# Effects of stochastic resonance whole-body vibration on sensorimotor function in elderly individuals—A systematic review

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**Introduction:** Due to demographic changes, falls are increasingly becoming a focus of health care. It is known that within six months after a fall, two thirds of fallers will fall again. Therefore, therapeutic procedures to improve balance that are simple and can be performed in a short time are needed. Stochastic resonance whole-body vibration (SR-WBV) may be such a procedure.

**Method:** An electronic search to assess the effectiveness of SR-WBV on balance in the elderly was conducted using databases that included CINAHL Cochrane, PEDro, and PubMed. Included studies were assessed using the Collaboration Risk of Bias Tool by two independent reviewers.

**Results:** Nine studies showing moderate methodological quality were included. Treatment parameters were heterogeneous. Vibration frequency ranged from 1 to 12 Hz. Six studies found statistically significant improvements of balance from baseline to post measurement after SR-WBV interventions. One article found clinical relevance of the improvement in total time of the "Expanded Time to Get Up and Go Test".

**Discussion:** Physiological adaptations after balance training are specific and may explain some of the observed heterogeneity. Two out of nine studies assessed reactive balance and both indicated statistically significant improvements after SR-WBV. Therefore, SR-WBV represents a reactive balance training.

KEYWORDS

stochastic resonance therapy, whole-body vibration (WBV), falls, aged, postural balance [MeSH]

## Introduction

Ageing is associated with sensorimotor deficits resulting in muscular weakness, mobility issues, balance disorders and in gait disorders, and this leads to falls and reduced independence in everyday life (1). The sensorimotor system constantly and unconsciously regulates its movements and postural control based on perceived information to achieve postural stability. Numerous research studies have assessed the effect of stochastic resonance (SR) stimulation to the lower extremity on postural regulation and balance performance in sub-populations such as healthy adults (mean age: 23.04 years, ±6.33 years) (2), elderly individuals (mean age: 73.00 years) (3), or individuals with comprised health suffering from Parkinson (4), or multiple sclerosis (5) or stroke (6, 7), SR has been shown in a variety of physiological systems (8–11), in which the presence of noise below the sensory threshold could enhance the response of the system to weak signals (12–14).

Collins et al. (12) postulated that SR could be used to elderly individuals with elevated sensory thresholds.

Whole body vibration (WBV) with stochastic resonance (SR) can easily applied. SR-WBV does not lead to exhaustion and blood pressure and lactate levels are low during vibration training (15). SR-WBV could be easily personalized to the individual's level of fitness (16). For example, elderly with low baseline fitness who want to start an exercise program should start with a program that meets their physical capabilities (16). Older people with frailty or pre-frail condition are advised to undergo a "skilling-up" phase before undertaking more traditional forms of training (17). SR-WBV can be used as a training modality for the "skilling-up" phase (16, 18, 19). Compared to traditional balance training, there are indications on how to design a training regime (sets, rest between sets, session per weeks, etc.) and on the other hand the training protocols are characterized by a short duration between 1 and 5 min of intermittent or continuous WBV application (20). There is no need to change clothes or shoes or to shower afterwards, which might be important in the working world or for adults who do not want to waste time on intensive training (2). Eichelberger et al. (21) were able to determine a decrease in accelerations with increasing distance from the vibrating plate due to damping properties of the involved body structures. However, it is known that a prolonged exposure to vibration (e.g., driving, hammering) may lead to musculoskeletal and neurological disorders (22, 23). Systematic reviews and meta-analysis (24–27) have shown that shorter exposure to vibration have a positive effect on muscle strength and postural control if the training regime (e.g., amplitude, duration and frequency of vibration) is correctly dosed.

SR-WBV differs from sinusoidal WBV in that the stimuli are randomized and amplified using noise (25, 28). This results in a generation of action potentials by the suprathreshold stimuli (29). SR-WBV induces an excitatory stimulus to the alpha motoneuron *via* mono- and polysynaptic pathways and elicits muscle activation in response, resulting in body stabilization (30). SR-WBV can be understood as reactive balance training that simulates a fall situation itself through the application of unpredictable, random, and multidirectional displacements of the stance surface (31). Reactive balance training means that a person has the ability to react to a loss of balance, because reactive balance is a key factor that ultimately determines whether an individual will sustain a fall (32). Reactive balance can be profoundly impaired in older adult populations (32).

