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SUMMARY

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Editorial

Mechanical Vibrations in Biosciences

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Mechanical vibrations are present in all living beings. With great emotion and vibration, the first editorial to the Brazilian Journal of Mechanical Vibrations in Biosciences - BJMVB – is being written. The BJMVB is being launched due to the support of the colleagues that were invited to be members of the Editorial Board. The acceptance of all the members that study effects and applications, at clinical and research levels, of mechanical vibration, was fundamental.

Mechanical vibrations are present and are produced systemically inside of the body, for organs and tissues up to the fundamental structures, such as molecules and atoms. The biomechanical characteristics of these mechanical vibrations are responsible for physiological effects. Moreover, the body is exposed to mechanical vibrations due to several normal activities, such as walking, running, and dancing, among others. Furthermore, an individual is in contact with various situations in which mechanical vibration is generated and transmitted by different sources, such as in transportation (car, bus, train, subway). In addition, in the workplace, individuals can be exposed to different sources that produce mechanical vibration, such as drivers of different types of vehicles, chain saw, ballast stop machine, straight grinder, and dental high-speed drill. Then, it is possible to verify that mechanical vibrations are added to an individual in different ways; and this would be associated with health. However, when, it is not possible to add mechanical stimulus to an individual normally, there is vibrating therapy, which can be local or systemic vibration therapy.

The devices used in local vibration therapy are relatively simple and small, and in general, are portable devices that apply mechanical vibration directly over the muscle or the tendon. Buttons are available for selecting the operational conditions of the intervention characteristics, which consider the frequency of mechanical vibration. Local vibration therapy is very important for several individuals that are in long-term immobilization, immobilization by a cast, or in the early rehabilitation period after surgeries. The device used in systemic vibration therapy is a vibrating platform.

Systemic vibration therapy is a clinical intervention in which mechanical vibration 2 generated on a vibrating platform is transmitted to the entire body of the person who is in contact with the base of the platform producing the whole-body vibration exercise. The challenge is to find the best protocols for the vibrating therapy, to a safe and effective intervention. In this context, a Consensus Statement from an International Group of Experts was published with the different steps to be followed in studies involving the use of the mechanical vibration in human beings, in animals and in *in vitro* model.

The BJMVB wants to publish papers that can aid to understand better the interaction of the mechanical vibration with the body of an individual and the physiological mechanisms that underline the effects due to this interaction. Authors are invited to accept this challenge and studies involving human beings in basic, clinical, ergonomics, or applied studies on the understanding, assessment, prevention, and treatment of diseases, and in the promotion of the quality of life in healthy and unhealthy individuals, and also with animals through possible translational research are welcome. Moreover, abstracts presented in scientific congress involving approaches related to the applications of mechanical vibration will be also published.

Keywords: mechanical vibration, vibrating therapy, biosciences, journal

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this editorial.

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ORIGINAL PAPERS

BJMVB 2023; 1(1): 9-32

Systematic review

Whole-Body Vibration Training at the workplace – A Promising Intervention for Workplace Health Promotion?

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Abstract:

Introduction: Considering the current demographic change and increasing health problems, as well as the growing relevance of the occupational setting as a suitable environment for the for the implementation of health-promoting measures, there is an increasing need for evidence based and easy-to-implement health promotion measures in this setting. A promising, movement-related method is whole-body vibration training (WBVT). **Aim:** The purpose of this systematic review was to provide an overview of the current scientific evidence for the use and benefits of WBVT as a workplace health promotion (WHP) measure. Material and methods: A systematic literature analysis was conducted to identify relevant studies on WBVT in WHP in the electronic database PubMed. The search strategy was based on the PICO model for systematic literature reviews. **Results and Discussion:** Six randomized, controlled trials including 438 participants were included in this systematic review. In terms of health and performance, a significant reduction in musculoskeletal pain and functional limitations, significant improvements in musculoskeletal well-being, surefootedness, and balance, and trends regarding positive effects on muscular performance were found. WBVT seems to reduce sick days and has the potential to be cost-efficient in the long term. Moreover, WBVT showed a high level of compliance and good feasibility due to its small time, organizational, personnel and infrastructural requirements. **Conclusion:** WBVT appears to be a safe, effective, and well-suited WHP measure for 4 white-collar and maybe blue-collar workers, especially for unfit employees and employees with pre- existing musculoskeletal complaints. Furthermore, WBVT seems to be particularly suitable for different occupational settings and the respective challenges (e.g., shift work) as a promising intervention in terms of long-term motivation, health benefits and economic aspects. Nevertheless, further research is still needed to consolidate the evidence of the effects of WBVT in WHP, and especially to determine long-term effects and optimal training parameters for WBVT.

