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Effects of Whole-body Vibration with Stochastic Resonance on Balance in Persons with Balance Disability and Falls History - A Systematic Review

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The aim of this systematic review was to identify and evaluate the evidence of the efficacy of stochastic resonance whole-body vibration (SR-WBV) on static, dynamic and functional balance in the elderly and in patients with neurodegenerative diseases. English and German studies were consulted in the CINAHL, Cochrane Central Register of Controlled Trials, ISI Web of Knowledge, PEDro and PubMed databases. Eight of 138 eligible studies were included, involving 381 participants. The included studies showed a low to high risk of bias. Three studies focused on long-term effects after SR-WBV. One study evaluated SR-WBV impact over three days while four studies examined its immediate effects. There is only limited evidence that SR-WBV may be effective in improving static, dynamic and functional balance among elderly individuals and patients with neurodegenerative diseases. In the future, more

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studies of high methodological quality are needed to improve the level of evidence.

KEYWORDS *random vibration, static balance, dynamic balance, functional balance*

INTRODUCTION

Poor balance ability increases the risk of falls and the risk of injury, and is associated with community dwelling (King & Tinetti, 1995) and institutionalized elderly individuals (Rubenstein, Josephson, & Robbins, 1994), as well as patients with neurodegenerative diseases (Benatru, Vaugoyeau, & Azulay, 2008; White & Dressendorfer, 2004). Impaired balance ability is also associated with a decline in the activities of daily living and decreased quality of life (Muslimovic et al., 2008). In addition, the risk of progression of degenerative diseases (sarcopenia, osteoporosis, heart disease, etc.) is increased as a result of hampered daily physical activity (Bauer & Sieber, 2008; Kaeding, 2009).

Adequate balance training is needed to enhance ability in persons with balance disorders and subject to frequent falls. Furthermore, to improve the specificity of the treatment regimen, the levels of impairment in static, dynamic or functional balance skills should be described. Static balance has been defined as the ability to maintain the center of gravity over a narrow base of support in an upright position (Overstall, 2003). Dynamic balance was defined as the ability to maintain a balance while the body`s center of gravity is in motion (Orr, Raymond, & Fiatarone Singh, 2008). Functional balance enables everyday tasks or activities without falling or predicts the risk of falls (Overstall, 2003).

Sensorimotor training is considered adequate as balance training (Steadman, Donaldson, & Kalra, 2003). It includes balancing exercises or whole-body vibration (WBV) and is offered to various populations. WBV devices may potentially stimulate sensorimotor processes (Rogan & de Bruin, 2013). There are two types of WBV: sinusoidal (S-WBV) and stochastic resonance whole-body vibration (SR-WBV) (Rogan & Hilfiker, 2012). S-WBV devices vibrate with frequencies between 20 and 50 Hz and amplitudes ranging from 2 to 6 mm. During S-WBV training, participants are standing on one single motorized plate (Cochrane, 2011). SR-WBV devices vibrate between 1 and 12 Hz while the feet of the participants are placed on two independent powered and stochastic (i.e. ‘noise’) vibrating platforms (Rogan, Hilfiker, Schmid, & Radlinger, 2012). The amplitude ranged between 3 and 6 mm.

During vibration, small changes in the muscle-tendon complex may occur leading to muscle spindle activation and stimulation of the Ia-afferents. The latter will facilitate the alpha motoneuron output via the medulla spinalis, resulting in a contraction of the extrafusal muscle fibers (Cardinale & Bosco, 2003).

Stochastic resonance dynamics have been found in a selection of anatomical structures, such as human muscle spindles (Cordo et al., 1996) or cutaneous receptors (Wells, Ward, Chua, & Timothy Inglis, 2005). In contrast to a sinusoidal signal, the stochastic stimulus has the ability to change the threshold values of the cell membrane potential (Fallon, Carr, & Morgan, 2004; Fallon & Morgan, 2005), which may explain why cells are easily excited under such stochastic conditions (Haas & Schmidtbleicher, 2008). In addition, stochastic signals occur in short-time quasi-resonance with the stochastic behavior of the nerve cells, activating neuro-muscular systems already at low stimulus intensities (Haas & Schmidtbleicher, 2008).

