THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 18, Number 1, 2012, pp. 29–41

DOI: 10.1089/acm.2010.0691

Using Whole-Body Vibration Training in Patients Affected with Common Neurological Diseases: A Systematic Literature Review

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Abstract

Objectives: This systematic review critically evaluates the effects of whole body vibration (WBV) exercises on gait, balance, proprioception, strength, and health-related quality of life in patients with common neurological diseases. It specifically focuses on assessing the quality of reported studies and comparing quantitative results.
Design: This is a systematic literature review.
Results: A specific search strategy of 11 databases identified 13 published articles (5 studies of patients with Parkinson disease, 2 with cerebral palsy, 3 with multiple sclerosis, and 3 with stroke) that fulfilled the selection criteria. The quality of the articles was evaluated using a Physiotherapy Evidence Database scale and Dutch Institute for Healthcare Improvement guidelines.
Conclusions: There is moderate evidence that one session of WBV has positive effects on strength, whereas there is a weak level of evidence that WBV could improve proprioception and health-related quality of life measures in neurological patients. With respect to long-term effects of WBV, there is minor evidence from the studies with the best methodological quality that WBV improves strength, proprioception, gait, and balance. Further research on the intervention is strongly needed.

Introduction

Neurological disorders (ND) encompass a group of clinically heterogeneous diseases, some of which are commonly associated with motor impairment syndromes. Problems in gait, balance, voluntary muscle control, and strength are some of the most important motor impairments associated with common ND; these contribute to low health-related quality of life (HRQoL).

The use of whole-body vibration (WBV) has increased in popularity during the last decade, and previous reviews of the literature on WBV have concluded that this modality of training is useful for improving physical capacity, hormonal production, bone mass, balance, proprioception, and HRQoL in healthy subjects.[1–3]

There are currently many vibration platforms on the market, and they differ in frequency range, amplitude, and type of vibration stimulation. These characteristics induce variations in transmissibility of vertical vibration to the (lower) body, and it could affect the effects of WBV therapies.[4] The WBV devices used in the published studies in field of neurological patient rehabilitation are shown in Table 1.

There are several reasons to think that WBV would also have positive effects in patients with ND. The seesaw-like displacement of the platform is reported to mimic human gait.[5] Postural responses are induced by vibration of the foot soles,[6] and WBV stimulates foot-sole sensory afferents[7]; WBV activates the Ia and II afferents of muscle.[8,9] WBV also increases the synchronization of the motor units[10] and the efficiency of agonist/antagonist pairs,[10,11] which could be affected in several types of ND.[12,13] Muscular vibration has contralateral effects on motor cortex excitability, suggesting transcallosal motor evoked potential modulation,[11] which could be especially important in patients with stroke.[14]

The purpose of this systematic review is to evaluate clinically relevant studies published through January 1, 2010, examining the methodological quality, likelihood of bias,

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Table 1. Whole-Body Vibration Devices Used in the Published Studies in Field of Neurological Patient Rehabilitation

Device	Reference	Pathology	Frequency (Hz) (max-min)	Amplitude (mm) (max-min)	Type of vibratory stimulus	Electronic source
ZEPTOR-med	Haas, 2006[27] Turbanski, 2005[26] Haas, 2006[30] Schuhfried, 2005[20]	Parkinson Parkinson Parkinson Multiple sclerosis	1–12	3	Stochastic, multidirectional (vertical, horizontal and inclined combined)	www.scisens.com
Galileo 2000	Ebersbach, 2008[28] Semler, 2007[21]	Parkinson Cerebral palsy	5–30	0–6.4	Horizontal sine-wave	www.galileo-training.com/index.php
Galileo 900	van Nes, 2006[23] van Nes, 2004[24]	Stroke Stroke	5–30	0–6.4	Horizontal sine-wave	www.galileo-training.com/index.php
NEMES	Ahlborg, 2006[22] Tihanyi, 2007[25]	Cerebral palsy Stroke	20–55	4	Vertical sine-wave	www.bosco-system.com
Vibro Gym	Schyns, 2009[19]	Multiple sclerosis	30–50	2–4	Vertical vibration	www.vibrogym.com/index.php
Mexuvibe	Jackson, 2008[18]	Multiple sclerosis	1–30	12.5	rotational	www.maxuvibe.com/
Fit Massage	Arias, 2009[29]	Parkinson	1–50	1–13	Horizontal Sine-wave	www.fit Massage.com/

Max, maximum; min, minimum.

and effects of WBV in the most commonly studied ND that has used the WBV as therapy.

Methods

The PRISMA methodology was used[15] to carry out this systematic review.

Applied resources

Studies were identified by searching the following electronic databases: AMED (2005 to the present), The Cochrane Library (2003 to the present), Google Scholar (2003 to the present), MEDLINE® (2000 to the present), PEDro (2003 to the present), PubMed (1973 to the present), SPORTdiscus (2002 to the present), CINAHL (2002 to present), EMBASE (2001 to the present), TRIP database (2002 to the present), and Web of Science (1988 to the present).

Article selection

Selection of the databases, search strategy, and the list of terms, including their compounding, was carried out by medical library science experts and experts in the field of WBV as applied to ND in order to locate the articles reported in the present systematic review. The search was finalized on January 1, 2010, with no submission deadline being imposed on the experts.