Keywords: Whole-Body Vibration Training, Workplace Health Promotion, Employee, Exercise, Intervention.

1. Introduction

Advancing research in the field of health sciences emphasizes the potential of the occupational setting and the workplace as a suitable environment for the implementation of health-promoting interventions (1-6). Considering current demographic and health-related trends and challenges, such as an aging society in Western countries and the increasing prevalence of various diseases in Western populations, there is potential for workplace health promotion (WHP) to improve the health of employees and prevent specific diseases by reducing respective health risks (3,4,7). Thus, there is evidence for the effectiveness of WHP interventions in preventing musculoskeletal disorders, mental illness, body weight-related risk factors and respective consequences reducing pain and symptoms of musculoskeletal disorders (1,8). In addition, there is moderate evidence for the reduction and management of stress, inconsistent results related to specific metabolic risk factors, and limited evidence regarding positive economic effects, such as reductions in absenteeism, savings in health care costs, increased productivity, or a positive return on investment (1,8). According to studies, multimodal interventions appear to be more effective than single measures, with physical activity or exercise usually being an integral part of such multimodal interventions and usually recommended for the implementation in the workplace setting (1,8,9,10). Thus, positive effects on cardiorespiratory fitness, muscular performance, reductions in pain intensity and physical limitations in employees with low back pain have been shown with physical activity and exercise interventions in the workplace (4,11,12).

A key challenge is the long-term motivation of employees, which is a decisive factor for long-term adherence and associated effectiveness of the respective WHP measures (13). Regardless of the specific type of WHP or exercise intervention, a general decrease in adherence is evident over time (14). Reduced or poor adherence is in turn associated with impaired effectiveness and long-term success of WHP (4,15). Given that lack of time is often stated as a significant barrier to adequate compliance, WHP with short, simple training sessions in particular appear to be especially suitable for increasing adherence and reducing absenteeism without negatively impacting work productivity (4,16).

Therefore, whole-body vibration training (WBVT) seems to be a promising movement-related measure in WHP, which is characterized by its low-threshold access and its time efficiency due to the short-needed application time and the fact that it can be performed autonomously by users after a short introduction (17-19). In WBVT, mechanical oscillations are transmitted to the whole body by respective devices (17). Two basic forms of WBVT are used today. The 5 most common WBVT devices use sinus like vibration stimuli, whereas other WBVT devices use random vibrations (18). The exercise intensity is controlled by the parameters duration, frequency, amplitude and the respective body position or movement performed on the device (18). Van Heuvelen et al, published a guideline to be considered in the protocols involving whole-body vibrations studies (20). Reviews on the effects of WBVT report improvements in muscular performance, balance, flexibility, blood flow, and bone density, as well as reductions in musculoskeletal pain from regularly performed WBVT (18,21-26). These physiological responses could be associated to the stimulation of mechanoreceptors by mechanical vibration used in the WBVT (27). These effects appear in particular in older, unfit and/or sick individuals with an initial lower level of physical performance (18). Because of this health and performance-enhancing potential, WBVT is used not only in mass and fitness related sports, but also primarily in prevention as well as a therapeutic intervention in various musculoskeletal, neurological, or degenerative diseases (21,23-25,28). Moreover, WBVT is often used in professional sports and the field of WHP because of the afore mentioned advantages and the potential to be efficiently integrated into the workplace setting and workflows due to its low organizational and spatial requirements of only 2 to 4 square meters for each device (18,19). Compared to classical types of exercise, WBVT is perceived as less strenous, which, together with the factors already mentioned, usually leads to a high compliance in users (18).