In contrast to SR-WBV, sinusoidal WBV are constant. If the stimulus remains the same, the body adapts very quickly and this slows down the impact of growth stimulus (27). Three WBV devices were used in clinical settings: sinusoidal vertical (SV-WBV), sinusoidal side-alternating (SS-WBV), and stochastic resonance (SR-WBV). While the sinusoidal WBV devices uses a single plate for standing, the SR-WBV device uses two plates for standing (24, 33–36). Due to the different physiological mechanisms of impact and use of equipment, this paper focuses on SR-WBV.

Furthermore, study results demonstrated that whole-body vibration training provides more than physiological effects (2,

37). Animals study showed that daily exposure to WBV over five weeks significantly improved cognition in young mice compared to non-vibrated mice (38, 39). Regterschot et al. (37) could determine that passive WBV could improve executive functions in healthy young adults. They postulated that WBV has the potential as a cognition-enhancing therapy. Chan et al. (40) reported that executive functions are a set of cognitive processes that regulate, manage and control other cognitive processes in order to achieve a goal, such as planning, mental flexibility, multi-tasking etc. Research findings described that cognitive decline and falls are linked (41–43) and that cognitive training improve balance and gait (44).

## Aim

A systematic literature review on the effects of SR-WBV on postural control have been conducted previously (27). As the number of publications on SR-WBV has increased significantly in recent years, this present systematic literature review aims to provide an update on the status quo of the efficacy of SR-WBV on postural control in frail elderly individuals. The research question was: could SR-WBV positively influence postural control in individuals with balance disability?

# Methods

## Study design

This paper is an update of the systematic review by Rogan et al. (27). In advance, a registration on PROSPERO (CRD420203194) was conducted and the guideline "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) was used for reporting. This current systematic review used the same methodological approach as the first study. The inclusion and exclusion criteria were identical. The same search terms were used on the same databases. The data collection process was more comprehensive in this study. Besides the training load, the intervention protocol and the measurement instrument tools were now included. The risk of bias was assessed with the same instrument (The Cochrane Collaboration Cochrane Risk of Bias Tool) as in the first study.

## Information sources

Electronic searches were conducted on CINAHL, Cochrane Central Register of Controlled Trials, Physiotherapy Evidence Database (PEDro), and PubMed up to August 2022. In addition, a hand search of the reference lists of included studies, research institution websites, and Google Scholar was conducted.

## Search strategy

The PICO model was used in this study. The PICO acronym stands for **P**opulation (elderly, frail elderly), **I**ntervention (WBV exercise), **C**omparator (no treatment, or other balance exercise),

Outcomes (postural control, static, dynamic, functional balance). Search terms included: (i) "stochastic resonance whole-body vibration" OR "SR-WBV" OR "stochastic vibration" OR "stochastic training" AND (ii) "balance" OR "postural control* " OR "postural stability".

## Eligibility criteria

This study included intervention studies and randomized controlled pilot studies. German- and English-language articles with intervention and control groups from the fields of geriatrics were considered. For studies with frail elderly persons, those aged 65 years and older were eligible. Studies with frail elderly persons under 65 years of age, studies with elderly persons with "fit" status, and studies with neurological diseases were excluded.

## Data collection process

Two independent study nurses screened and analyzed the title and abstract for inclusion and exclusion criteria. In the next step, the full text was read and included in this systematic literature review if eligible. For each included article, authors, population, intervention protocol, outcome parameters, results, and training load were extracted and electronically recorded by two independent study nurses.

## Study risk of bias assessment

The Cochrane Collaboration Cochrane Risk of Bias Tool (RoB) (45) was used to assess the internal validity of the included articles. Two independent reviewers (SR, JT) 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 each item were scored with + for yes, with—for no, and with? if the information was not provided or was unclear. A study was determined 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. The level of agreement between the independent reviewers who rated the primary studies was 98%.

# Results

## Study selection

There were 1,206 matches of studies. Of these, 262 duplicates were removed. A total of 944 titles and abstracts were screened, and 917 articles were removed due to systematic reviews articles ($n = 8$), application of sinusoidal vibration ($n = 898$), application of stochastic vibration *via* the sole of the foot or knee ($n = 7$), effects of SR-WBV on postural control or pain ($n = 2$), pelvic floor muscle ($n = 2$). The remaining 27 full texts were read, of which 9 articles were included in this systematic review (Figure 1). Three articles originated from Germany (4, 46, 47), and six from Switzerland[1] (16, 19, 30, 36, 48, 49). Six trials were designed as pilot study (16, 19, 30, 36, 48, 49) and three as randomized controlled trials (4, 46, 47).