The articles were located using terms from WBV training or therapy and the most common ND, combining them with Boolean operators (AND, OR, NOT) in a precise way in order to scan all underlying articles of relevance to the subject at hand. The following terms were used in the PubMed search (whole body vibration OR whole-body vibration OR whole body-vibration OR whole-body-vibration OR wbv) AND (parkinson OR multiple sclerosis OR cerebral palsy OR alzheimer OR ischemic stroke OR epilepsy OR huntington OR dementia OR ictus OR syncope OR amyotrophic lateral sclerosis OR maladie de charcot OR lou gehrig disease OR muscular dystrophy OR becker's muscular dystrophy OR congenital muscular dystrophy OR duchenne muscular dystrophy OR distal muscular dystrophy OR emery-dreifuss muscular dystrophy OR facioscapulohumeral muscular dystrophy OR limb-girdle muscular dystrophy OR myotonic muscular dystrophy OR oculopharyngeal muscular dystrophy OR brain tumor OR meningitis OR post-poliomyelitis OR poliomyelitis OR post-polio syndrome OR post poliomyelitis OR neurological OR neuromuscular OR disease OR problems). Duplicate articles were manually removed by one of the authors who took part in the initial review process. The articles were indexed based on the following inclusion criteria: (1) inclusion of WBV treatment or training; (2) treatment aimed at individuals with ND; (3) investigation of gait, proprioception, balance, functional tasks, strength, or HRQoL; (4) published in a peer-reviewed journal; (5) written in English; and (6) performed as an original clinical study. Articles were selected by two independent experts and potential disagreements were resolved through mutual consensus. An overview of the article selection process is shown in Figure 1.

Quality assessment

Risk of bias. The Physiotherapy Evidence Database (PEDro) scale was used to assess the risk of bias. Although this scale was developed and tested using clinical trials,[16] it was used in all studies that were included in the current systematic review. This scale was selected due to its easy design and capacity to provide a global overview of the external and internal validity of the studies included in the present systematic review, and because its repeatability and

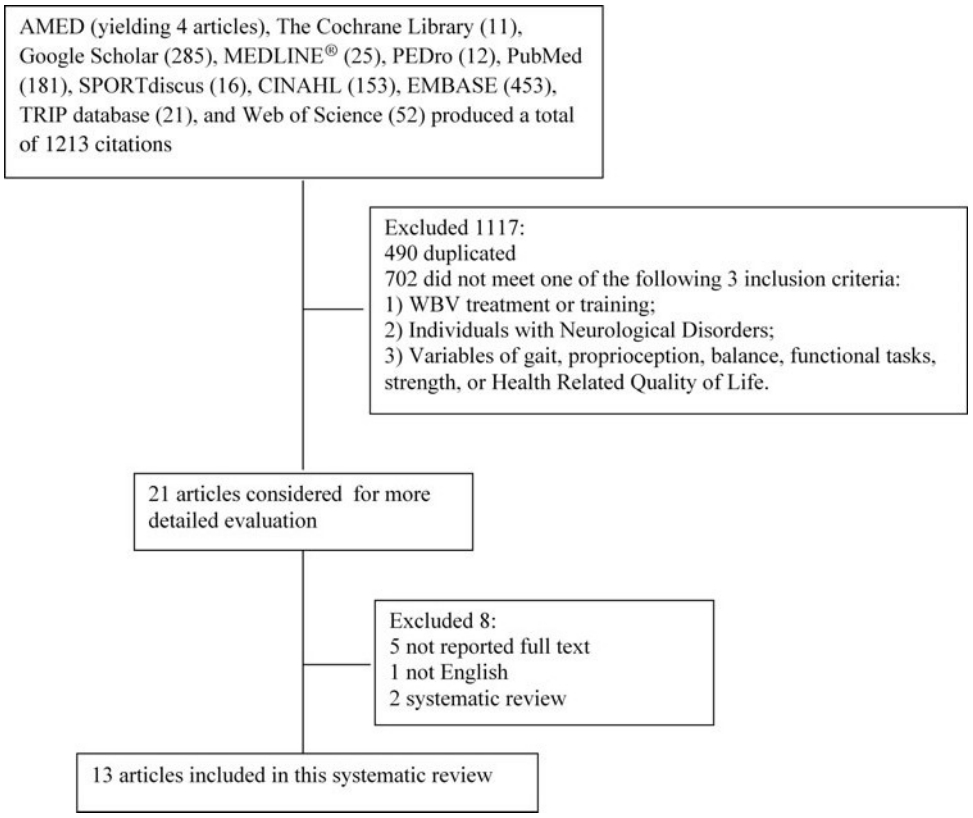

FIG. 1. Process of data selection. WBV, whole-body vibration.

applicability have been evaluated.[16] Each article was graded independently by 2 reviewers who took part in the study. Table 2 shows the consensus results for each article.

Level of evidence. The level of evidence was assessed according to the Dutch Institute for Healthcare Improvement (CBO) guidelines[17] (Appendix).

Data extraction process and the main measurements used. The data were extracted from the selected articles by one of the authors of the current review and subsequently checked by another. Potential disagreements were discussed among them, and a third author resolved any remaining disagreements. The following information was extracted separately from each selected manuscript: (1) participant

Table 2. Risk of Bias and Level of Evidence

	Pathology/study													
PEDro scale	*S [23]*	*S [24]*	*S [25]*	*MS [18]*	*MS [20]*	*MS [19]*	*PD [26]*	*PD [30]*	*PD [27]*	*PD [28]*	*PD [29]*	*CP [21]*	*CP [22]*	
1	*	*	*		*	*	*	*	*		*	*	*	
2	*		*	*	*	*			*	*			*	
3	*		*											
4	*		*	*	*			*	*	*	*		*	
5	*													
6														
7	*								*	*				
8	*	*	*	*	*	*		*	*			*	*	
9	*	*	*						*					
10	*	*		*	*		*	*		*	*			
11	*	*	*	*	*	*		*	*	*	*		*	
Score	10	5	7	5	6	4	2	5	7	5	4	2	5	Median score 5
Level of evidence	A2	C	B	B	B	B	C	C	B	B	C	C	B	Topic evidence 2

Question number on PEDro scale: 1—Eligibility criteria were specified; 2—Subjects were randomly allocated to groups or to a treatment order; 3—Allocation was concealed; 4—The groups were similar at baseline; 5—There was blinding of all subjects; 6—There was blinding of all therapists; 7—There was blinding of all assessors; 8—Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9—Intention-to-treat analysis was performed or all subjects received the treatment or control condition as allocated; 10—The results of between-group statistical comparisons are reported for at least one key outcome; 11—The study provides both point measures and measures of variability for at least one key outcome. Levels of evidence (Appendix).