Mechanical stochastic resonance might be important in persons with balance disability and a history of falls. Compared with S-WBV, the plate is vibrating at a lower frequency and with small amplitude during SR-WBV. This may explain why the latter method can be used without major risks for involuntary events directly from the start of a reconditioning therapy for elderly or deconditioned persons, or in neurological patients. Hence, SR-WBV offers a challenging but promising form of balance training.

Previous reviews on S-WBV postulated beneficial effects on muscle strength in the elderly (Marin & Rhea, 2010a, 2010b), on postural control in the elderly and in patients with neurodegenerative diseases (Rogan, Hilfiker, Herren, Radlinger, & de Bruin, 2011; Santos-Filho, Cameron, & Bernardo-Filho, 2012; Sitja Rabert et al., 2012) and on bone density in the elderly (Lau et al., 2011).

All previously published systematic reviews on whole body vibration included sinusoidal vibration (S-WBV), omitting stochastic vibration (SR-WBV). Therefore, the aim of this systematic review was to identify and evaluate the evidence of the efficacy of SR-WBV on static, dynamic and functional balance in persons with balance disability and falls history.

METHODS

Methods of the present analysis and the inclusion criteria were developed and documented elsewhere as a protocol prior to the review procedure (https://www.gesundheit.bfh.ch/fileadmin/wgs_upload/users/rgs2/Protokoll_SR-WBV_postural_control_2014_02_15.pdf). This systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Liberati et al., 2009).

Search Strategy

The following electronic databases were searched from December 2012 through November 2013: CINAHL, Cochrane Central Register of Controlled

Trials, ISI Web of Knowledge, PEDro and PubMed. In addition, a hand search was performed in Google Scholar, the Register of Controlled Trials and in the reference lists of the included studies to check for possible topic-related manuscripts.

The PICO model was used to establish the search question and to delineate the search algorithm (Sackett, Straus, Richardson, Rosenberg, & Haynes, 2000). In this study, the PICO acronym stands for Population (elderly, patients with neurodegenerative diseases), Intervention (WBV exercise), Comparator (no treatment, or other balance exercise), Outcomes (postural control, static, dynamic, functional balance). Hence the research question was: what is the effect of SR-WBV training on static, dynamic and functional balance in persons with balance disability and a history of falls? Two independent reviewers (AS, AV) screened the titles and abstracts for eligibility.

Because elderly individuals and patients with neurodegenerative diseases show impaired balance abilities, they are at higher risk of falling, and hence of injury compared with healthy persons (Horak, 2006). Therefore, the following inclusion criteria were defined: randomized control studies (RCT) and non-RCT studies in English and German languages, elderly aged over 65 years, neurodegenerative diseases such as Parkinson's disease, multiple sclerosis and clinical outcome measures of static, dynamic and functional balance performance. Excluded were studies with sinusoidal vibration and electrical stochastic vibration.

Data Extraction

Two independent reviewers (AS, AV) assessed the methodological quality of the eligible studies with 'The Cochrane Collaboration's tool for assessing risk of bias'. The criteria list comprised six items and represents the aspects of internal validity. Each item was scored with + for yes, with – for no, and with ? if the information was not provided or was unclear. A study was defined as having a low risk of bias if all criteria are fulfilled with yes. A study has a moderate risk of bias when one or more items are scored with unclear, while a study has a high risk of bias if one or more key domains have been rated with no. Where discrepancies existed, a third reviewer (SR) intervened to obtain a consensus.

In addition, the following study characteristic was extracted using the 'Data Extraction Template for Cochrane Reviews' by two independent authors (AS and AV): (1) design and sample; (2) inclusion criteria; (3) training parameters; (4) outcome variables static, dynamic and functional balance; and (5) outcome conclusions of the studies and statistical significance.

Due to partially unavailable data and high heterogeneity of measurement methods and outcome data, (meta-) statistical analysis to estimate the individual and pooled effect sizes and 95% CI could not be conducted.