## Balance survey method

A total of six articles examined static balance (16, 19, 30, 47–49), six studies examined dynamic balance (4, 16, 19, 30, 47, 49) while five studies observed functional balance (19, 46–49).

## Result overview of the studies

Overall, four of nine studies showed statistically significant balance improvements within the SR-WBV group in the before-after comparison (4, 19, 46, 48). Table 1 summarizes the findings of the individual articles.

## Training loads

In four of the nine studies, participants received a single training session with SR-WBV (4, 19, 30, 46). The remaining five studies determined the effect of SR-WBV after multiple interventions. The range was 12–36 training sessions (16, 36, 47–49).

In three studies (4, 46, 48), the frequency was increased and the starting position on the vibration device was progressively adjusted to the participants. All three studies use 5 sets and 60 s of vibration. One study did not specify a frequency (47). In three trials, continuous vibration was performed at a frequency of 5 Hz and five series with a duration of 60 s and rest of 60 s (19, 36). Four studies applied a frequency of 6 Hz, with 5–6 series of 60 s duration and 60 s rests (4, 16, 30, 46, 49).

The control group (CG) received no active intervention in four out of nine studies (19, 46, 47, 50). In one study, the CG completed a different intervention (4). Sham intervention was performed in four other studies. Table 2 gives an overview of the training load.

The evaluation of the methodological quality was classified as followed (Table 3): one study did not use the method of allocation concealment (47), seven studies (4, 16, 19, 30, 46, 47, 49) did not report the blinded status of the investigator or participant, and four studies (4, 19, 46, 49) 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. Table 3 provides an overview of the risk of bias of the included studies.

# Discussion

During aging, sensory symptoms such as absent reflexes are clinically relevant. They are not only debilitating but also responsible for changes. This systematic literature review addressed the research question "could SR-WBV positively

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[1]These articles are from the authors of this systematic review.

FIGURE 1
Flow chart of the search.
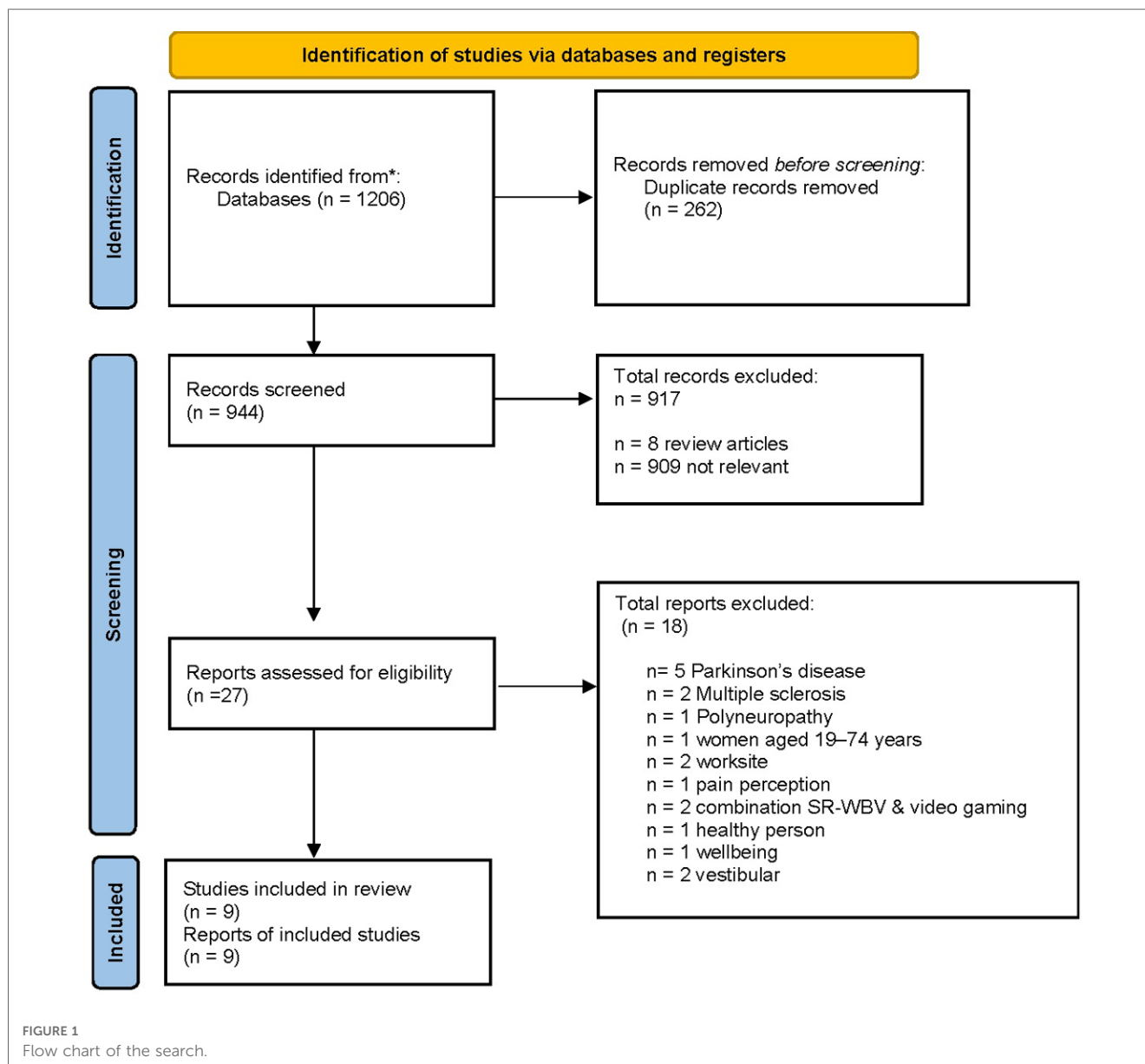
influence postural control in individuals with balance disability?" using published results.