S, stroke; MS, multiple sclerosis; PD, Parkinson; CP, cerebral palsy.

characteristics (age and gender); (2) type of intervention (including type of machine, oscillation, frequency, amplitude, duration of the intervention, number of series and intervening rest periods, exposure time per series, body posture, knee angle, and number of WBV sessions); and (3) presentation of pathology (Table 3). An identical procedure was followed to assess the main measurements in the articles included in this study. Table 4 displays the main measurements arranged by pathology (disorder): (1) mobility, (2) motor symptoms, (3) postural control, (4) balance, (5) strength, (6) spasticity, (7) daily-life activities, and (8) proprioception; various other measurements included in each study are also noted.

Results

Article selection

Figure 1 shows the process by which articles were selected for systematic review. Electronic search of AMED (yielding 4 articles), The Cochrane Library (11), Google Scholar (285), MEDLINE (25), PEDro (12), PubMed (181), SPORTdiscus (16), CINAHL (153), EMBASE (453), TRIP database (21), and Web of Science (52) produced a total of 1213 citations. After duplicates were removed, 723 citations were reviewed. Of these, 702 publications were rejected for inclusion in the systematic review, because review of their summaries showed that they clearly did not match the proposed inclusion criteria. Eight (8) studies were subjected to a more detailed analysis because their summaries did not reveal whether they fulfilled the inclusion criteria; these were subsequently eliminated for the following reasons: 5 provided partial text only, 1 was written in a language other than English, and 2 were systematic reviews themselves. A total of 13 articles were identified for inclusion in the current systematic review.

Quality of reviewed articles

Risk of bias. A bias score was given to each analyzed study (Table 2). Of the 13 studies included, 8 studies were randomized controlled trials, 3 were nonrandomized controlled trials, 1 was a within-subjects study of one group, and 1 was a case study. The score on the PEDro scale ranged from 2 to 10, with a median of 5. The articles were then subdivided by the ND of the subjects. For studies examining patients with multiple sclerosis (MS),[18–20] the scores ranged from 4 to 6, with a median of 5. None of the studies reported concealed allocation or blinding for assessors. Generally, the studies performed well on the statistical analysis, and all studies assessed point measures and measure of variability; two studies reported between-group comparisons for every outcome. Two (2) studies reported inclusion criteria, but the third did not.

Two (2) studies enrolled patients with cerebral palsy (CP).[21,22] The PEDro scores for these studies were 2 and 5. Poor results were in concealed allocation and blinding for assessors and therapists, which were not reported by either study. In the statistical analysis area, neither of the studies reported point measures, measures of variability, or between-group comparisons for every outcome.

In three studies of patients with stroke,[23–25] the score ranged from 5 to 10, with a median of 7. Poor results were in concealed allocation and blinding for assessors, which only one study reported. None of the studies reported blinding for the therapists. All reported intent-to-treat analyses. For statistical analyses, all of the studies reported point measures, measures of variability, and between-group comparisons for every outcome.

Finally, in five studies of patients with Parkinson disease (PD),[26–30] the score ranged from 2 to 7, with a median of 5. None of the studies reported concealed allocation or blinding for assessors and therapists. Two of the studies reported point measures and measures of variability, and three did not. Four (4) of the articles reported between-group comparisons for every outcome, whereas one did not. All of the studies reported inclusion criteria and obtained sufficient information about the subjects' characteristics.

In summary, most of the studies had poor results in concealed allocation and blinding for patients, assessors, and therapists, but were mixed in other areas.

Levels of evidence

Table 2 shows the level of evidence of each study. One (1) article reported A2-level evidence, seven articles reported B-level evidence, and five articles reported C-level evidence, according to the CBO criteria. The summary level of evidence of the topic was 2.

Study characteristics. Table 3 summarizes the studies' characteristics, using the PICOS approach (Patients, Intervention, Control, Outcomes, Subjects).[31]

Three (3) studies included patients with MS,[18–20] two studies included patients with CP,[21,22] five included patients with PD,[26–30] and three included patients with ischemic stroke.[23–25] Sample sizes ranged from 6 to 68 participants and age ranged from 8.6 to 75.0 years.

WBV equipment used. There were some differences in the type of equipment, amplitude, frequency, and type of vibration stimulation used in the studies (Table 1).