The aim of this systematic literature analysis is to provide a current overview of the current evidence on the use of WBVT in WHP. Therefore, this review focused on the following research question: "Does WBVT in WHP have positive effects on employee health, performance, motivation and compliance, as well as on cost-effectiveness and feasibility in the workplace and is it safe?"

2. Materials and methods

A systematic literature analysis was conducted to identify relevant research on WBVT in WHP in the electronic database PubMed and recommended literature by experts. In general, this systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (29).

2.1 *Data sources and search strategy*

The electronic database PubMed was searched for appropriate research on the use and effects of WBVT in WHP from the inception of the database to January 2023. In addition, we screened literature recommended by experts. The search strategy was based on the PICO model for systematic literature reviews. By combining keywords, synonyms, and free text terms with the Boolean operators "OR" and "AND", a searchstring was created to find relevant studies (final search string can be found in the appendix).

2.2 *Inclusion and exclusion criteria*

For this systematic review only randomized controlled trials published in English or German language were included. The studies had to include WBVT as an intervention. Thus, the subjects had to be employees and study outcomes should include endpoints regarding health, physical performance, motivation, compliance, as well as cost-effectiveness or feasibility of WBVT in this setting. Study protocols and animal-experimental studies were excluded. Other exclusion criteria were interventions, subjects, or settings that were inappropriate in terms of content (e.g., isolated vibration training of individual body parts or in a therapeutic setting).

2.3 *Study selection and data extraction*

Two researchers independently screened title, abstract and full earch all identified research to include all relevant studies in this systematic review according to the inclusion and exclusion criteria. All relevant data were extracted from the selected articles by one of the authors and cross-checked by the second one. For each article categorized as suitable, the following data were extracted: authors, year of publication, study design, sample size and earc sample characteristics of the sample (age, sex, employment-related characteristics). In addition, type of intervention, primary and secondary endpoints and the respective results were extracted from the available studies.

3. Results

A total of 13 potentially eligible studies was identified by searching the electronic database PubMed and recommended literature by experts according to the predefined earch strategy. Of these, seven studies were excluded after screening the titles and abstracts because they did not match the predefined inclusion and exclusion criteria in terms of subjects, interventions, or settings. Finally, six randomized controlled trials were included in this systematic literature review. A flowchart of the study selection process through the PRISMA flowchart is shown in Fig. 1.