RESULTS

Study Characteristics

A total of 315 studies (CINAHL = 8, Cochrane library = 31, ISI Web of Knowledge = 115, Pedro = 4, PubMed = 126 and hand search = 31) were found, and 253 remained after removal of duplicates. After screening the titles and abstracts, full texts were read from 14 studies. Five articles were excluded because they were not SR-WBV studies and one because it covered another topic. Finally, eight papers were included in this systematic review, totaling 381 participants (Figure 1).

Three studies examined long-term effects (Dittrich, Eichner, Schmidtbleicher, & Beyer, 2012; Hartmann, Mohokum, Sitter, & Wolf, 2011; Rogan, Hilfiker, et al., 2012). Kaut et al. (2011) evaluated SR-WBV effects on balance over three days while four studies (Haas, Turbanski, Kessler, & Schmidtbleicher, 2006; Rogan, Radlinger, et al., 2012; Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; Turbanski, Haas,

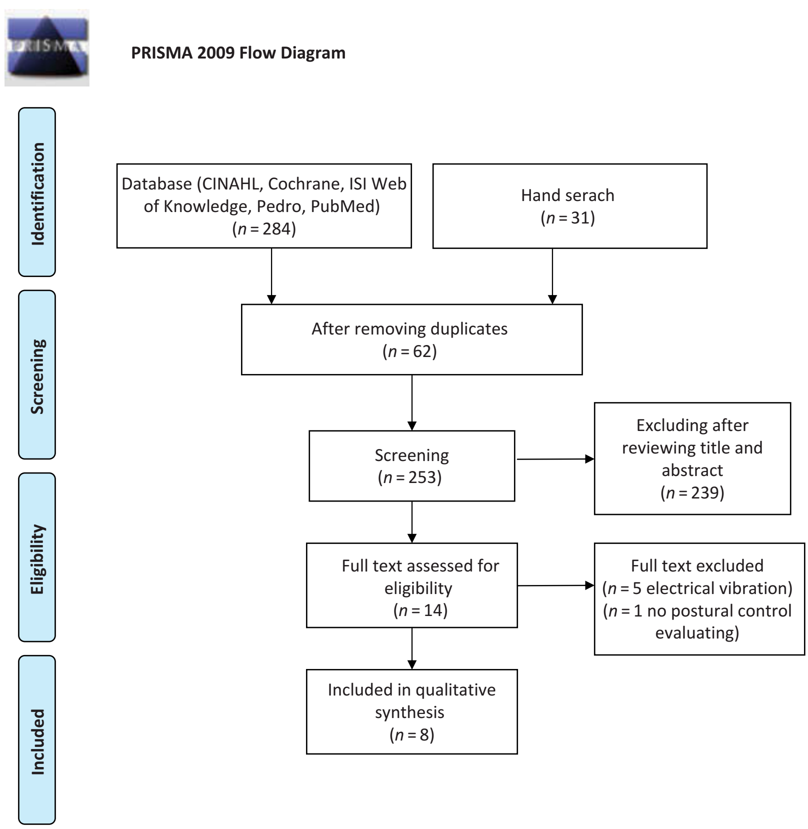

FIGURE 1 PRISMA Flow diagram.

Schmidtbleicher, Friedrich, & Duisberg, 2005) examined the immediate effects of a single SR-WBV intervention.

The effects of SR-WBV were examined in Parkinsonian (Haas et al., 2006; Kaut et al., 2011; Turbanski et al., 2005), multiple sclerosis (Schuhfried et al., 2005), and polyneuropathy (Hartmann et al., 2011) patients and in the elderly (Dittrich et al., 2012; Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012). One study was performed in Austria (Schuhfried et al., 2005), five studies in Germany (Dittrich et al., 2012; Haas et al., 2006; Hartmann et al., 2011; Kaut et al., 2011; Turbanski et al., 2005) and two in Switzerland (Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012).

According to the 'Cochrane risk of bias tool' (Table 1) one study (Dittrich et al., 2012) did not use an adequate method of 'allocation concealment', three studies (Dittrich et al., 2012; Haas et al., 2006; Hartmann et al., 2011) did not report the blinded status of the investigator or participant, and two studies (Haas et al., 2006; Turbanski et al., 2005) showed incomplete outcome data. They presented only change percentage data. They did not give any information about baseline and intervention data and no effect size calculation was used.