Vibratory loading parameters

Frequency (Hz) and amplitude (mm). Three (3) types of platforms were used: vertical, reciprocating, and stochastic (Table 1). The frequencies and amplitudes used with vertical platforms by pathology were as follows: MS (30 Hz and 50 Hz, 2–6 mm)[19] and stroke (20 Hz, 3–5 mm)[25]; with reciprocating platforms: MS (2 Hz and 26 Hz, 4 mm),[18] PD (6–25 Hz, 3 mm),[28,29] stroke (30 Hz, 5 mm),[23,24] and CP (15–22 Hz, 4 mm)[21]; and with stochastic platforms: MS (2–4.4 Hz, 2 mm),[20] and PD (6 Hz, 7–14 mm).[26,30]

Position and knee flexion angle. In all of the studies, the subjects were in a static posture.[18–26,28–30] The knee flexion angle was reported in six studies[18,20–23,25] and ranged from 45° to 130°, and 5 studies did not report flexion angle.[19,26–28,30] Two (2) studies reported slight knee flexion.[24,29]

Description of training. Training with WBV included short-term training (3 or fewer sessions) and long-term training (10 or more sessions). In short-term training, patients with MS[18] were exposed for 30 seconds in a single series without a rest period. Patients with PD[26,27,30] were exposed to 5 total series with no rest periods, with 1-min exposures per series. For stroke patients,[24,25] the number of series ranged

Table 3. Characteristics of Participants

Pathology	*Reference*	*Sample size*	*Age mean (years)*	*Sex (no.)*	*Study design*	*Vibration equipment used*	*Frequency (Hz)*	*Amplitude (mm)*	*No. series (rest periods, sec)*	*Time per series (sec)*	*Posture (static or dynamic)/knee angle*	*Activity of control group*	*Activity of experimental group*	*No. sessions of WBV*
Multiple sclerosis	Jackson, 2008[18]	15	54.6	Female: 12 Male: 3	NRCT	Mexuvibe vibration platform	2–26	6	1 (not rest)	30	Static/25°	*	WBV	1
	Schuhfried, 2005[20]	12	47.7	Female:* Male:*	RCT	Zeptor-Med system	2–4.4	3	5 (60)	60	Static/90°	TENS	WBV	3
	Schyns, 2009[19]	16	45.8 (CG) 49.5 (EG)	Female:* Male:*	RCT	Vibro gym	30–50	2–4	11 (180)	50–60	Static/ *	Exercise alone first, follow WBV	WBV follow exercise	3 times a wk for 4 wks
Parkinson	Turbanski, 2005[26]	52	69.1	Female: 14 Male: 38	NRCT	Zeptor-Med system	6±1	3	5(*)	60	Static/ *	Rest	WBV	1
	Haas, 2006[30]	28	63.1	Female: * Male:*	NRCT	Zeptor-Med system	6±1	*	5(*)	60	Static/ *	Rest	WBV	1
	Haas, 2006[27]	68	65.0	Female: 15 Male: 53	RCT	Zeptor-Med system	6±1	3	5(*)	60	Static/ *	Rest	WBV	1
	Ebersbach, 2008[28]	21	72.5 (EG) 75.0 (CG)	Female: 7 Male: 14	RCT	Galileo 2000	25	7–14	2	900	Static with slightly bended knees and hips. Participants not to hold/*	Standard therapy	Standard therapy +WBV	2 sessions day (5 d/wk) 3 wks
	Arias, 2009[29]	21	66.9(CG) 66.5 (PG)	Female: 9 Male: 12	RCT	Fit Massage	6	*	5 (60)	60	Feet separated at a stable and comfortable position. The knees slightly bent/*	Patients adopted the same position but vibration was not applied	WBV	12 stimulation sessions over 5 wks, on nonconsecutive days
Stroke	Van Nes, 2006[23]	53	59.7 (EG) 62.6 (ETM)	Female: 23 Male: 30	RCT	Galileo 900	30	3	4 (60)	45	Static 45°	ETM	WBV	120
	Van Nes, 2004[24]	23	58.1	Female: 10 Male: 13	WSOG	Galileo 900	30	3	4 (60)	45	Squat–slight flexion	*	WBV	1
	Tihanyi, 2007[25]	16	58.2	Female: 6 Male: 10	RCT	Nemes-Bosco	20	5	6 (180)	60	Static 45°	Patients adopted the same position but vibration was not applied	WBV	1
Cerebral palsy	Semler, 2007[21]	6	8.6	Female: 6 Male: 0	Case study	Galileo WBV-system	15–22	0–6	3 (*)	*	Static/tilt angle (10°–90°)	*	WBV and drugs	2 dailies (5 d/wk), for 24 wks
	Ahlborg, 2006[22]	14	31.2	Female: 6 Male: 8	RCT	NEMES	25–40	4	10 (120)	60	Static/50°	Resistance training	WBV	8 wks, 3 times per wk

WBV, whole-body vibration training; NRCT, no randomized controlled trial; RCT, randomized controlled trial; TENS, cutaneous electrical nerve stimulation; EG, exercise group; CG, control group; PG, placebo group; *, not reported or not applicable according to the study design; ETM, exercise therapy with music; WSOG, within-subjects study of one group.