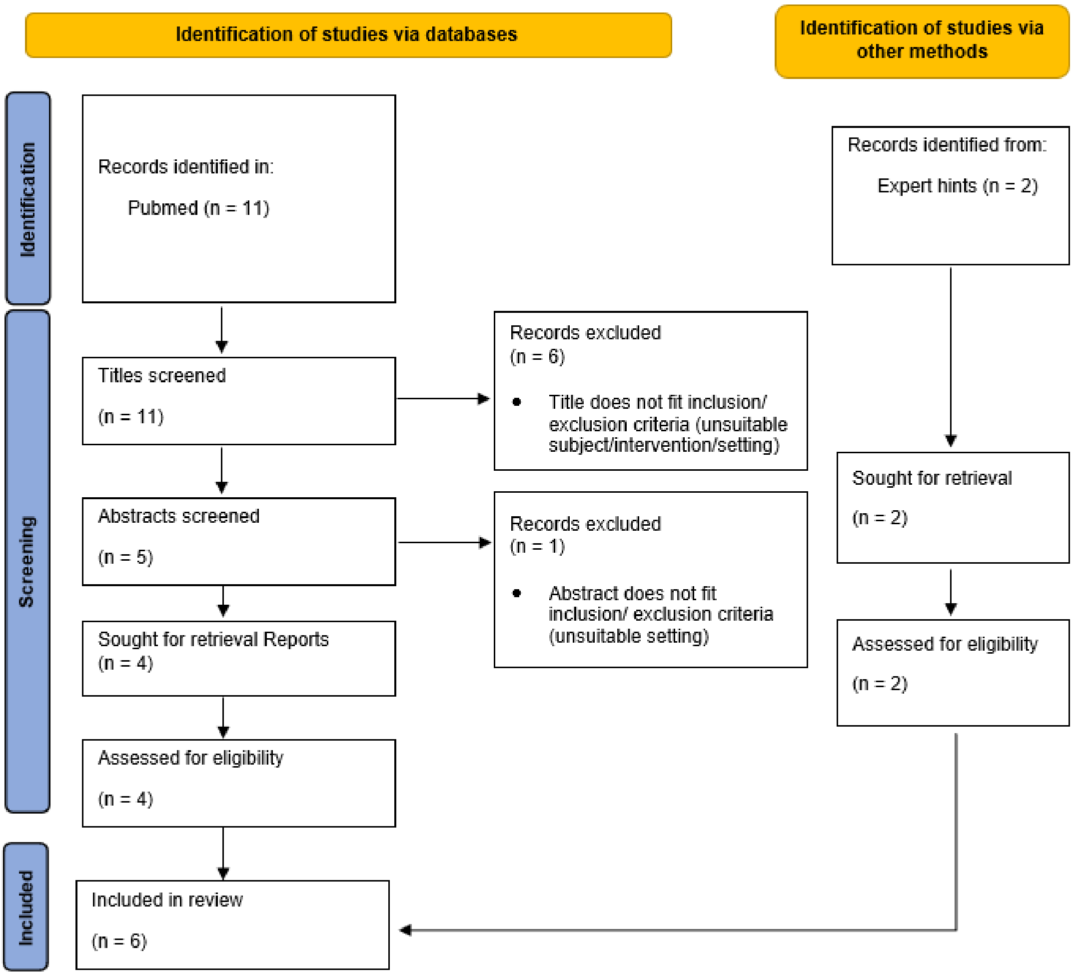

Figure 1 - PRISMA flowchart

The characteristics of the included randomized controlled trials published from 2012 to 2018 are summarized in Table 1. The majority of the studies show a wide range in terms of the age of the subjects, with a mean age between 39.8 and 45.5 years (27-32). In addition, three of the six studies have a sex distribution with a majority of female employees, two studies with a majority of males, and one study with an almost balanced sex distribution (27-32). Four of the studies investigated the effects of WBVT on white-collar workers, while one study focused on white-collar and blue-collar workers, and another study considered employees from different work areas of a medical facility (27-32). A majority of four studies used WBVT with applying random vibrations, while the remaining two studies used WBVT with sinus like vibrations (27-32).

Table 1 - Overview of the included articles

Authors & year	*Studydesign Sample size (n)*	*Sample size (n)*	*Sample characteristics*	*Intervention*	*Primary and secondary endpoints*	*Outcomes*
Burge r et al. (2012) (30)	- randomized controlled crossover trial - n=38	38	Age: 19-62 years, mean of 45.45 years Sex: 86.6% men, blue- & white-collar employees	4 weeks of supervised WBVTwith random vibration, 3 sessions per week, each with 3 sets of 1 min load & 1 min rest,position: standing, static, without arm involvement Frequency: 1-12 Hz, mean of 5.52 Hz Amplitude: 3 mm *Switching design:* Group A (n = 22): 4weeks intervention,then 4 weeks no training Group B (n = 16): 4 weeks no training, then 4 weeks intervention.	Daily questionnaire with subjective assessment of musculoskeletal pain and functional limitations, musculoskeletal well-being, sense of balance & near-accidents.	Significant reductionof musculoskeletal pain ($p < 0.01$) and functional limitations($p < 0.001$), significant increase of musculoskeletal well-being ($p < 0.001$) (greater effects for employees with the risk factors "time pressure", "amount ofstanding", "working in twisted posture") No significant improvement in sense of balance andnear-accidents High compliance regarding training units (mean of 10.11of given 12 units) Good feasibility (time efficiency, low organizational effort).
Elferin g et al. (2013) (31)	- randomized controlled crossover trial	54	Age: 18-61 years, mean of 39.8 yearsSex: 85.2% men, white-collar employees	4 weeks of supervised WBVTwith random vibration, 3 sessions per week, each with 3 sets of 1 min load & 1 min rest,position: standing, static, without arm involvement Frequency: 4-8 Hz, mean of 6,4 Hz Amplitude: 3 mm *Switching design:* Group A (n = 27): 4weeks intervention,then 4 weeks no training Group B (n = 27): 4 weeks no training, then 4 weeks intervention.	Daily questionnaire with subjective assessment of musculoskeletal pain, musculoskeletal well-being, surefootedness Balance (CTSIB)	Significant reductionof musculoskeletal pain only in subjectswith frequent back pain in the last 6 months before study($p < 0.001$), significant increase in musculoskeletal well-being ($p < 0.05$) and surefootedness ($p < 0.001$) Significant increasein balance in the CTSIB ($p < 0.001$) Good feasibility (low time, infrastructural & organizational effort) High compliance regarding training units (mean of 11.7 ofgiven 12 units), no study dropouts No long-lasting unwanted side effects