Training protocols

Table 2 depicts the studies' characteristics and results. Three studies operated over five series for 60 seconds with 6 Hz, noise level 4 and an amplitude of 3 mm (Haas et al., 2006; Kaut et al., 2011; Turbanski et al., 2005), while two studies vibrated with 5 Hz, Noise level 4 (Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012). Schuhfried et al. (2005) started with 1 Hz and increased the frequency while it was still comfortable for the participant. Hartmann et al. (2011) described a frequency between 4 and 8 Hz and Dittrich et al. (2012) described no exercise parameters.

TABLE 1 Methodological Quality of the Included Studies

Study	Allocation concealment	Blinding	Incomplete data outcome	Selective outcome reporting	Other sources of bias
Dittrich et al. (2012)	–	–	+	?	–
Haas et al. (2006)	?	–	–	–	–
Hartmann et al. (2011)	+	–	+	+	–
Kaut et al. (2011)	+	?	+	+	–
Rogan, Hilfiker, et al. (2012)	+	+	+	+	+
Rogan, Radlinger, et al. (2012)	+	–	?	+	+
Schuhfried et al. (2005)	?	+	–	+	–
Turbanski et al. (2005)	?	?	–	+	–

TABLE 2 Study characteristics of all included studies

Study	Subjects	Study design	*N* at start / age (±SD) (years)	WBV	Control	Outcome measures	Main effects (within group and between groups)
Dittrich et al. (2012)	Elderly	RCT	SR-WBV: 41 Age: 67.75 (±4.50) Control: 52 Age: 69.05 (±7.15)	12 wk 3/wk D: 3 sets × 45 sec R: 30 sec F: ? A: ? Pos: exercise during vibration	No change in life style	SB: Tandem stance DB: TUG FB: CR	The women in the SR-WBV group are significant faster during TUG by 0.4 sec ($P < 0.001$). Women rise significant faster by 0.9 sec in the SR-WBV group ($P = 0.003$) compared to controls.
Haas et al. (2006)	Parkinson`s disease	Cross-Over RCT	All: 65.0 (± 7.8)	One session D: 5 sets × 60 sec R: 1 min between set F: 6 Hz A: 3 mm Pos: stance with slightly bent knee and hips	rest	SB: UPDRS motor scores. Subscale gait and posture.	Significant improvement in the SR-WBV group by 15.8% in the UPDRS motor score ($P < 0.001$).

Hartmann et al. (2011)	Patient with neuropathy	RCT	SR-WBV: 15 Age: 63.13 (±8.30) Control: 17 Age: 70.12 (±8.47)	8 wk 2/wk D: 5 sets × 60 sec R: 1 min between set F: 6 Hz A: 3 mm Pos:	8 wk 2/wk D: 30 min water therapy	SB: stance on a force plate measured sway: medial-lateral & anterior posterior DB: stance on a movable platform (Cortex) measured sway: lateral-lateral & anterior posterior	Significant medial-lateral sway decrease by 20.2 cm (P <0.05) in the SR-WBV group.
Kaut et al. (2011)	Parkinson`s disease	RCT	SR-WBV: 18 Age: 70.1 (±4.27) Sham: 17 Age:68.6(±4.04)	3/wk D: 5 sets × 60 sec R: 1 min betweenset F: 6. 5 Hz A: 3 mm Pos: Static semi-squat position	3/wk D: 5 sets × 60 sec R: 1 min between set F: 1 Hz A: 1 mm	SB: UPDRS motor scores.	Not significant improvements of UPDRS in the WBV group (>20%) were seen.
Rogan, Hilfiker, etal. (2012)	Elderly (untrained)	Cross-Over RCT	SR-WBV: 10 Age: 80.2 (±6.8) Sham: 10 Age: 77.4 (±7.1)	One session D: 5 sets × 60 sec R: 1 min between set F: 5 Hz A: 3 mm Pos: stance with slightly bent knee and hips	One session D: 5 sets × 60 sec R: 1 min between set F: 1 Hz A: 3 mm Pos: stance with slightly bent knee and hips	SB: Semi-tandem stand on a force plate and measured sway: lateral-lateral & anterior posterior DB: ETGUG, ST, DTFB: TTS during CR on a force plate	No significant changes.