Table 4. Outcome Measures for Neurological Diseases

Pathology	*Reference*	*Outcome measure*	*Control group*	*Experimental group*	*Reported effect*
Multiple sclerosis	Jackson, 2008[18]	*Isometric peak torque (N.m)*	*1 min/10 min/20 min (mean ± SD)*	*1 min/10 min/20 min (mean ± SD)*	*1 min/10 min/20 min (mean ± SD)*
		Quadriceps— 2 Hz	*	102.5 (±37.2)/108.5 (±34.4)/ 107.9 (±29.6)	↑/↑/↑
		Quadriceps— 26 Hz	*	107.3 (±34.4)/111.5 (±36.5)/ 111.8 (±34.8)	↑/↑/↑
		Hamstrings—2 Hz	*	39.6 (±13.7)/40.7 (±12.6)/39.4 (±12.2)	=/=/=
		Hamstrings—26 Hz	*	40.9 (±13.9)/41.5 (±12.1)/42.0 (±14.2)	=/=/=
	Schuhfried, 2005[20]		*After 15 min /after 1 week /after 2 weeks*	*After 15 min /after 1 week / after 2 weeks*	*After 15 min /after 1 week / after 2 weeks*
		Sequential changes of the results of the posturograhic assessment (points)	-1.2 (±6.5)/0.3 (±5.8)/3.8 (±2.5)	5.8 (±9.7/7.0 (±5.0)/6.3 (±10.1)	=/↑/=
		Time Up and Go Test (sec) (15 min post/1 week post/ 2 weeks post)	0.1 (±0.8)/0.6 (±0.8)/-0.3 (±0.6)	-0.6 (±0.6)/-1.0 (±1.1)/-1.2 (±1.1)	=/↑/=
		Functional reach test (mm) (15 min post/1 week post/ 2 weeks post)	-6.1 (±33.1)/34.4 (±42.0)/35.3 (±64.5)	0.3 (±40.1)/32.8 (±71.6)/7.8 (±65.4)	=/=/=
		MAS (points)	*% Decrease in score/no change % increase in score*	*% Decrease in score/no change/% increase in score*	*% Decrease in score/no change/% increase in score*
	Schyns, 2009[19]	Quadriceps	23.8 /47.6/28.6	50/27.8 /22.2	*
		Hamstrings	19.1/71.4/9.5	11.1/83.3/5.6	*
		Hip adductors	23.8/71.4/4.8	27.8/72.2.4/0	*
		Gastrocnemius	14.3/52.4/33.3	5.6/72.24/22.2	*
		MSSS-88 (points) (Pain/Spasm/ADL/ Social functioning/ Stiffness/Gait/ Body movement/ Emotional Health)	*	*	All items (=)
		Time Up and Go Test (sec)	*Baseline — post-treatment. Mean (±SD)*	*Baseline — post-treatment. Mean (±SD)*	*Baseline — post-treatment*
			1.50	1.25	=
		Muscle force (N.m) (hip flexors, extensors, abductors, adductors, quadriceps, hamstrings, ankle DF)	*	*	=

(*continued*)

Table 4. (Continued)

Pathology	*Reference*	*Outcome measure*	*Control group*	*Experimental group*	*Reported effect*
		NSA (points)	*% Decrease in score/% no change/% increase in score*	*% Decrease in score/% no change/ % increase in score*	*% Decrease in score/% no change/ % increase in score*
		Light touch	9.5/61.9/2.6	5.5/77.8/16.7	*
		Pinprick	4.8/71.4/23.8	33.3/55.6/11.1	*
		Pressure	4.8/76.2/19.0	16.7/72.2/11.1	*
		Temperature	0/47.6/52.4	22.2/44.5/33.3	*
		Propioception	14.3/47.6/38.1	16.7/72.2/11.1	*
			Baseline — post-treatment (mean)	*Baseline — post-treatment (mean)*	*Baseline — post-treatment*
		Walking speed 10 m (sec)	0.50	1.00	=
		MSIS-29 (points)			
		Physical	4.00	1.00	=
		Psychologic	0.00	2.00	=
Parkinson	Turbanski, 2005[26]	*Postural control*	*% Sway reduction*	*% Sway reduction*	*% Sway reduction*
		(1) Narrow standing	-7.1%Δ	-14.9%Δ	=
		(2) Tandem standing	-11.3%	-24%Δ	↑
	Haas, 2006[30]	Proprioceptive performance			
		The average maximum knee angles	*	*	=
		The average minimum knee angles	*	*	=
		UPDRS motor (points)	*% Reduction*	*% Reduction*	*% Reduction*
	Haas, 2006[27]	Group A	*	- 16.8% Δ	↑
		Group B	*	- 14.7% Δ	↑
	Ebersbach, 2008[28]		*Post-treatment. Mean (±SD)*	*Post-treatment. Mean (±SD)*	*Post-treatment*
		Tinetti Balance Scale (score)	11.5 (±2.4)	12.8 (±1.9) Δ	=
		Posturography (mm)	2256.0 (±681.0)	1306.0 (±331.0)	=
		Walking speed 10 m (sec)	16.5 (±2.5)	15.1 (±3.5) Δ	=
		Stand-walk-sit test (sec)	9.5 (±2.1)	8.5 (±2.1) Δ	=
		UPDRS III sum (score)	16.9 (±5.0)	17.6 (±4.5) Δ	=
		Pull test (score)	1.32 (±0.4)	1.17 (±0.72)	=
	Arias, 2009[29]	*Stability and Gait*	*Post-treatment. Mean (±SD)*	*Post-treatment. Mean (±SD)*	*Post-treatment*
		Velocity (m/sec)	*	*	=
		Cadence (steps/sec)	*	*	=
		Step amplitude (mm)	*	*	=
		Turn Time (sec)	*	*	=
		UPDRS (score)	*	*	=
		Berg balance (score)	*	*	=
		Functional reach (mm)	257.2 (±72.4) Δ	324.1 (±51.6) Δ	=
		Pegboard (#rods)	*	*	=
		PDQ-39 (points)	*	*	=

(*continued*)

Table 4. (Continued)

