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Review Article

Effects of Whole-Body Vibration Exercises on Muscle Responses and on Risk of Falls in Elderly Individuals: A Systematic Review

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Abstract

Background: This systematic review was conducted to assess the effects of whole-body vibration (WBV) exercises on muscles responses and on risk of falls in elderly individuals.

Methods: Searches were conducted in MEDLINE/PubMed, Physiotherapy Evidence Database (PEDro), Web of Science, CINAHL and Scopus databases in Feb 2023 to identify studies with the potential to be included according to the eligibility criteria. Relevant data from included studies were extracted. The methodological quality was evaluated for each study included by PEDro scale, risk of bias (Cochrane Collaboration's tool), and the level of evidence by National Health and Medical Research Council (NHMRC).

Results: Six randomized clinical trial (RCT) were included. In respect of the level of evidence, all studies were classified as Level II (NHMRC) and regarding to the methodological quality (PEDro scale), four studies were considered 'high' and two were 'fair'. Two publications presented low risk of bias, three with high risk of bias and one unclear. All the selected studies reported positive effects and improvements on risk of falls and muscle response after WBV exercise.

Conclusion: WBV exercise may contribute to reduce the risk of falls and improve muscle responses in the elderly individuals.

Keywords: Physical exercise; Vibration therapy; Risk of falls; Elderly

Introduction

According to the WHO, the elderly population (those aged 60 years and over) is gradually increasing. Therefore, there is a concern to provide health and a good quality of life to these individuals (1). The decrease in sex hormones, mitochondrial dysfunctions and apoptosis, which happen naturally due to aging, are associated with sarcopenia (2). Women in early and late perimenopause present a decline in muscle strength and power during the transition to post-menopause (1). Physical exercise can influence physical performance during the menopause transition (3). In addition, in male, the sarcopenia is more prevalent in individuals with hypogonadism also known as andropause, due to the decline in testosterone levels (4-6).

In addition, sarcopenia can be exacerbated by physical inactivity (2,6), which can be a result of musculoskeletal changes caused by age-related conditions that generate persistent pain and decreased mobility, such as osteoarthritis (7,8). Consequently, the elderly population is more fragile, considering mobility and functional capacity due to the decrease in muscle mass and strength, speed or stability of gait and proprioception, decreasing balance and increasing the risk of falls (2,9); and still can suffer serious injuries that require long-term care and/or institutionalization, favoring physical inactivity (10). Therefore, strategies to prevent falls are desirable (10,11).

Physical exercise is recommended as a non-pharmacological strategy to prevent falls in the elderly (10,11). In this context, one alternative for the management of the physical inactivity of these individuals, might the whole-body vibration (WBV) exercise, that is a generated in an individual in the systemic vibratory therapy (SVT) (12). The SVT is an intervention in which the whole body of the individual is exposed to mechanical vibration produced by a vibrating platform (VP). The SVT is useful, easily accessible, and has a low impact, and low perception of effort, for the elderly individuals (12). However, detailed reporting of WBV exercise protocols is required (13,14). Still, there remains a gap in the literature about the ideal SVT protocol to promote benefits in muscle response parameters and risk of falls in the elderly. Therefore, we aimed to describe, in a systematic review, effects of WBV exercise on muscle responses and on risk of falls in elderly.

Methods

Protocol and Registration

The protocol for this systematic review was registered in advance in the International Prospective Register of Systematic Reviews (PROSPERO) under the number CRD42020198858 and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)(15) was followed.

Research question

The current study aimed to answer the following question: What are the effects of WBV on muscle responses and risk of falls in the elderly? To define the five major components of the research question, the PICOS (P = Patients - elderly aged 60 and over; I=Intervention- WBV; C=Comparison - WBV versus no WBV; O=Outcomes - muscle responses and risk of falls, S = Studies - Randomized Clinical Trial - RCT) strategy was used (15).

Search strategy used to find the publications

Three independently reviewers (AGM, ACGS and EMM) accessed five databases on Jul 20th, 2020 and repeated on Feb 2nd, 2023. The databases MEDLINE/PubMed, Physiotherapy Evidence Database (PEDro), Web of Science, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Scopus. The detailed search strategy in Supplementary Materials.

Inclusion criteria

The selection of publications followed the inclusion criteria: 1) to be an randomized clinical trial (RCT) about effects of WBV exercise on muscle responses and on risk of falls in elderly; 2) to be published in English; and 3) to have static or dynamic exercises on the VP.