Kaeding et al. (2017) (34)	randomized controlled trial	41	Age: mean of 45.5years Sex: 68.3% women, sedentary white- collar employees with chronic back pain	*INT:* (n = 21) 12 weeks of non- supervised progressive WBVTwith sinus like vibration, at least 2.5 sessions per week, each with 5sets of 1-2 min load &1 min rest, position: standing,static, hands on handrail Frequency: 10-30 Hz, Amplitude: 1.5-3.5mm *CON:* (n =20) No training	Questionnaires: Subjective assessment of back pain-related limitations (RMQ,ODI), work ability(WAI), health- related quality of life (SF-36), physical activity (FAQ), Performance of trunk muscles byisokinetic force measurement (flexion, extension) Postural controlby static posturography Compliance Days absent &sick leaves	Significant improvement in backpain-related limitations (RMQ (p = 0.27), ODI (p =0.002)) and health- related quality of life(SF-36) (p = 0.013), Significant higher decrease of physical activity (FAQ) in CON(p = 0.022), Trend regarding positive effect on trunk muscle performance in flexion (p = 0.056) No significant improvement in work ability (WAI) and postural control (by static posturography) High compliance of 81,1 % regarding training units Significant reduction of days absent & sickleaves by a mean of 1.4 days per month in follow up (p = 0.008) No long-lasting, unwanted side effects Good feasibility (low infrastructural, temporal & organizational effort)
Kaeding et al. (2018) (35)	randomized controlled trial	119	Age: mean of 41.6years Sex: 78% women, Healthy white-collaremployees	*INT:* (n = 60) 24 weeks of non-supervised progressive WBVTwith sinus like vibration, at least 2.5 sessions per week, each with 5sets of 1-2 min load &1 min rest, position: standing, static, hands on handrail Frequency: 10-30 Hz, Amplitude: 1.5-3.5 mm *CON:* (n =59) No training	Blood test (including creatine kinase), cardiovascular mortality risk (ESC-EUROscore) Questionnaires: health-related quality of life (SF-36), physical activity (FAQ), postural controlby static posturography Jumping performance and muscular performance of lower extremity (jumping mechano-graphy) Lifting performance (PILE)	No significant changein blood parameters, but trend of increasedcreatine kinase (p = 0.088) No significant changein SF-36, FAQ & ESC-EUROscore, No significant change in postural control and lifting performance (PILE) No significant changein jumping performance, but trend towards improvement in maximum jump height (p = 0.062) High compliance of 71,6 % regarding training units

					Compliance Days absent & sick leaves	No significant changes in absent days & sick leaves No long-lasting, unwanted side effects& good feasibility
Faes et al. (2018) (33)	randomized controlled trial	62	Age: 18-63 years, mean of 40.6 years Sex: 32 men, 30 women, white-collar employees	*INT:* (n = 26) 4 weeks partially supervised WBVTwith random vibration, at least 3 sessions per week, each with 3sets of 1 min load & 1min rest, position: standing, static, without arm involvement Frequency: 5-6 Hz, Amplitude: 3 mm *CON:* (n =35) No training	Daily questionnaire with subjective assessment of musculoskeletal well-being and muscle relaxation,sense of balance,surefootedness Static balance (BESS) Compliance	Significant improvement in musculoskeletal well-being & muscle relaxation (p = 0.014), sense of balance & sure-footedness (p = 0.016) Significant improvement in staticbalance (BESS) (Total Angle Area: p = 0.011, Total Velocity Area: p = 0.001) Very high compliance, mean of 3.87 training sessions completed per week (29% more than required) Good feasibility (low organizational & time).