Pathology	*Reference*	*Outcome measure*	*Control group*	*Experimental group*	*Reported effect*
Stroke	van Nes, 2006[23]		*Post-treatment. Mean (±SD)*	*Post-treatment. Mean (±SD)*	*Post-treatment*
		Berg Balance Scale (0–56 points)	41.1 (±14.3)	40.6 (±12.8)	=
		Barthel Index (0–20 points)	14.9 (±3.9)	15.3 (±3.9)	=
		Trunck Control Test (0–100 points)	79.8 (±21.3)	80.5 (±21.6)	=
		Rivermead Mobility Index (0–15 points)	8.8 (±4.0)	8.7 (±3.6)	=
		Motricity Index (0–100 points)	66.7 (±25.9)	59.8 (±25.8)	=
			Post-treatment. Median (range)	*Post-treatment. Median (range)*	*Post-treatment. Median (range)*
		Functional Ambulation Categories (0–5 points)	3 (0–5)	3 (0–5)	=
	van Nes, 2004[24]		*Average AB vs C /D) mean (±SD)*	*Average AB vs C /D) mean (±SD)*	*Average AB vs C /D*
		RMS COP velocity M-L with eyes-closed (mm/sec)	*	9.8 (±4.3) vs (9.7 (±6.0) / 9.6 (±5.3))	=
		RMS COP velocity M-L with eyes-opened (mm/sec)	*	7.8 (±3.7) vs (7.7 (±3.9) /7.7 (±3.5))	=
		RMS COP velocity A-P with eyes-closed (mm/sec)	*	19.1 (±7.9) vs (16.7 (±8.6) / 17.0 (±8.6))	↑
		RMS COP velocity A-P with eyes-opened (mm/sec)	*	14.0 (±6.5) vs (13.0 (±5.9) / 13.5 (±6.5))	=
		Frontal plane weight-shifting (WS) speed (hits of WS)	*	11.09 (±2.51) vs (10.71 (±2.51) / 10.22 (±2.12))	↑
	Tihanyi, 2007[25]		*Post-treatment. Mean (±SD)*	*Post-treatment. Mean (±SD)*	*Change after treatment (%)*
		Maximal voluntary Isometric Torque (MIT) (N.m)	45.8 (±38.0)	53.1 (±29.0)	↑(36.6%)
		Rate of Torque Development (N.m/sec)	138.9 (±105.0)	162.2 (±70.4)	↑(19.0%)
		Maximal voluntary Eccentric torque (MEC)(N.m)	69.9 (±56.6)	88.7 (±63.9)	↑(22.2%)
		MEC at 60° of knee flexion (N.m)	65.2 (±52.4)	80.7 (±58.1)	↑(23.1%)
		Work during maximal eccentric voluntary contraction (J)	55.0 (±38.1)	55.3 (±39.7)	↑(15.7%)
		MIT Vastus Lateralis (VL) EMG (μV)	219.1 (±182.5)	270.1 (±150.9)	↑(44.9%)
		MIT Biceps Femoris (BF) EMG (μV)	43.4 (±32.5)	40.04 (±23.2)	=
		Fast Isometric Contraction VL EMG (μV)	189.4 (±143.3)	204.3 (±99.3)	=
		Fast Isometric Contraction BF	40.5 (±24.7)	39.6 (±20.2)	=

(*continued*)

Table 4. (Continued)

Pathology	*Reference*	*Outcome measure*	*Control group*	*Experimental group*	*Reported effect*
		EMG (μV)			
		MEC VL EMG (μV)	69.9 (±53.7)	216.1 (±120.7)	↑(33.2%)
		MEC BF EMG (μV)	60.8 (±45.4)	44.4 (±25.5)	↓(22.5%)
Cerebral palsy	Semler, 2007[21]				
		Reduction of the muscular tonus (observational case study)	Descriptive	descriptive	↑
		Mobility (observational case study)	Descriptive	descriptive	↑
	Ahlborg, 2006[22]		*Post-treatment. Median (range)*	*Post-treatment. Median (range)*	*Post-treatment. Median (range)*
		Time Up and Go Test (sec)	16 (7–30)	14 (8–72)	=
		Six-Minute Walk Test (m)	237 (98–610)	376 (83–439)	=
		Gross motor funtion (% of total score)	69 (47–90)	77 (38–96) Δ	=
		Concentric work participant's weaker leg at 30°/s(J)	50 (14–75) Δ	35 (3–41)	=
		Eccentric work participant's weaker leg at 30°/s(J)	85 (18–119) Δ	51 (15–69)	=
		Concentric peak torque participant's weaker leg at 30°/s(N.m)	120 (27–146) Δ	75 (25–104)	=
		Eccentric peak torque participant's weaker leg at 30°/s(N.m)	152 (32–222) Δ	105 (51–133)	=
		Concentric work participant's weaker leg at 90°/s(J)	31 (4–56) Δ	26 (1–34) Δ	=
		Eccentric work participant's weaker leg at 90°/s(J)	88 (24–112)	61 (28–83) Δ	=
		Concentric peak torque participant's weaker leg at 90°/s(N.m)	71 (10–103)	53 (11–68)	=
		Eccentric peak torque participant's weaker leg at 90°/s(N.m)	151 (31–234)	122 (38–160) Δ	=