(*Continued*)

TABLE 2 (Continued)

Study	Subjects	Study design	N at start / age (±SD) (years)	WBV	Control	Outcome measures	Main effects (within group and between groups)
Rogan, Radlinger, et al. (2012)	Elderly (frail)	RCT	SR-WBV: 10 Age: 76.8 (±7.7) Sham: 10 Age: 80.7 (±8.7)	4 wk 3/wk D: 5 sets × 60 sec R: 1 min between set F: 5 Hz A: 3 mm Pos: stance with slightly bent knee and hips	4 wk 3/wk D: 5 sets × 60 sec R: 1 min between set F: 1 Hz A: 1 mm Pos: stance with slightly bent knee and hips	FB: CR time and time to stabilization on a force plate	Significant changes (P = 0.09) in the SR-WBV group in rising time by 0.4 sec.
Schuhfried et al. (2005)	MS Patients	Cross-Over RCT	SR-WBV: 6 Age: 49.3 (±13.3) Control: 6 Age: 46 (±12.7)	One session D: 5 sets × 60 sec R: 1 min between set F: 3 Hz up to increasing until no longer tolerated A: 3 mm Pos: static squat position	One session: Standing on WBV devices without vibration and receiving TENS.	SB: Sensory Organization Test (SOT) FB: TUG, FRT	For TUG the SR-WBV group decreased by 1.0 sec and the control group increased by 0.7 sec. Significant between group changes (P = 0.041) in the TUG test one week after the intervention.

Turbanski et al. (2005)	Idiopathic PD	Matched controlled trial	All: 52 Age: 69.1 (±8.9)	One session D: 5 sets × 60 sec R: 1 min between set F: 6 Hz A: 3 mm Pos: stance with slightly bent knee and hips	rest	SB: UPDRS motor scores. Subscale gait and posture. DB: narrow stance & tandem stance on a movable platform to determine anterior-posterior and medial-lateral sway	Sway decreases significantly in the SR-WBV group by 24% ($P = 0.01$) compared to controls

RCT: randomized controlled trial; SR-WBV: stochastic resonance whole-body vibration; D: Duration, R: rest; F: frequency; A. Amplitude; mm: millimeter sec:seconds; min: minutes; Hz: hertz; Pos: position; SB: static balance, DB: dynamic balance; FB: functional balance; CR: chair rise, TUG: Time Up-and-Go,UPDRS: Unified Parkinson's Disease Rating Scale; FRT: Functional Reach Test

In four studies, the control group received no intervention (Dittrich et al., 2012; Haas et al., 2006; Rogan, Radlinger, et al., 2012; Turbanski et al., 2005). Hartman et al. (2011) permitted the control group to perform water therapy twice a week for half an hour while a sham intervention was carried out in two studies (Kaut et al., 2011; Rogan, Hilfiker, et al., 2012).

Outcome Measures

In total, 11 different outcome measures for postural control could be found in the eight studies. For static balance, three studies recorded the sway of the center of pressure data of participants in a two-legged stance (Dittrich et al., 2012; Hartmann et al., 2011) and in semi-tandem stance (Rogan, Radlinger, et al., 2012) using biomechanical devices on a force plate. Kaut et al. (2011) and Haas et al. (2006) measured the static balance with the aid of subscales of the Unified Parkinson`s Disease Rating Scale (UPDRS).