Abbrevations: Whole-body vibration training = WBVT; intervention group = INT; control group = CON, Clinical Test of Sensory Integration on Balance = CTSIB; Roland and Morris disability ques1tionnaire = RMQ; Oswestry Disability Index = ODI; Short Form 36 = SF-36; Freiburger activity questionnaire = FAQ; Work Ability Index Questionnaire = WAI; European System for Cardiac Operative Risk Evaluation of the European Society of Cardiology = ESC-EUROscore; Progressive Isointernal Lifting Evaluation = PILE; Balance Error Scoring System = BESS.

Two of the randomized controlled trials were also crossover studies. For example, Burger et al. conducted a four-week supervised WBVT with random vibrations on 38 blue- and white-collar workers aged 19 to 62 years with a mean age of 45.45 years (86.6% men), with INT (n = 22) and CON (n = 16) switching after the first four weeks of the study, and thus both randomized groups each completed four weeks of WBVT and four weeks without intervention (30). The WBVT was performed in three sessions per week, each consisting of three trainings sets (30). The subjects only were required to take a static standing position with slightly bent knees on the vibration plate and were able to set the vibration frequency at their own choice between 1 and 12 hertz (a mean of 5.52 hertz was selected), with a fixed amplitude of 3 millimeters (30). The intervention showed a significant reduction in musculoskeletal pain (p < 0.01) and functional limitations (p < 0.001) as well as a significant increase in subjectively perceived musculoskeletal well-being (p < 0.001) during the four-week intervention period of the intervention group (INT) compared to the control group (CON) measured by daily questionnaires (30). Burger et al. found a larger effect of these parameters among blue-collar workers than in white-collar workers who were exposed to the risk factors "time pressure" (p < 0.05), "amount of standing" (p < 0.01) or "working in twisted posture" (p < 0.001) (30). While no significant improvements in sense of balance and near-accidents were found, there was a high level of compliance with regard to the training sessions, as employees completed a mean of 10.11 of the specified 12 sessions (30). The authors also reported a good feasibility of WBVT in the setting due to the low time requirement compared to other movement related measures and the low organizational effort (no change of clothes necessary, training sessions are even possible during short work breaks, independent use of WBVT by employees after a short introduction) (30).

Elfering et al. also used the study design of a randomized, controlled crossover study and conducted the WBVT intervention identically to the study of Burger et al (INT: n = 27, CON: n = 27) (30,31). The self-adjustable frequency range in this study was 4 to 8 hertz, with a mean 12 selected frequency of6.4 hertz (31). 54 white-collar workers aged 18 to 61 years, with a mean age of 39.8 years (85.2% men) participated in this study and wrote diaries regarding musculoskeletal complaints and well-being, as well as surefootedness, and were assessed at the beginning and end of the intervention by the Clinical Test of Sensory Integration on Balance (CTSIB) (31). Thus, a significant reduction in musculoskeletal pain ($p < 0.001$) was shown across the intervention phase, but only in subjects with frequent low back pain in the last six months before the start of the study, as well as a significant increase in musculoskeletal well-being ($p < 0.05$), surefootedness ($p < 0.001$) and balance in the CTSIB ($p < 0.001$) (31). Likewise, there was a high level of compliance, as a mean of 11.7 training sessions of the predefined twelve sessions were completed by the subjects and dropouts throughout the study period happened (31). The authors also reported that the feasibility of WBVT was mainly due to very low infrastructural and time requirements, as well as the little physical effort required from the participants (31).