Exclusion criteria

The exclusion criteria used were: 1) review articles; 2) study protocol, 3) studies with individuals younger than 60 years old, 4) WBV associated with pharmacological interventions and 5) WBV associated with another physical exercise. After the search, the pooled publications were screened according to the inclusion and exclusion criteria.

Study selection and data extraction

All studies found in the five databases were exported to data management software (Excel), and the duplicates were removed. The review was carried out following a few steps: 1) Identification - the articles were identified through database research and reference screening, 2) Screening - two reviewers (ACGS and YTS) independently examined titles and abstracts and they applied the eligibility criteria to include the works, 3) Eligibility - relevant complete texts were analyzed by the same reviewers for inclusion in the systematic review. A third reviewer (AGM) solved disagreements between the two reviewers.

An Excel spreadsheet was elaborated containing the data extracted from each paper: 1) author and year, 2) participants/groups (sample size, age, sex), 3) objectives, 4) muscle assessment, 5) risk of falls evaluation, 6) WBV exercise protocols, 7) biomechanical parameters of the mechanical vibration (frequency, peak-to-peak displacement and peak acceleration), 8) level of evidence classified by National Health and Medical Research Council (NHMRC) and methodological quality assessed with the PEDro scale, and 9) outcomes about the muscle responses and risk of falls. Two researchers (ACGS and VSC) extracted the data and the disagreements were solved by a third reviewer (AGM).

Levels of evidence (LE), methodological quality and risk of bias of the selected articles

The selected articles were independently appraised by two reviewers (VCS and VSC), and when there were disagreements, a third researcher was consulted (AGM). The methodological quality was classified following the PEDro scale. This scale assesses the methodological quality of clinical trials of physical therapy interventions (10 items established based on an "expert consensus"). The classification was established as 'high' (score ≥ 7); 'fair' (score 5 and 6) and 'poor' (score ≤ 4) (16). The level of evidence of each selected work was based on the National Health and Medical Research Council (NHMRC) hierarchy of evidence (Fig. 1) (17).

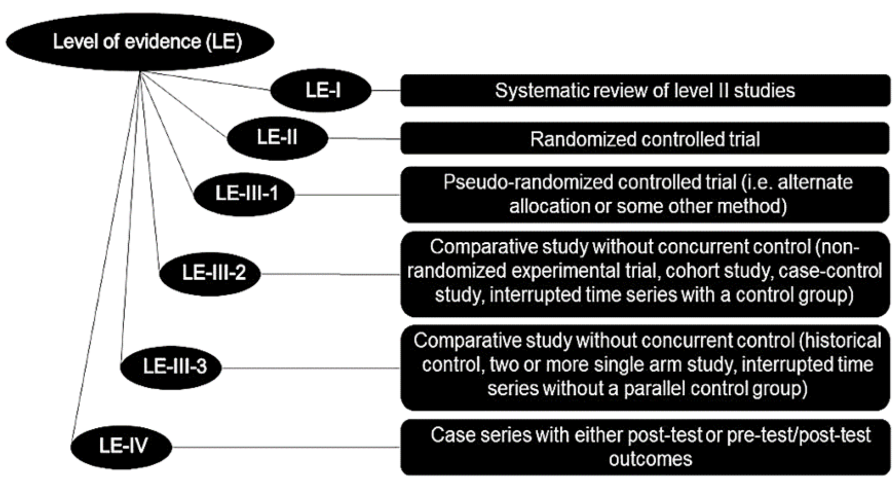

Fig. 1: National Health and Medical Research Council (NHMRC) hierarchy of evidence of the studies

The Cochrane Collaboration's tool was used to analyze the risk of bias of the included studies. This tool assesses the internal validity of the trial and the assessment of the risk of possible bias in different steps of the studies (random sequence generation, allocation concealment, blinding of participants, personnel and outcome assessment, incomplete outcome measures, selective outcome reporting and other types of bias). Each item of the tool was qualified as low risk (green), unclear risk (yellow) or high risk (red) (18,19). The selected articles were independently appraised by two reviewers (VCS and MCMF), and when there was disagreement, a third researcher was consulted (EMM).