Dynamic balance was measured in three studies (Dittrich et al., 2012; Haas et al., 2006; Turbanski et al., 2005) on a movable and unstable platform (Coordex, Fa. Ruf, 64347 Griesheim, Germany and Biodex Stability Systems, Biodex, New York, USA), using the two-leg stance and semi-tandem stance. An accelerometer measured the anterior-posterior and lateral-lateral body sway. Also to assess dynamic balance, two studies used the Timed Up and Go Test (TUG) (Dittrich et al., 2012; Schuhfried et al., 2005), one study used the Expanded Timed Get-Up-and-Go Test (ETGUG) (Rogan, Radlinger, et al., 2012) and two studies the Functional Reach Test (Rogan, Radlinger, et al., 2012; Schuhfried et al., 2005) while Schuhfried et al. (2005) additionally measured with the Sensory Organization Test (SOT).

Functional balance was evaluated in five studies (Dittrich et al., 2012; Kaut et al., 2011; Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012; Schuhfried et al., 2005). Three studies examined the gait with (Rogan, Radlinger, et al., 2012) and without (Haas et al., 2006; Rogan, Radlinger, et al., 2012) cognitive task and three with chair rising (Dittrich et al., 2012; Kaut et al., 2011; Rogan, Hilfiker, et al., 2012).

From the eight studies under investigation, significantly improved aspects of static or dynamic balance were observed in two studies, while significantly improved aspects of functional balance were found in three out of the eight studies (Table 2). Table 2 also summarizes the heterogeneity of the observed methods and results, which made a meta-analysis impossible.

DISCUSSION

The goal of this systematic review was to identify and evaluate the best evidence after SR-WBV on static, dynamic and functional balance in persons with balance disability and a history of falls. To achieve this aim a sensitive literature search was conducted. This review includes eight studies evaluating static, dynamic and functional balance with a variety of different outcome measurements. SR-WBV has beneficial effects to enhance static, dynamic and functional balance among elderly individuals and patients with neurodegenerative diseases.

Methodological Aspects

The meaningfulness of a clinical investigation depends crucially on its internal validity. High internal validity corresponds to preventing bias that can falsify study results. The main instruments for maintaining high internal validity are allocation concealment, randomization and blinding. Rogan, Hilfiker et al. (2012) and Rogan, Radlinger et al. (2012) satisfied these requirements for a low risk of bias. The remaining seven studies included in this systematic review showed a moderate to high risk of bias, according to the risk of bias tool. Schulz and Grimes (2002a, 2002b) reported that studies using unclear allocation concealment, when compared with those that used suitable concealment, yielded up to 40% higher estimates of effect. Three further studies (Hartmann et al., 2011; Kaut et al., 2011; Rogan, Radlinger, et al., 2012) fulfilled the criteria of allocation concealment. In research, allocation concealment is often confused with tables of random numbers or flipping coins (Schulz & Grimes, 2002a). In addition, some researchers confuse allocation concealment with blinding of treatments (Schulz, Chalmers, & Altman, 2002). Allocation concealment secures strict implementation of a random allocation sequence without foreknowledge of treatment assignments. An independent person or institution should carry out allocation concealment without prior knowledge of the upcoming investigation. Furthermore, the method of allocation concealment must be described, for example sequentially numbered, opaque sealed envelopes (SNOSE), or central randomization.

Blinding prevents ascertainment bias and protects the sequence after allocation. Besides Rogan, Hilfiker, et al. (2012) and Rogan, Radlinger, et al. (2012) only Schuhfried et al. (2005) carried out a blinding procedure for participant and outcome assessors. Blinding means that investigator or participants or statisticians are unaware of an assigned treatment, so that they are not influenced by their knowledge. If possible, blinding should take place in randomized controlled studies (RCT). Exceptions would be, for example, randomized controlled pilot studies with the focus of feasibility regarding recruitment, randomization, adherence and safety. Among the included studies, two pilot studies are available (Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012).

Six studies (Dittrich et al., 2012; Hartmann et al., 2011; Kaut et al., 2011; Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012; Schuhfried et al.,

2005) showed a low bias for incomplete data outcome reporting. Reporting of a missing data outcome should necessarily be carried out in an RCT (Wood, White, & Thompson, 2004). The missing data are taken into account in the analysis and reporting. Studies should track missing data and analyze, for example, differences in baseline characteristics between missing and observed outcomes. Participants with no data after baseline measurements cannot easily be included in statistical analysis or participants who drop out may need to be handled in different ways in the statistical analysis.

