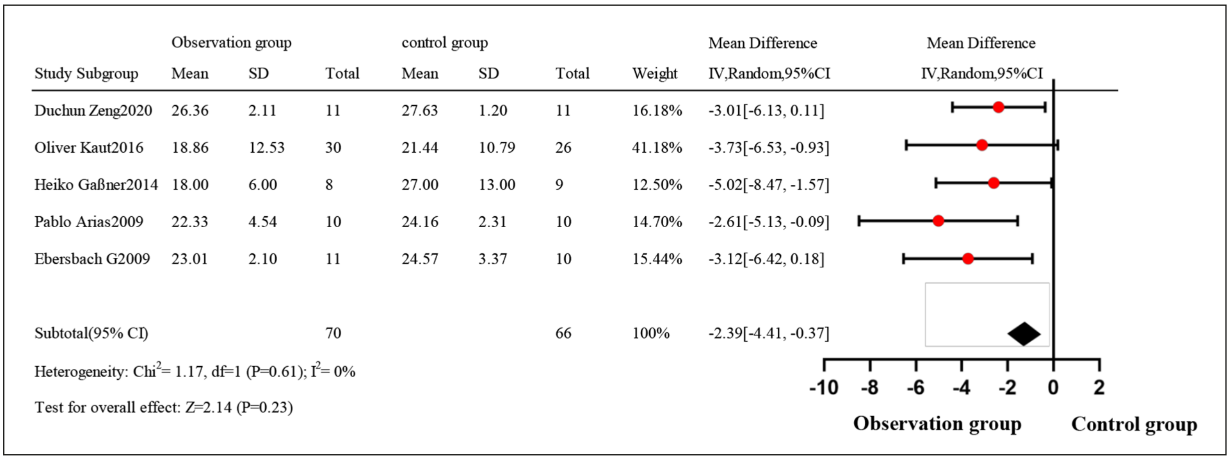

Figure 4. Forest plot of UPDRSIII score comparison between two groups.

	Observation group			control group				Mean Difference	Mean Difference
Study Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV,Random,95%CI	IV,Random,95%CI
Zhiguo Lei2021	46.65	3.29	40	43.58	4.21	40	39.41%	0.16[-0.76, 1.08]	
Duchun Zeng2020	41.27	3.71	11	42.18	2.31	11	10.84%	-0.28[-1.12, 0.56]	
Zhenhua Jin2014	44.20	2.04	35	38.09	2.46	35	34.48%	0.43[-0.65, 1.51]	
Eduardo2020	43.25	3.03	14	41.06	3.16	17	15.27%	-0.11[-1.19, 0.97]	
Subtotal(95% CI)			100			103	100%	-0.06[-0.77, 0.65]	

Heterogeneity: $Chi^2 = 0.13$, df=1 (P=0.48); $I^2 = 0\%$

Test for overall effect: Z=1.07 (P=0.19)

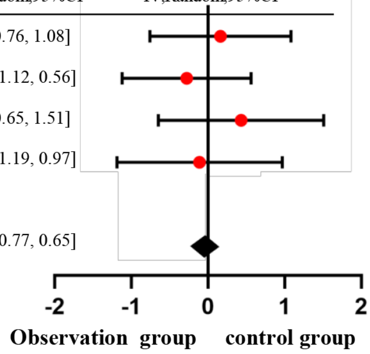

Figure 5. The forest plot of BBS score comparison between the two groups.

	Observation group			control group				Mean Difference	Mean Difference
Study Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV,Random,95%CI	IV,Random,95%CI
Oliver Kaut2016	8.31	3.65	30	10.46	7.73	26	30.77%	-1.34[-2.33, -0.35]	
Heiko Gaßner2014	9.00	2.20	8	10.10	1.60	9	9.34%	-0.84[-1.40, -0.28]	
Zhiguo Lei2021	31.20	5.10	40	30.80	4.20	40	43.96%	0.13[-0.27, 0.53]	
Kuan-yi Li2021	9.93	4.80	13	10.14	2.40	16	15.93%	-0.52[-0.64, -0.4]	
Subtotal(95% CI)			91			91	100%	-1.96[-2.71, -1.21]	

Heterogeneity: $Chi^2 = 0.58$, df=1 (P=0.86); $I^2 = 0\%$

Test for overall effect: Z=1.17 (P=0.03)

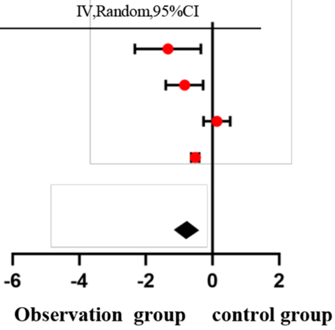

Figure 6. Forest plot of TUGT score comparison between two groups.