Results

Overall, 158 publications were initially found (CINAHL=22, Web of Science=62, MEDLINE/PubMed=46, PEDro=3, Scopus=25). Afterwards, the duplicates were removed, and 82 papers were screened. The eligibility criteria were applied, and six studies met the inclusion criteria and were included in this review (20) (Fig. 2).

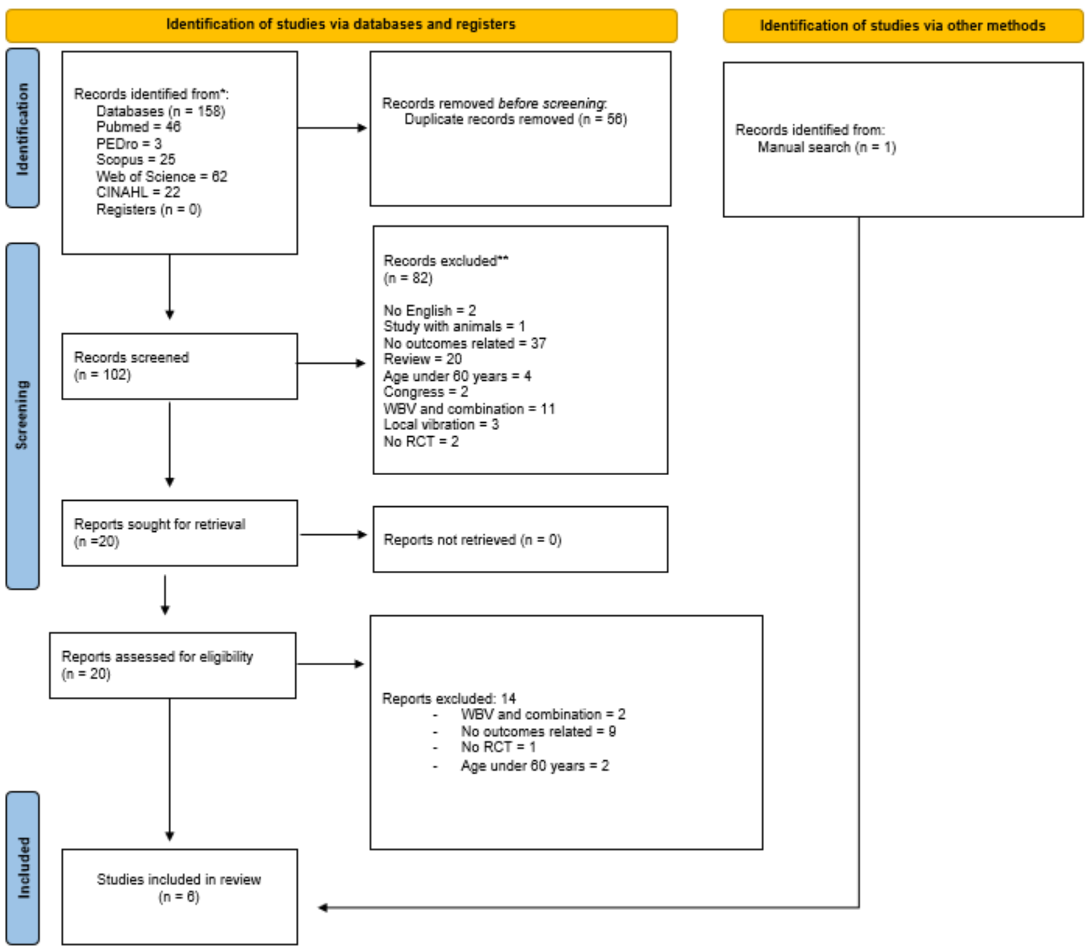

Fig. 2: Shows the PRISMA flowchart of the selection process of the publications

Table 1 shows the study population of the selected studies included mainly females among a total of 971 elderly individuals (n= 84 males and n= 887 female). The age of the participants was ≥ 60 yr old (elderly according to WHO) (21). About the WBV exercise protocol, the side-alternating VP was used in three studies (22–24) and vertical VP in two other studies (25,26). The type of VP was not reported in one work (27). The frequency and peak-to-peak displacement *(D)* of the mechanical vibrations ranged from 6 to 50 Hz and from 2 to 5 mm, respectively, and in one publication (25) was reported that *D* was < 0.1 mm with peak acceleration of the 0.3g. In respect of the methodological quality, all studies were classified as Level II according to the NHMRC classification (17). Regarding to the methodological quality (PEDro scale), four (23,24,25,27) studies were considered 'high' (≥7) and two (22,26) were 'fair' (5 or 6).