In summary, the effect of SR-WBV on postural control presents a mixed picture. The statistically significant results from four studies were contrasted with five statistically unsound results. However, the effect size was strengthened by Rogan et al.'s (49) indication of clinical relevance. They were able to demonstrate clinical relevance (2.9 s) for the Expanded Timed Get-up-and-Go (ETGUG) test (51) in frail individuals after SR-WBV training. The SR-WBV group was a median of 3 s faster after the intervention period compared with the baseline measurement ($P = 0.043$; ES: 0.91). This study result has immediate consequences in terms of treatment recommendation for frail individuals with a postural control deficit of dynamic balance (52). It is known that a normal sensory system is necessary for successful postural control and movement. The central nervous system must accurately assess the position of the body in space and the limbs in relation to each other (proprioception). Postural reflexes must be released efficiently when external perturbations are detected. Maintaining balance must be automatic so that it is not impaired by other tasks. During aging, impairments of the sensorimotor system lead to a loss of postural control and to falls. The process of postural control depends on many sensory signals and neurological pathways and maintaining the quality of these systems at their optimal level is fundamental. SR-WBV could play an important role toward addressing postural control, by involving an interaction of different types of neurophysiological sensors and the adaptation of afferent and efferent signals, the SR-WBV likely serves as an exercise for the sensorimotor system. Tan et al. (53) demonstrated in their systematic review a significant positive benefit on postural control (SMD = 0.61, 95% CI: 0.12 to 1.09, $P = 0.01$) and muscle activity in tibialis anterior (SMD = 0.46, 95% CI: 0.04 to 0.88, $P = 0.03$) and gastrocnemius (SMD =

TABLE 1 Overview of the study characteristics of the included studies.