	Observation group			control group				Mean Difference	Mean Difference
Study Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV,Random,95%CI	IV,Random,95%CI
Zhiguo Lei2021	61.75	6.25	40	55.27	6.18	40	78.43%	1.02[0.15, 1.89]	
Duchun Zeng2020	46.81	6.03	11	48.63	4.52	11	21.57%	-0.42[-1.68, 0.84]	
Subtotal(95% CI)			51			51	100%	0.03[-0.68, 0.74]	

Heterogeneity: $Chi^2 = 0.50$, df=1 (P=0.46); $I^2 = 0\%$

Test for overall effect: Z=0.24 (P=0.87)

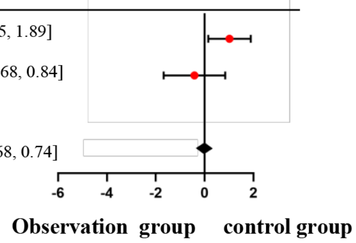

Figure 7. The forest plot of MBI score comparison between the two groups.

end of the 19th century to treat gait disturbances in patients with neurological diseases, especially PD. In 1987, Russian coaches first applied WBV and strength training to rehabilitate gymnasts. Whole-body vibration therapy follows the principle of mechanical vibration to improve the body's proprioception and dysfunction after central nervous system injury. Gloeckl et al[21] found that vibration stimulation, as an exogenous stimulus, can prompt the central nervous system to issue adjustment instructions under the premise of active muscle contraction, activate potential motor units, and make muscles move in actual motion. More motor units are recruited, which increases muscle contraction force. This is consistent with the research results of Kim et al[22], who also confirmed that whole-body vibration can improve bone mineral density and reduce osteoporosis in patients. Chang et al[23] found that vibration stimulation of the upper limb muscles on the affected side can significantly reduce muscle tension and pain and improve the function of the upper limb on the affected side.

At present, there are few meta-analyses[9] on the motor symptoms of PD patients treated with WBV in China. In the current study, a total of 346 PD patients were included in 9 RCTs, and the meta-analysis of the third part of the Unified Parkinson's Disease Rating Scale (UPDRSIII) was performed. The results suggest that WBV can improve motor function in PD patients. Some studies[24,25] have revealed that compared with traditional rehabilitation treatment programs, movement observation therapy based on the principle of mirror neurons can significantly improve the motor function of stroke patients and effectively improve their cognitive function and motor learning ability. Therefore, this study suggests that WBV may also improve the limb motor function of patients with Parkinson's disease by improving cognitive function and motor learning ability. In addition, patients with Parkinson's disease often have different degrees of limb movement disorders and may also be accompanied by different degrees of brain nerve damage.

TUGT's meta-analysis[25] forest plot showed that WBV improved the walking stability of PD patients. In the whole body vibration training research on the walking function of the elderly, the test indicators of step length, stride frequency, and stride speed are most commonly used. Some studies[25,26] have summarized the indicators for evaluating the walking function of the elderly in whole-body vibration training research, including timed up-go test, Tinetti test, 10-m walking speed test, and 6-min walking test. Among them, there are experiments with significant results (compared with conventional training) on the TUGT index, and there are also studies that improve but do not reach the significance between groups (compared with conventional training).

Further analysis of the experimental population found that the elderly who were frail or had impaired lower limb function could outperform the healthy elderly. According to the above analysis and discussion on muscle function, balance function, and walking function, whole-body vibration training can be implemented to improve the lower limb function of the elderly. However, to benefit the elderly better, attention should be given to the following points. First, whole-body vibration training may not be comparable to conventional training in improving the muscle strength of the elderly. For fitness needs, whole-body vibration training can be used to help the elderly improve their muscle strength. Second, the benefits of whole-body vibration training for the elderly with different physical conditions are different, and the effect is more obvious for the weaker elderly[26]. For the elderly with normal functions and no obstacles, the main function of whole-body vibration training is to enhance the function of the limbs[27]. Moreover, the association of body fat with health status and depression in the oldest old is still debated. Giovannini et al[28] reported that high body fat percentage (BF%) is significantly positively associated with poor health-related quality of life and depression, underpinning the clinical relevance of testing BF% in older adults. These associations appear stronger in women than in men, highlighting the need to investigate deep inside this gender discrepancy. Laudisio et al[29] pointed out that quality of life represents the principal outcome of health interventions for the oldest old. However, little is known about the determinants of quality of life in this population stratum. Therefore, they evaluated the association between health-related quality of life (HRQoL) and handgrip strength in a cohort of 331 participants aged 90+ living in the Mugello area and concluded that muscle strength is associated with both physical and mental HRQoL among nonagenarians. Hence, further studies are needed to explore the subsystems involved in this association, and whether improving muscle performance might improve global mental and physical quality of life in the most advanced age.

The present study found that WBV training may yield the greatest effect, but given the paucity of related studies, more prospective, multi-center, and large-sample trials are required for verification.

Limitations

There are some limitations to the current research which are as follows: Firstly, the research only includes patients with mild to moderate disease (Hoehn-Yahr stage I-III), who can perform the required posture for treatment correctly and may benefit the most from it. Patients with severe PD were excluded from the research. Secondly, there is heterogeneity in the sample and methodology of the literature included in this study. Lastly, the included studies are mostly in English, and there are very few multi-center, double-blind RCTs on motor symptoms of PD patients treated with WBV in China. As only Chinese and English studies were included, and literature in other languages was not searched, it may result in bias.

Conclusions

Compared with conventional therapy, WBV has certain advantages in improving the balance function and gait performance of PD patients, but the effect on balance ability and daily living ability is not significant. Thus, more high-quality research is required for further verification.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Funding

This study was supported by the Science and Technology Plan Project of Maoming (No. 2021033).

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' Contribution

The authors declare that this work was done by the authors named in this article, and all liabilities pertaining to claims relating to the content of this article will be borne by them. All authors reviewed the manuscript. All authors have read and approved the manuscript.

Informed Consent

Not applicable.

Ethics Approval

Not applicable.

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