Additionally, about the assessment of the measured variables: The Physiological Profile Assessment (PPA) present tests of vision, peripheral sensation, muscle strength, reaction time, and postural sway (11,28). PPA was used by Parsons et al (27) to evaluate muscle strength and risk of falls in elderly women during hospitalization period (muscle strength and balance domains). The scale Functional Independence Measure (FIM) was used to assess the independence of the individuals (29). In addition, to evaluate the risk of falls, Parsons *et al*,(27) used the Modified Falls Efficacy (MFES), which consists in a 14-item scale, which requires participants to rate their confidence in performing a range of activities without falling (30). Leung et al (25) used an instrument to self-report fall and fracture incidence to evaluate risk of falls and a dynamometer to assess the peak isometric force of knee extensors; moreover Yang et al (24) evaluated the isometric strength capacity via an isokinetic dynamometer (Biodex System 3, NY) by the maximal voluntary isometric contractions of knee extensors; foot cutaneous sensation, the sensory assessment was performed via a Semmes–Weinstein nylon monofilament touch-test kit (NC12775-14, North Coast Medical, CA), on each participant's right foot; and, the chair-rise test was used to quantify leg muscle power.

Three of the selected studies (22,23,26) used the timed up and go (TUG) test, that is a sensitive, validated, and reliable tool, originally purposed to test basic functional mobility skills and falls risk in the elderly (gait function, balance while turning, lower-limb strength, and falls risk) (11,31,32). Wadsworth and Lark (23) used TUG test to evaluate muscle strength and risk of falls, and Dudoniene et al (26) used the test to assess the risk of falls together with the Modified clinical test for sensory interaction of balance that measures the person's ability to use somatosensory, visual, and vestibular inputs for balance (33), and the Dynamic gait index that is a tool to assess gait, balance and risk of falls (34). In addition, Wadsworth and Lark (23) and Dudoniene et al (26) evaluated the lower limb muscle strength using the 10-meters Timed Walk and 30-s chair stand test respectively (35). Wadsworth and Lark (23) also used the parallel walking test (PWT) to evaluate the risk of fall, as it is a toll that assesses dynamic balance and dynamic stability during gait, being considered as a test with optimal association with the risk of falls. The five-times-sit-to stand test (FTSTS), functional reach test (FRT), one leg stance (OLS), postural sway and the Berg balance scale (BBS) were described as appropriate tests for predicting falls in the elderly (11,24,36). The FTSTS was used by Lee et al (22), to evaluate muscle strength and risk of falls and the BBS, FRT, OLS and postural sway (using a force platform) were used to evaluate the risk of falls. The FRT is used to measure physical stability, the dynamic balance and flexibility during the performance of functional tasks (11), and the OLS is used to assess postural balance (11). Furthermore, the BBS is used to evaluate the capacity (or incapacity) of the elderly to balance safely during determining activities, predicting indirectly the risk of falls (11,24,36). Only one study used Laboratory-induced slip-falls, to evaluate the risk of falls, through an ActiveStep treadmill (TM), where the individuals were exposed to standardized slips induced, during walking on the TM. All the included studies reported improvements in the risk of falls and muscle responses (Table 1).