| Study | Population | Intervention protocol | Target parameters | | Results | |
|---|---|---|---|---|---|---|
| | Group: SR-WBV; intervention group (IG); control group (CG), (n), sex (men (m)/ women (w)), mean years (±SD) | | Biomechanical measurement method | Functional parameter/outcome | Effect within group (effect size: ES) | Effect between groups |
| Dittrich et al. (47) | Prospective controlled study SR-WBV: n = 41 (m: 13/ w: 28) CG: n = 52 (m: 13 / w: 39) SR-WBV: m: 69.1(±4.0) w: 66.4(±5.0) CG: m: 68.1 (±6.8)/ w: 70.0 (±7.5) | WBV: Exercises on ZeptorMed (4 exercises per training session from a pool of 15; individual, not listed which exercises). IG: activity in everyday life was not changed | Static & dynamic balance with Biodex Stability System | Dynamic, functional balance with motoric assessment according Runge [Chair Rising, Timed-up-and-Go (TUG), Tandem walk, etc.] | IG (women) Chair Rising significantly decreased by 0.9 s ($p = 0.003$; ES = 0.4) TUG significantly reduced by 0.4 s ($p = 0.000$; ES = 0.4) | |
| Haas et al. (46) | RCT cross-over Group A: n = 34 Group B: n = 34 m: 53/w: 15 65.0 years (±7.8) | SR-WBV: Free two leg stand with shoes, with slightly bent knees CG: rest for the same duration | | Static and functional balance with UPDRS motor scores und Sit-to-Stand (STS) | Significant reduction in UPDRS motor score ($p < 0.01$) after SR-WBV Group A: - 16.8% Group B: - 14.7% | |
| Kessler et al. (48) | RCT pilot study SR-WBV: n = 13 (m: 5/w: 8) CG: n = 11 (m: 3/w: 8) SR-WBV: 90.7 years (±7.5) KG: 83.8 years (±9.3) | SR-WBV: Parallel stance (increase possible without holding), tandem stance, slow dynamic squats CG: Sham therapy without increasing 1 Hz | | Static and functional balance with chair rise Test during Short Physical Performance Battery test (SPPB) | Chair rising significantly reduced ($p = 0.001$; ES r = 0.89) | Significantly higher SPPB score significantly for SR-WBV compared to CG ($p = 0.035$; ES r = 0.43) |
| Rogan et al. (16) | RCT crossover pilot study Group A: n = 10 Group B: n = 10 Group A: 76.8 years (±7.7) Group B: 80.7 years (±5.7) | Parallel stance with shoes with slightly bent knees | Static balance with Kistler force plate | Dynamic balance with functional reach test FRT; Expanded Timed get Up and Go Test (ETGUG); (Single-task / Dual-task) | | |
| Rogan et al. (49) | RCT crossover pilot study SR-WBV: n = 9 (m/w: n.i.) SR-GKV: 88.5 Jahre (±6) | Parallel stance with shoes with slightly bent knees | | Static, dynamic and functional balance with semitandem/tandem stand & Chair Rise Test (during SPPB Test), ETGUG | Large ES in SPPB score after SR-WBV ($p = 0.039$) | Large ES for ETGUG ($p = 0.043$) |
| Rogan et al. (30) | RCT crossover pilot study SR-GKV: n = 9 (m:4/w:4) SR-GKV: 88.5 Jahre (±5.9) | Parallel stance with shoes with slightly bent knees | | Static, dynamic balance by ETGUG, chair rising | Large ES for SPPB ($p = 0.121$); ETGUG ($p = 0.011$); | |
| Rogan et al. (19) | RCT crossover pilot study SR-WBV: n = 10 (m: 5/w: 5) CG: n = 10 (m:5/w:5) SR-WBV: 80.2 years (±6.8) CG: 77.4 years (±7.1) | SR-WBV: Parallel stance with shoes with slightly bent knees KG: Sham intervention with 1 Hz; same position as SR-WBV | | Static, dynamic and functional balance with semitandem/tandem stand & Chair Rise Test (during SPPB Test), ETGUG | | |

*(Continued)*

TABLE 1 Continued

| Study | Population | Intervention protocol | Target parameters | | Results | |
|---|---|---|---|---|---|---|
| | Group: SR-WBV; intervention group (IG); control group (CG), (n), sex (men (m)/ women (w)), mean years (±SD) | | Biomechanical measurement method | Functional parameter/outcome | Effect within group (effect size: ES) | Effect between groups |
| Rogan et al. (36) | RCT crossover pilot studie SR-WBV: n = 10 (m/w: n. i.) CG: n = 10 (m/w: n.i.) SR-WBV: 76.8 years (±7.7) KG: 80.7 years (±5.7) | SR-WBV: Parallel stance with shoes with slightly bent knees KG: Sham intervention with 1 Hz; same position as SR-WBV | Functional balance by chair rising on a Kistler force plate | | Significantly faster rising (p = 0.09) | |
| Turbanski et al. (4) | Case-control-study SR-WBV: n = 26 (m/w: n.i.) CG: n = 26 (m/w: n. i.) n = 52 (m: 38/w: 14) n = 69.1 years (± 8.9) | SR-WBV: Upright standing on ZeptorMed CG: 15 min walk | Dynamic balance by means of TS and narrow PS on moving platform | | Tandem stance was significantly longer after SR-WBV over 20 s (p = 0.04) | |