Multiple sclerosis: Ankle DF, ankle dorsiflexion; MAS, Modified Ashworth Scale; MSSS-88, Multiple Sclerosis Spasticity Scale 88; NSA, Modified Ashworth Scale and Nottingham Sensory Assessment; MSIS-29, Multiple Sclerosis Impact Scale; **Parkinson:** Group A, first training and then rest; Group B, first rest and then training; Narrow-standing, both feet together focused postural control in the anterior–posterior direction; Tandem-standing, one foot ahead of the other focused postural control in the medial-lateral direction; UPDRS, Unified Parkinson's Disease Rating Scale; PDQ-39, The Parkinson's Disease Questionnaire; Pull test, test to know the postural stability; Pegboard, to test hand dexterity; **Stroke:** RMS, Root mean square; COP, center of pressure velocity; A, first measure balance; B, second measure balance; C, third measure balance; D, Fourth measure balance; AB, baseline; MIT, Maximal voluntary Isometric Torque; MEC, maximal voluntary eccentric torque; VL, vastus lateralis; BF, biceps femoris; EMG, electromyography. *, not reported or applicable; =, not significant differences ; ↑, effects statistical significant differences in favor of whole-body vibration (WBV) group; ↓, effects statistical significant differences in favor of control group; Δ, statistically significant differences between pretest and post-test intragroup ; ↑↑, improvement in the WBV + exercise group in relation to exercise group and control group ($p < 0.05$); SD, standard deviation; ADL, activities of daily living.

from four to six, with rest periods ranging from 60 to 180 seconds, and with 45–60-second exposure time per series.

For long-term training, the number of series for patients with MS[19,20] ranged from 5 to 11, with rest periods of 60–180 seconds and 60-second exposure per series. The total number of training sessions ranged from 3 to 12. In studies of patients with PD,[28,29] 2–5 series with 60-second rest periods and 12–30 total training sessions were used. Stroke patients[23] were exposed to 6 series with 180-second rest periods and 45-second exposure time per series. A total of 120 series were performed. Finally, in patients with CP,[21,22] a total of 24 weeks, 2 daily sessions (5 days per week) with 3–10 series, 120-second rest periods, and 60-second exposure per series were performed.

Outcome measures and effects by disease. Table 4 shows the main outcomes for each neurological disease. Effects were classified as acute effects (those resulting from three or fewer sessions) and long-term effects.

The main outcome measures in MS disease were related to balance, proprioception, strength, and HRQoL. Within acute effects,[18,20] patients affected by MS showed an improvement on the Sensory Organization Test (SOT), Time Up and Go (TUG) tests[20] and have shown an increase in quadriceps isometric strength after WBV exposure at 2 Hz and 26 Hz.[18] Long-term effects had been reported exploring muscle tone, muscle force, sensation, and functional performance by only one article,[5] without any effects in favor of WBV therapy in the performed measures.

In PD, the main outcome measures were related to postural control, gait, balance, proprioception, and HRQoL. In accordance with acute effects reported,[26,27,30] improvements were found in postural control tandem standing[26] and HRQoL measures showed statistical differences on Unified Parkinson Disease Rating Scale (UPDRS) motor items (stiffness, gait, posture, bradykinesia, and tremor).[27] Two (2) studies report long-term effects,[28,29] with only positive effects in favor of WBV training for HRQoL measured with the UPDRS scale.[28]

In stroke, the main outcome measures were related to gait, balance, proprioception, and strength. As to acute effects,[24,25] there were no concordant data showing a small improvement in sagittal plane postural instability in the eyes-closed condition and speed of weight-shifting in the frontal plane.[24] On the other hand, knee extensor muscles increased both in maximum isometric strength (36% over baseline) and maximum eccentric strength (22% over baseline).[25] As to long-term effects, no statistical differences were reported between a group treated with WBV and a group treated with exercise therapy on music (ETM) in the only study carried out.[23]

Muscular tone, motor function, gait, and balance related measures were explored in patients with CP. Any article explored the acute effects of WBV therapy in this specific condition. Only long-term effects had been studied,[21,22] and its effects were explored using WBV therapy, but there are no results with a clear effect in favor of this kind of physical therapy.

Discussion

Quality

On the quality assessment, only one of the reviewed articles was of high quality, three of the articles were deemed to be of medium quality, 7 articles scored less than 50% (low quality), and 2 articles scored less than 20% (very low quality).

The methodological quality varied among studies of patients with different pathologies, but in general the methodology was poor, and few articles were published per pathology. The studies of stroke patients had the best methodological quality, but only three articles meeting this review's inclusion criteria have been published on this subject. Also included were three articles on patients with MS, but these were of lower methodological quality than the stroke studies. More articles have been published about the use of WBV in patients with PD, but none of them were of high methodological quality. Only two articles on CP were included, and these were of low quality.

Thus, the results of this systematic review point to the existence of a limited number of studies related to the effects of WBV on ND. This may be because this is still a very new subject (the first completed study dates to 2004), and a wide variety of patient types, types of vibration platforms, types of training, methodology, and outcomes were reported. The lack of homogeneity of the data made it difficult to conduct a meta-analysis of the results.[32] In view of all this, the scientific evidence on the subject was limited, yielding a level 3 agreement using the CBO criteria.[30]

What is known about the effects of WBV in MS

Acute effects. In the two studies that examined the acute effects of WBV in patients with MS,[18,20] only minor effects were observed. Jackson et al.[18] showed that isometric strength and peak torque increased in the quadriceps muscle at 2 Hz and 26 Hz (but not in the hamstring muscles at the same frequencies). This study was of medium methodological quality but did not report the minimal differences needed for the effect to be considered real, so it is not possible to establish the clinical meaning of the reported effects.

Schuhfried et al.[20] showed only minor WBV effects on postural control and balance. This study was of low methodological quality and did not report the minimal differences needed for the effect to be considered real, so it is not possible to establish the clinical meaning of the reported effects.

Long-term effects. The measurements of gait, balance, proprioception, strength, and HRQoL in long-term interventions indicated a similar effect in both WBV and conventional therapy groups in one MS study.[5] However, this study was of low methodological quality and unless otherwise noted, the studies did not report the differences between groups needed to establish the effects as valid, and so the clinical importance of the reported effects cannot be established.