One year later, Elfering et al. published another randomized controlled trial with 124 subjects aged 18 to 64 years (mean age 45.5 years, 86 % women), who were mainly employed as healthcare professionals in various fields or in administration (32). Subjects in the INT (n = 68) performed supervised WBVT with random vibrations for eight weeks with the same design, frequency, and timing of the respective training sessions as previously used by Burger et al. and Elfering et al., while the CON (n = 56) did not participate in an intervention (30-32). Subjects were instructed to start with a vibration frequency of 3 hertz but were then allowed to change this independently to a frequency that was comfortable for them and thus selected a mean frequency of 6.64 hertz (32). Postural sway measurements on a force plate showed a significant reduction in mediolateral sway by WBVT ($p < 0.01$), which is associated with an improvement in postural control (32). Although only 48% of subjects in the INT and 58% in the CON completed the study, 75% of the remaining subjects in the INT reported that they "almost always" or "quite often" adhered to their training schedule (32). Low time, organizational, and infrastructural requirements of WBVT were also emphasized by the authors (including no warm-up or cool-down or special clothing required, little space needed) (32). In addition, no long-lasting unwanted side effects, or complications from WBVT were observed in the subjects (32).

Faes et al. also chose random vibrations as intervention for the INT (n = 26) within their study on 62 white-collar workers aged 18 to 63 years (mean age of 40.6 years, 32 men, 30 women,), while the CON (n = 35) did not perform any exercise (33). The intervention also consisted of three, only partially supervised, training sessions per week, each with three training sets of one minute load and one minute rest, at a frequency of 5 to 6 hertz and an amplitude of 3 millimeters (33). The analysis of the daily filled in questionnaires revealed a significant improvement in musculoskeletal well-being and muscular relaxation (p = 0.014), surefootedness and sense of balance (p = 0.016), as well as a significant improvement in static balance in the Balance Error Scoring System (BESS) in the INT (Total Angle Area: p = 0.011, Total Velocity Area: p = 0.001) (33). In addition, compliance was high, as the subjects in the INT completed a mean of 3.87 training sessions per week instead of the predefined three units per week (29% more than required) (33). Furthermore, a good feasibility of WBVT in the workplace setting was reported in terms of the low time requirement and organizational effort (33).

Kaeding et al., on the other hand, investigated the effects of sinus like WBVT in 41 sedentary white-collar workers with chronic low back pain and a mean age of 45.5 years (68.3% women) 13 (34). While the CON (n = 20) did not take part in an intervention, the subjects in the INT (n = 21) completed a progressive, non-supervised WBVT with at least 2.5 trainings sessions per week over the 12-week period of the study (34). One of these approximately 15-minute sessions consisted of five sets of 1 to 2 minutes each, with a frequency of 10 to 30 hertz and an amplitude of between 1.5 and 3.5 millimeters, depending on the specific training schedule (34). As in the other studies, participants took a simple, static standing position for this purpose (34). After completion of the 12-week intervention, the INT showed a significant improvement in back pain-related limitations in the Roland and Morris disability questionnaire (RMQ) (*p* = 0.27) and the Oswestry Disability Index (ODI) (p = 0.002), health-related quality of life in the Short Form 36 (SF-36) (*p* = 0.013), and a significant reduction in post-interventional sick-leaves of 1.4 days per month on average (p = 0.008) (34). Moreover, there was a significantly higher decrease in physical activity over the study period in the Freiburger activity questionnaire (FAQ) in the CON compared with the INT (p = 0.022), as well as a trend toward a positive effect of WBVT on trunk muscle performance in flexion by isokinetic strength measurement (*p* = 0.056) (34). In addition to a high compliance of 81.1%, the authors also reported a good feasibility of the sinus like WBVT due its low time, personnel, organizational, and infrastructural requirements, without interfering with the usual work routines (34). Regarding the ability to work in the Work Ability Index Questionnaire (WAI) and the postural control, measured by static posturography, no significant changes were observed (34). No longer-lasting, unwanted side effects due to WBVT were be found (34).

Kaeding et al. conducted a second randomized controlled trial using the same WBVT intervention over a 24-week period, examining the effects of WBVT in 119 healthy white-collar workers of a pension insurance scheme with a mean age of 41.6 years (78% women) (35). Here, only a trend to an increased creatine kinase level in the blood (*p* = 0.088) as well as a trend to an improvement of the maximum jump height in a jumping mechanography (*p* = 0.062) in the INT (n = 60) could be detected compared to the subjects of the CON (n = 59) (35). However, all other parameters, such as various blood parameters, cardiovascular mortality risk (European System for Cardiac Operative Risk Evaluation of the European Society of Cardiology (ESC-EUROscore)), postural control, lifting performance in the Progressive Isointernal Lifting Evaluation (PILE), as well as the SF-36, FAQ, and post-interventional days absent and sick days, showed no significant changes (35). As in the other study by Kaeding et al., a high compliance rate of 71.6% was observed with respect to the training sessions completed by the subjects and no unwanted side effects, as well as longer-lasting unwanted side effects were noted (34,35).