In recent years, implementation according to Good Clinical Practice (GCP) criteria has increasingly been demanded for non-drug studies. The goal is to guarantee consistent standards of data quality, safety for participants and to reduce risk of bias. In addition to a study protocol it is necessary to register the study in a recognized WHO clinical trial according to ethical and scientific principles. The study leader is encouraged to carry out accurate planning and an efficient procedure of quality assurance. A comprehensive registration of clinical trials can improve the completeness of reporting of study results and reduce 'publication bias'. Two studies (Rogan, Hilfiker, et al., 2012; Rogan, Radlinger, et al., 2012) were included in the US National Institute of Health (NIH registry, Veterans Administration tab). Further studies should be published according to publication guidelines. Inaccurate descriptions and reports of scientific studies increase the risk of an incorrect conclusion and misinterpretation. Reporting should be done using the CONSORT guideline (Moher, Schulz, & Altman, 2001) for reporting RCTs and for pilot studies refer to Thabane et al. (2010). Only Rogan, Hilfiker, et al. (2012) and Rogan, Radlinger, et al. (2012) used reporting guidelines.

The selected outcome variables and measurements mentioned in the methods sections of all studies were discussed and analyzed in their results and discussion sections, reducing the risk of bias by selective reporting. For this reason, and bearing in mind the above-mentioned limitations, it is legitimate to draw conclusions from the results after SR-WBV intervention.

Clinical Aspects

SR-WBV is a sensorimotor training method to optimize the integration of afferent information during specific movement programs (Granacher, Gollhofer, & Strass, 2006).

In general, training on SR-WBV devices showed immediate as well as long-term effects (Rogan & Hilfiker, 2012). It is known that postural control deficits are closely related with risk of injury and risk of falls. This systematic review indicates clinically meaningful effects of SR-WBV training.

After SR-WBV intervention, static balance improved significantly in patients with neurodegenerative diseases (Haas et al., 2006; Hartmann et al., 2011; Kaut et al., 2011). Schuhfried et al. (2005) found no between-group differences (P = 0.065), but their results showed improvements in the SOT score by 7 points within the SR-WBV group. These results are not consistent with the study from Arias, Chouza, Vivas, and Cudeiro (2009) and Ebersbach, Edler, Kaufhold, and Wissel (2008). Both studies investigated the effects on S-WBV on UPDRS after 12 sessions (Arias et al., 2009) and four weeks (Ebersbach et al., 2008), respectively. They found no significant changes.

Rogan et al. (2012) and Dittrich et al. (2012) found no improvements on static balance in elderly participants after SR-WBV training. Rogan et al. (2012) evaluated immediate effects while Dittrich et al. (2012) focused on long-term effects. In addition, in both studies the participants were mobile, home living and self-caring. To ensure an individualized training regimen, performance ability of older persons should be assessed prior to training commencement. Recently, the Physical Performance Classification for Elderly (PPCfE) tool has been proposed as valid to classify the elderly in 'pre-frail or frail', 'mobile' or 'trained' (Rogan & de Bruin, 2013; Rogan, Schmidtbleicher, & Radlinger, 2014). Meta-analysis showed a (Rogan et al., 2011) small effect size (SMD = –0.26) of S-WBV on static balance (95% CI –1.09 to 0.57). This meta-analysis, however, pooled 'pre-frail or frail' with 'mobile' elderly individuals, which may explain the relative small effect size. Although not statistically significant, this result may be clinically relevant.

Based on the findings of the Rogan et al. (2011) meta-analysis and the Zhang et al. (2013) study, reporting significant effects (P = 0.009) of four weeks S-WBV training on dynamic balance (TUG) in 'frail elderly', it can be hypothesized that SR-WBV training may be a valid method for static balance training in the 'pre-frail or frail' elderly and deconditioned persons with Parkinson diseases.