Table 1: Table of the characteristics of selected studies

Author/ Country/ Year	*Age (yr)*	*Muscle assessment*	*Risk of falls evaluation*	*WBV exercise protocols*	*Frequency/ peak-to-peak displacement or amplitude/ a_{peak}*	*NHMRC/ PEDro scale*	*Outcomes*
Dudoniene et al Lithuania, 2012(26)	67.7 ± 4.1	-30-s chair stand test	-Modified clinical test -TUG Test -Dynamic gait index	VP: vertical Twice a week for 8 wk 6 static exercises performed on the VP Session: 30s of vibration in each exercise and 1 min of rest	F: 27Hz *D*: 3mm a_{peak}: 4.46 g	LE=2 PEDro 6/10	A significant improvement (in both groups) was found considering all outcome measures.
Lee et al South Korea, 2013 (22)	CG 75.77 ± 5.69 WBV and Balance Group: 76.31 ± 4.78 Balance Group: 74.05 ± 5.42	-FTSTS	-FTSTS -TUG Test -BBS -FRT -Postural sway (force platform) -OLS	VP: side-alternating 3 times/week for 6 wk Position: 110° squat Session: 3 times of 3 min of vibration and 1 min of rest	F: 15 until 30 Hz D: 1 until 3 mm a_{peak}: 2.5g – 5.51 g	LE=2 PEDro 6/10	The postural sway, the FTSTS, the TUG test, the BBS and the OLS showed a significant improvement in the WBV group compared to the other groups, and the FRT showed significant improvements in the WBV and BE groups but not in the control group.
Leung et al China, 2014 (25)	WBV Group: 74.5 ± 7.1 CG: 71.3 ± 7.2	-Peak isometric force of knee extension (dynamometer)	-Self-report falls and fractures incidence on a fall and fracture calendar	VP: vertical 5 d/week for 18 months Position: Stand on platform Time:20 min	F: 35 Hz A/D < 0.1 mm a_{peak} = 0.3 g	LE=2 PEDro 8/10	Significant improvement on the quadriceps muscle strength Lower incidence rate of fracture and falls comparing to CG
Parsons et al New Zeland, 2016 (27)	WBV Group: 82.07 ± 6.4 CG: 81.76 ± 8.0	-Physiological Profile -Assessment (PPA) (muscle strength domain) FIM	-PPA (balance domain) -MFES	VP: not reported Thrice a week (during hospital stay) Position: Semi squat 6 static exercises 2 sets of 30 seconds	F: 30 until 50 Hz A: 2 until 5 mm a_{peak}: 3.67 g – 25.5 g	LE=2 PEDro 8/10	There was no significant difference on PPA (both domains) Significant improvements on Functional Independence Measure score (p= 0.03) and MFES (p= 0.007)
Wadsworth and Lark, Australia, 2020 (23)	WBV Group: 79.4 ± 1.1 CG: 84.3 ±1.3 Shan Group: 83.7± 1.2	-10mTW -TUG Test	-TUG Test -PWT	VP: side-alternating 3 times/week for 16 wk Position: isometric knee flexion ≈ 20º (±5º) Session: 5 to 10 times of 1 min of vibration and 1 min of rest	F: 6 until 26 Hz A: 2 until 4 mm a_{peak}: 0,14 g – 5,51 g	LE=2 PEDro 7/10	Significantly improvements in TUG test, PWT and 10mTW.
Yang et al USA, 2023 (24)	WBV Group: 72.7 ± 5.6 CG: 71.0 ± 4.9	-Isokinetic dynamometer.	-Berg Balance Scale	VP: side-alternating 3 times/week for 8 week Position: knees slightly bent at 20°, and trunk upright Session: 5 times of 1 min of vibration and 1 min of rest	F: 20 Hz A: 2 mm a_{peak}: 1,63 g	LE= 2 PEDro 8/10	The vibration training program significantly reduced the risk of slip-falls and improved all fall risk factors immediately after the training course.

Abbreviations: WBV - whole-body vibration; CG – control group, VP - vibrating platform, *f* - frequencies; *D* - peak-to-peak displacement; A - amplitude; a_{peak} - peak acceleration; NHMRC - levels of evidence according National Health and Medical Research Council; SD – standard deviation; FIM - Functional Independence Measure , MFES - Modified Falls Efficacy; FTSTS - Five-times-sit-to stand test, BBS - Berg balance scale; FRT - functional reach test; OLS - one leg stance; 10mTW - 10-meters Timed Walk; TUG Test - timed Up and Go test; PWT - parallel walking test; Physiological Profile Assessment (PPA) PEDro score – (a)'high' methodological quality ≥7, (b)'fair' methodological quality = 5 or 6, (c)'poor'≤4.
* The g values were calculated by the authors, except for the work by Leung et al 2014.

The risk of bias was evaluated according with the Cochrane Collaboration's tool (18,19). The detailed assessment of risk of bias was presented in Fig. 3. Two publications presented low risk of bias (22,27), three with high risk of bias (23,24,25) and one unclear (26).