What is known about the effects of WBV in PD

Acute effects. Two (2) studies[26,27] showed improvement after only one session of WBV. Hass et al.[27] found improvements on the UPDRS motor symptoms assessment in a study with medium methodological quality, but the study did not report the minimal differences needed to be considered valid, so it is not possible to establish the clinical meaning of the effects. Turbanski et al.[26] reported improvements on balance, but in our opinion this finding must be evaluated with caution because of the poor methodological quality. In addition, this study did not report the sample or effect size or the minimal differences needed for the effect to be considered real, so it is not possible to establish the clinical meaning of the reported effects.

One (1) study[30] did not find changes in proprioceptive performance after one session of WBV. However, the study did not report sample or effect size, so it cannot be affirmed that the one session of WBV did not affect proprioceptive performance.

Long-term effects. Ebersbach et al.[28] found that WBV improved results on the Tinetti balance scale, 10-m walking speed, stand–walk–sit test, and UPDRS compared with baseline values but not compared with a standard therapy group. This study showed no improvement in posturography. This article had low methodological quality and did not report sample or effect size, so it is not possible to determine from these results whether WBV training is more or less effective than standard therapy.

Arias et al.[29] found that WBV improved gait parameters (velocity, cadence, step, and amplitude) and UPDRS, Berg balance score, and functional reach compared with baseline values, but not compared with a placebo group. This study showed no improvement in the Parkinson's Disease Questionnaire. This article was of low methodological quality and did not report sample or effect size, so it is not possible to determine whether WBV training is more or less effective than placebo training.

What is known about the effects of WBV in stroke

Acute effects. Two (2) studies were found that measured the acute effects of WBV on patients with stroke.[24,25] Van Nes et al.[24] found only minor effects on balance after one session of WBV. This study was of low methodological quality and did not report the minimal differences needed for the effect to be considered real, so it is not possible to establish the clinical meaning of the reported effects.

Thianyi et al.[25] found effects on strength, and the methodology was of medium quality. This study did not report the minimal differences needed to be considered valid, so it is not possible to establish the clinical meaning of the reported effects.

Long-term effects. Van Nes et al. performed the only study that measured the long-term effects of WBV effects on patients with stroke.[23] This article was of high methodological quality, and it is the only study to report follow-up data after training. In this study, there were no group differences (ETM versus WBV) in functional improvement on any of the selected outcome measures (Berg Balance Scale, Barthel Index, Trunk Control Test, Rivermed Mobility Index, Functional Ambulation Categories, Motricity Index). The absence of a third group receiving no therapy makes it impossible to determine whether the two treatments were equally beneficial or whether neither yielded improvements. The originals authors think that the duration and selected intensity of WBV training used in this study was insufficient to induce lasting changes in the somatosensory pathways or sensorimotor cortices.

What is known about the effects of WBV in CP

Long-term effects. One (1) study[22] of low methodological quality did not find improvements in any of the measured parameters (TUG, 6-minute walk test, gross motor function, and eccentric peak torque at 30°/second and 90°/second). This article did not report sample or effect size, so it is not possible to determine whether the WBV therapy was effective.

In the current authors' opinion, the report by Semler et al.[21] was of sufficiently poor quality to call the reported improvements into question. The subject with CP was a young girl whose improvements could have been due to growth, and we do not consider the method used for measurement (observation) to be clinically relevant.

It can therefore be concluded that to date there is no evidence that body vibration exercise is beneficial in persons with CP.[22]

Limitations. There are some limitations to the current review. The criteria used to judge the level of evidence have not yet been standardized. Different authors of systematic reviews employ different criteria,[33] and the same author may use different criteria in different studies.[34] The use of different criteria is related to the decision of whether to include only randomized clinical studies or to also consider studies of low methodological quality, in which scales of measurement may also vary. In addition, the best method for assessing the risk of bias has not been determined.[33]

The applied search strategy involved a risk of bias, because only articles in English were searched. Publishing significant results is easier than publishing nonsignificant results, and the latter are more likely to appear in national journals written in languages other than English.[35]

An investigation is needed as to whether all the beneficial effects related to the application of WBV in healthy populations can be extrapolated to ND. For Alzheimer's and post-polio disease, two diseases with major global prevalence,[36,37] there are currently no studies involving WBV.

Furthermore, an optimal dose–response study according to disorder and type of WBV is urgently needed, as is greater awareness of the cost-effectiveness and cost-utility of various WBV treatments.

Conclusions

In conclusion, the heterogeneity of the WBV devices, the outcome measures used, and the different interventions make comparison difficult. There is moderate evidence that one session of WBV has positive effects on strength, whereas there is a weak level of evidence that WBV could improve proprioception and HRQoL measures in patients with ND. With respect to long-term effects of WBV, there is minor evidence from the studies with the best methodological quality that WBV improves strength, proprioception, gait, and balance. Further research on the intervention is strongly needed.

Disclosure Statement

No competing financial interests exist.

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(Appendix follows →)

Appendix I. Levels of Evidence and Conclusion According to the Dutch CBO Guidelines

Levels of evidence according to the Dutch CBO guidelines
A1 Systematic review containing at least 2 independent trials of level A2
A2 Randomized comparative double-blind study of good quality and sufficient size
B Comparative trials, but not all characteristic of A2 (also patient control studies and cohort studies)
C Noncomparative trials
D Expert opinion
Level of conclusion according to the Dutch CBO guidelines
Conclusion based on:
1 Research on level A1 of at least 2 independent trials of level A2
2 1 trial of level A2 of at least 2 independent trials of level B
3 1 trial of level B or C
4 Expert opinion

CBO, Institute for Healthcare Improvement.