0.68, 95% CI: 0.14 to 1.23, $P = 0.01$) using sinusoidal whole-body vibration in individuals with a sensorimotor deficit after ankle injury. They concluded that whole body vibration has the potential to improve sensorimotor deficits involving balance, strength, joint position sense, and muscle activity in people with chronic ankle instability. However, Lesinski et al. (54) formulated in their systematic review and meta-analysis article a balance training regime for healthy elderly by a training period of 11–12 weeks, a training frequency of three sessions per week, a total number of 36–40 training sessions, a duration of 31–45 min of a single training session, and a total duration of 91–120 min of balance training per week. Comparing these findings with findings from young healthy adults, it seems plausible that

TABLE 2 SR-WBV training load as used in the different studies under investigation.

| Study | Duration / (sessions per week) | Frequency | Sets, duration, rest |
|---|---|---|---|
| Dittrich et al. (47) | 12 weeks / (3×) | n. i. | 3 × 45–60 s, 3 s |
| Haas et al. (46) | 1 day / (1×) | 6 Hz (±1 Hz) | 5 × 6 s, 6 s |
| Kessler et al. (48) | 4 weeks / (3×) | 3–6 Hz | 5 × 6 s, 6 s |
| Rogan et al. (16) | 2 × 4 weeks / (3×) | 5 Hz | 5 × 6 s, 6 s |
| Rogan et al. (49) | 2 × 4 weeks / (3×) | 6 Hz | 5 × 6 s, 6 s |
| Rogan et al. (30) | 1 day / (1×) | 6 Hz | 6 × 6 s, 6 s |
| Rogan et al. (19) | 1 day / (1×) | 5 Hz | 5 × 6 s, 6 s |
| Rogan et al. (36) | 4 weeks / (3×) | 5 Hz | 5 × 6 s, 6 s |
| Turbanski et al. (4) | 1 day / (1×) | 6 Hz (±1 Hz) | 5 × 6 s, n. i. |

n. i., no indication; h, hertz; s, seconds.

almost the same balance protocols are effective in healthy young and older adults and there seems to be no age effect (54). In this current article, no of the included articles reported this amount of training regimes. Fisher et al. were able to illustrate in their meta-analysis, that long-term WBV (between 4 weeks and 32 weeks) could significantly improve functional balance (Timed-up-Go test: SMD = −0.18; 95% CI: −0.32, −0.04; 10 min walking test SMD = −0.28; 95% CI: −0.56, −0.01). However, no significant changes were found in elderly individuals (tinetti gait scores: SMD = 0.04; 95% CI: −0.23, 0.31, 6 min walking test: SMD = 0.37; 95% CI: −0.03, 0.78).

It is known that muscle strength is a potentially important factor contributing to postural control (61). Large effects of strength training could be determined for static and dynamic balance in elderly individuals, but only a small effect was found for dynamic balance in young adults (62). Son et al. (63) were able to demonstrate that strength training increase muscle strength in ankle musculature and improve one-leg-standing balance compared to control situation. It can be concluded that the intensity of strength training is fundamental not only for increasing muscle strength but also for improving postural balance in elderly participants.

Furthermore, Kingwell described that exercise has the potential to improve cognitive function (64). Explanatory models address the fact that WBV stimulate mechanosensory receptors (e.g., tactile corpuscles). These signals are transmitted to the primary somatosensory cortex. These areas have connection with region in the prefrontal cortex that strongly involved in cognitive processing (37, 65). An indirect pathway involves the limbic system (e.g., amygdala and hippocampus, important areas of learning and memory), which can mediate the effects of sensory correlations on the prefrontal cortex (66). The amygdala has projections to non-thalamic nuclei (e.g., the cholinergic nuclei of the basal forebrain) with diffuse connections to several brain

TABLE 3 Risk of bias of the included studies.