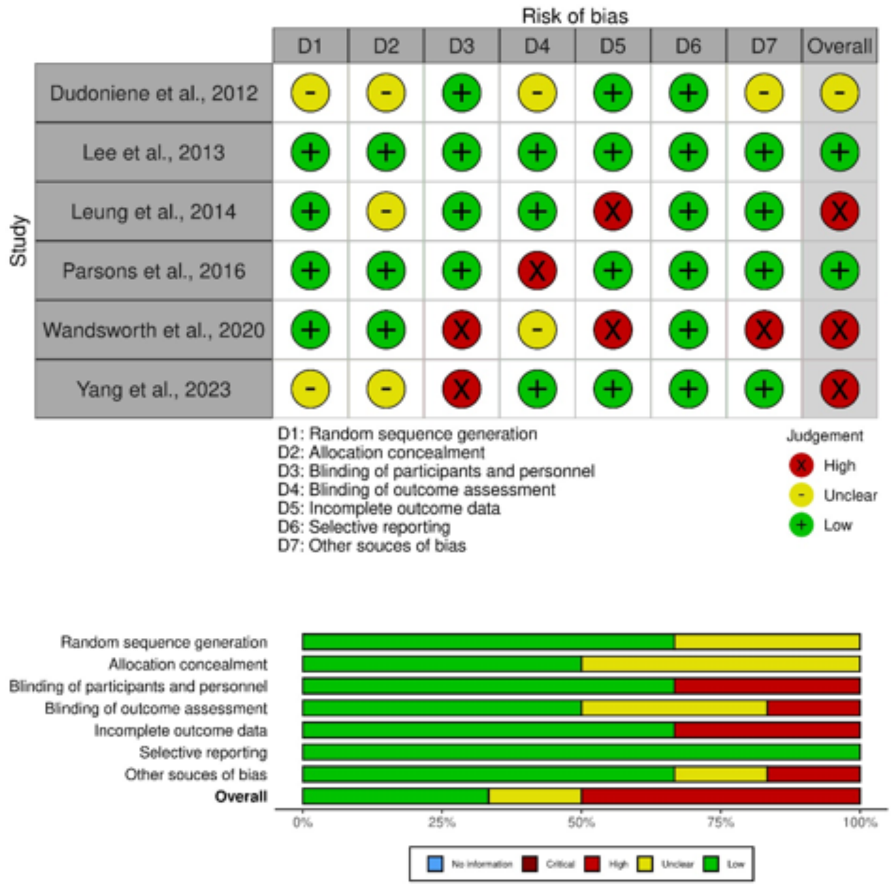

Fig. 3: Assessment for risk of bias for the included studies [22-27]

Discussion

This systematic review was conducted to assess the effects of WBV on muscles responses and on risk of falls in elderly individuals. All the included publications evaluated muscle strength and the risk of falls using subjective outcomes and/or functional measures. The analysis of methodological quality (PEDro scale) (Table 1) evidenced that four studies (23,24,25,27) had 'high' methodological quality (≥7) and two (22,26) had 'fair' methodological quality (5 or 6). The average of the included studies was 7, that is, the included studies had a high methodological quality. Furthermore, the risk of bias evaluation presented two studies with low risk of bias (22,27), three with high risk of bias (23–25) and one with unclear risk of bias (26) .

In this context, it would be important to define a safe and efficient WBV exercise protocol with well-established parameters, such as frequency, peak to peak displacement, amplitude, peak of acceleration (a_{peak}), time of vibration exposure and time of rest (20,22). However, the protocols varied in these parameters and that only one study (25) reported the a_{peak} parameter, it is difficult to determine if the results were better in low or high intensity of the SVT.

The findings of this review suggest that WBV exercise may be useful to decrease the risk of falls due to its capacity to improve physical function in elderly individuals. The protocols used in the included studies were highly heterogenous. Therefore, it is not possible to determine a gold or ideal protocol for reducing the risk of falls in the elderly. There is high evidence that physical exercise programs, including balance and functional exercises, reduce the risk of falls in elderly individuals (37,38). Bemben et al (39) concluded that WBV exercise was effective for counteracting the loss of muscle strength associated with sarcopenia in elderly individuals suggesting that the balance and leg and plantar flexor strength improvements have a positive impact in the risk of falls, frailty, and fracture incidences. Corroborating with another findings (39,40), in a meta-analysis suggested that the WBV exercise may prevent fractures by decreasing the risk of falls, without producing effect on bone mineral density or bone microarchitecture. This could support the findings of the current review, strengthening the idea that reducing the risk of falls could be related to improving muscle strength and can be promoted by the SVT, showing the potential of WBV exercise as an alternative to physical exercise for these individuals.