In four studies (Dittrich et al., 2012; Hartmann et al., 2011; Schuhfried et al., 2005; Turbanski et al., 2005) significant improvements after SR-WBV intervention on dynamic balance are shown. Only Rogan et al. (2011) presented no significant improvements in dynamic balance. One reason could be that this study evaluated immediate effects. Compared with the findings of the SR-WBV studies, the results of the S-WBV studies demonstrated less consistency. After long-term S-WBV, no significant improvement was found in dynamic balance in patients with Parkinson diseases (Arias et al., 2009; Chouza, Arias, Vinas, & Cudeiro, 2011) or multiple sclerosis patients (Schyns, Paul, Finlay, Ferguson, & Noble, 2009; Wunderer, Schabrun, & Chipchase, 2010). Ebersbach et al. (2008) observed significant effects on dynamic balance after S-WBV in patients with Parkinson diseases. In their study the WBV group trained five days a week, for two 15-minute sessions a day over 4 weeks.

In elderly individuals, dynamic balance was moderately improved (SMD –0.34, 95% CI –0.60 to –0.08) after S-WBV intervention (Rogan et al., 2011). In contrast to the studies included in this current review, the standing position during S-WBV was conducted in a static squat position or was performed dynamically. It can be questioned that the observed effects resulted from reflex activity or from body weight exercise.

Based on the weak evidence, SR-WBV intervention may be prescribed as a training therapy to improve dynamic balance in 'pre-frail or frail' elderly individuals and neurodegenerative disease patients three times a week, with a frequency of 3 to 6 Hz and Noise level 4 to 5 during 5 × 60 seconds leaving a 60 second rest period in between.

The following studies reported on functional balance in 'mobile' elderly persons. A four-week study reported significant SR-WBV effects (Rogan, Hilfiker, et al., 2012). Bautmans, Van Hees, Lemper, and Mets (2005) showed no effects on functional balance as measured by the Tinetti Test after six weeks of S-WBV intervention (intensity: 35 to 45 Hz, amplitude: 2 to 5 mm and duration: 30 to 60 seconds with squat-type static exercise during vibration). After six weeks of S-WBV training (frequency: 10 to 26 Hz, amplitude: 3 to 7 mm, duration: 4 × 60 seconds, additional off-plate physical therapy: gait, balance and strength exercise) Bruyere et al. (2005) found an increase of 3.5 points on the Tinetti Test in the intervention group compared with a decrease of 0.3 points in the control group ($P < 0.001$).

These findings suggest that SR-WBV can positively influence functional balance (time to stabilization after chair rising) after a four-week SR-WBV intervention in the elderly.

Study Limitation

This study has some limitations that should be discussed. First, publication bias may be present, given that the search included only English and German language publications. Secondly, the eight studies included in this current review used a variety of assessments. Some of the assessments may lack validity (UPDRS, SOT) with regards to biomechanical measuring devices (e.g. force plate), making it difficult to draw definitive conclusions. Third, the time factor may play an essential role. The study durations are very short, leading to heterogeneous results. Howe, Rochester, Neil, Skelton, and Ballinger (2011) described in their systematic review that, in general, successful balance programs offer exercise sessions ranging from 15–20 minutes up to 70 minutes per session that are performed over periods spanning from 5 weeks up to 12 months. Compared with these recommendations, four of the eight SR-WBV studies offer training sessions that are rather short in duration. Four studies investigated immediate effects after one session (Haas et al., 2006; Rogan, Radlinger, et al., 2012; Schuhfried et al., 2005; Turbanski et al., 2005) and one study (Kaut et al., 2011) after three sessions. Finally, due to the high methodological heterogeneity and the small number of long-term studies, plausibility to conduct a meta-analysis was lacking.

CONCLUSION

This systematic review suggests that there is only limited evidence that SR-WBV may improve static, dynamic and functional balance in the elderly and in neurodegenerative-disease patients. Well-designed and high-quality RCTs covering a longer period are needed to confirm these findings and to investigate long-term effects of SR-WBV on different types of balance.

DISCLOSURE

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AUTHORS' CONTRIBUTORS

SR initiated the idea for the systematic review. AS, AV and SR collected the data. AS and AV analyzed the methodological quality of the retrieved studies. SR, RH wrote the draft while JT critically revised and edited the manuscript. All authors have read and approved the final manuscript

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