| | Random sequence generation (selection bias) | Allocation concealment (selection bias) | Blinding of participants (performance bias) | Blinding of personnel (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Other bias |
|---|---|---|---|---|---|---|---|
| Dittrich et al. (47) | ? | − | − | + | ? | ? | − |
| Haas et al. (46) | ? | ? | − | + | − | + | − |
| Kessler et al. (48) | + | + | − | − | + | + | + |
| Rogan et al. (30) | + | + | + | ? | ? | − | + |
| Rogan et al. (16) | + | + | + | − | + | + | + |
| Rogan et al. (49) | + | + | − | − | − | − | − |
| Rogan et al. (19) | + | + | − | − | − | − | + |
| Rogan et al. (36) | + | + | − | − | + | + | − |
| Turbanski et al. (4) | ? | ? | ? | ? | − | + | − |

Bias rating: (+) = there is a small risk of bias; (−) = there is a risk of bias; (?) = unclear bias because not enough information available.

regions (65). It can be speculated that mechanosensory receptor stimulation can increase cognitive function. Furthermore, it has been assumed that improvement in cognitive function depends on increased production of neurotrophins [e.g., brain-derived neurotrophic factor (BDNF)] (67). BDNF is recognized as the most significant neurotrophic growth factor related to neuronal plasticity and has a key role in the differentiation and survival of neurons (68). Studies could demonstrate a close correlation between increased BDNF levels and WBV (69, 70). However, so far it is unclear how mechanical vibrations may influence the expression of BDNF (71).

The loss of balance ability is an important risk factor for falls in elderly individuals. Reactive balance is a crucial part of avoiding and adapting to complex environments that threaten postural stability (72). In German-speaking countries, the balance ability is considered to be a coordinative ability (73). We describe this ability as the aggregate understood to maintain and regain balance, taking into account the necessary personal conditions.

Various types of exercises (e.g., airex pad, tilting board, swinging platforms) are used in treatment settings and summarized with the synonym balance training (74–77). The goal is to optimize balance. It is assumed that balance is a skill, and that balance training improves several balance tasks at the same time (29). However, recent studies indicate that only those balance tasks that are trained can also improve (77, 78). Giboin et al. (32) showed that the group which trained in a single-leg stand on the tilting board and the group that trained in a single-leg stand on the swinging board (Posturomed) improved statistically significantly only in the area in which they trained.

Recently, there have been attempts to move away from the term ability towards the definition of skill (73). Taube (78) explained that balance training does not change the behavior of the spinal reflex *per se*. It seems rather to improve the ability of finding the right reflex settings for specific conditions of postural control.

Thus, balance training improves task-specific reflex modulation. Low et al. (55) postulated, that specific balance exercise could be the only one likely to improve postural balance. Slackline training improves postural balance in young and elderly individuals in a one-leg stance (56, 57). However, the impact of slackline training is limited or negligible for standard static and dynamic bipedal stances (58–60). Paillard (79) explains that specific balance training optimizes postural skills, but it is not known whether these skills improve motor skills in all types of physical activity. He further refers to the fact that additional studies are required to address this question accurately. Grabiner et al. (80) indicates that task-specific perturbation training is superior to traditional balance exercise training in improving reactive balance capacity and thus preventing falls. Kim et al. (72) performed a network meta-analysis to specify which exercise method is most effective to improve reactive balance in elderly individuals. They analyzed data of 39 RCTs including 1,388 elderly individuals receiving balance training with reactive components (perturbations training) demonstrated the most amount of improvement in reactive training, followed by power training and gait training. SR-WBV is power training. SR-WBV has the potential to improve race of force development after four weeks SR-WBV training in elderly individuals (48). In relation to gait, SR-WBV can be used as skilling up in elderly not able to perform standard gait training. It is known that SR-WBV could significantly improve gait in older adults (19, 47, 49). In the case of a reactive balance, the better the gait, the sooner gait training can be started.

## Limitation

The observed heterogeneity in the individual studies' study quality and findings impede a clear-cut answer to the research question. Furthermore, the study design of the pilot study does

not allow a clear conclusion on efficacy because the primary aim of the pilot study is not to assess an exact intervention effect size, but rather to determine the sample sizes and evaluate feasibility of the study protocol (81–83).

## Conclusion

We found a heterogeneous situation on effects for balance according to SR-WBV. One study showed clinical relevance for ETGUG. Two studies examined the skill in reactive balance. Since balance is a skill and SR-WBV trains reactive balance, future studies should focus on the parameter reactive balance.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

## Author contributions

This research project was developed by SR. Data collection was undertaken by two independent bachelor students. SR wrote and JT edited the manuscript. All authors contributed to the article and approved the submitted version.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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