About muscle weakness, age-related muscle weakness can be induced by physiological changes such as: hormonal disorders, cellular apoptosis, physical inactivity and inflammaging (2–3,8,41,42). These physiological changes could be delayed or prevented by physical exercise, including the WBV exercise (43,44). Therefore, the WBV's mechanism of action to reduce the risk of falls and improve muscle strength in the elderly could be explained by direct or indirect changes caused by vibratory stimulus, acting directly on the muscle component or indirectly through the physiological responses triggered by this stimulus in the central nervous system (44).

The studies included in the current review described improvement in muscle strength in the elderly. The FIM was used and observed an improved activity and participation across the FIM tasks (13 motor and 5 cognitive) with significant changes in FIM scores following WBV (27). A decrease of the execution time of the FTSTS was showed in elderly individuals after 6 wk of the WBV (22). Dudoniene et al (26) showed improvement in the 30-s chair stand test after 8-week exercise with and without WBV. A significant improvement was found in the: 1) TUG test after 8 and 16 week of WBV when compared with the control group and sham group and 2) 10-meters timed walk (10mTW) after 3 months of WBV when compared with sham group (23). Wich an isokinetic dynamometer, increase in the knee extensor strength from baseline to post-training in the WBV group was significantly larger than the control group immediately after 8 week (24). On the other hand, a dynamometer was used to measure the peak isometric force of knee extensors, finding a significant increase on the quadriceps muscle strength after 18 months of WBV in post-menopausal elderly women (25). WBV exercise can improve the capacity functional and muscle in elderly individuals, with some of these benefits being maintained for at least 6 months post-WBV.

Considering that WBV exercise is generated in the SVT as a physical exercise modality, the findings of this systematic review are according with Bao et al (45) who showed that exercise programs have significant positive effects on muscle strength and physical performance, although not reporting changes in muscle mass in elderly participants with sarcopenia. SVT may be viable to help in functional performance, preparing the individual for different activities.

Reduced muscle strength in elderly individuals is an important risk factor for falls, along with gait and balance impairments (11). This is online with the results of the current review, where all the included studies showed an improvement both in muscle strength and in the risk of falls in elderly individuals. Parsons et al (27) observed an improvement in the MFES score and in the FIM test. Leung et al (25) showed a decrease in the self-report falls and fractures incidence using a fall and fracture calendar and observed an improvement in the quadriceps muscle strength. Likewise, Lee et al (22) found an improvement in several risk of falls tests (FTSTS, BBS, FRT, OLS and postural sway

- force platform), also using the FTSTS as muscle strength test. Wadsworth and Lark (23) demonstrated an improvement of PWT after 8 and 16 week of WBV when compared with control group and sham group, after 3 months of WBV exercise when compared with sham group and after 6 and 12 months of WBV exercise when compared with control group. In addition, an improvement has been also found in the functional capacity through the TUG test and the 10mTW. Dudoniene et al (26) showed an improvement in the tests related to the risk of falls (modified clinical test for sensory interaction of balance, dynamic gait index and TUG test) with a decrease of the execution time of the 30-s chair stand test. Additionally, mechanical vibration training reduces the fall risk as it lowered the risk of lab-induced slip-falls and improved the fall risk factors immediately after the training program (24). Furthermore, the training effect may last three months as the number of daily-living falls was lower over the three months following the training and the improvements in the foot sensation and chair-rise time in the training group were greater than the control group. In this context, as observed in the included studies, Jepsen et al in a systematic review, concluded that numerous studies have examined the SVT with different protocols, with positive results, which promoted reduced fall risks and improved performance in older adults (40).

The current systematic review presents some limitations. The inclusion of studies only written in English, could contribute to the exclusion of relevant articles written in other languages. Moreover, although five important databases were searched, adding more databases to the search strategy could have increased the number of included articles. In addition, only three were considered 'high' quality, and only two had global low risk of bias, which reduces the strength and confidence in the findings.

The strength of the current systematic review is to provide evidence towards the use of WBV exercises in this population with the intention of increasing the adherence to the practice of exercise, since SVT is a non-pharmacological intervention, safe and well acceptable.

Conclusion

WBV exercise, generate in the SVT, is a strategy with a good acceptability, feasibility, and may reduce the risk of falls and improve muscle responses in the elderly. Nevertheless, the low number of publications suggests that more high-quality studies are needed to improve the scientific evidence of these findings.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interests.

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