4. Discussion

We did a systematic literature analysis to determine the current evidence regarding the implementation of WBVT as a stand-alone intervention or part of a multimodal intervention in WHP. We found six articles on WBVT being used as a stand-alone intervention in white- and blue-collar workers with different exercise parameters. As mentioned before, the occupational setting and the workplace have a large potential to be as a suitable environment for the implementation of health-promoting interventions (1-6).

In relation to the research question formulated at the beginning of this paper concerning the evidence for the use of WBVT in WHP, rather sparse evidence can be found for this novel type 14 of intervention in this specific field to date, even though there is a lot of evidence accessible on WBVT in general. The existing studies are of a relatively high quality as they are all are randomized controlled trials and provide promising positive results for the use of WBVT in WHP.

Facts and perspectives

None of the studies recorded longer-lasting unwanted side effects, complications, or injuries due to the intervention. Therefore, an intervention with WBVT in WHP seems to be safe in white- and blue-collar workers (30-35).

In terms of positive effects on employee health and performance, all studies showed significant results or at least trends toward positive effects. Thus, four of the six studies reported significant reductions in self-reported musculoskeletal pain and associated functional limitations, including studies on healthy individuals and employees with low back pain (30-32,34). Four studies also recorded a significant increase in musculoskeletal well-being or health-related quality of life, with one of these studies finding a significantly higher effect among employees exposed to the risk factors "time pressure," "amount of standing," and "working in twisted posture" (30,31,33,34). All six studies also examined employees' balance skills, as a deficit in this area is associated with an increased risk of tripping, slipping, or falling and is particularly frequently associated with lost working hours accidents in the occupational setting, but can bereduced by improving balance (30-38). Two studies reported significant improvements in subjectively perceived surefootedness and sense of balance, and three studies reported significant improvements in balance in various balance tests or measurements (31-33). In contrast, the two studies using sinus like WBVT did not find significant improvements in postural control (34,35). This may be due to different effects of sinus like and random vibrations and therefore a stronger sensorimotor activation and thus more effective training of balance skills by WBVT with random vibrations, and/or to a relatively low potential for improvement due to the subjects' relatively good baseline levels at the start of the intervention (34,35). These two studies also provide first signs of positive effects of WBVT on the muscular performance of employees (34,35). The studies found a trend towards a positive effect on the performance of the trunk muscles in flexion and the leg muscles in terms of the maximum jump height, while the lifting performance in the PILE and the other parameters of the tests measuring muscular performance showed no significant effects or respective trends (34,35). This could be caused by the possibly too short intervention periods for long-term muscular adaptation processes or by the assumed little potential for improvement in healthy employees due to their comparatively high muscular performance level at the beginning of the study in combination with clinical tests that may not have sufficient sensitivity for the use in healthy subjects (e.g., in the case of the PILE in Kaeding et al.) (35). Thus, WBVT in the workplace can be considered overall as a safe and effective health-promoting intervention for white-collar employees as well as blue-collar employees even with low back pain. These results also support previous scientific assumptions that particularly unfit employees and employees with existing musculoskeletal complaints benefit from this minimal preventive intervention (18,35).

Regarding the cost-effectiveness of WBVT, none of the existing studies conducted a comprehensive analysis or concrete calculation. However, in one of the two studies that recorded the days of absence and sick leave of the subjects with chronic back pain, there was a significant reduction in the mean number of sick leave of 1.4 days per month in the INT in 15 the three-month follow-up, which can be interpreted as a notice regarding a possible cost effectiveness of WBVT in WHP in employees with chronic back pain (34). In this context, it is generally difficult to evaluate the cost-effectiveness of health promotion measures in studies with a relatively short intervention period, since long-term health or preventive effects and the associated cost savings usually take several years to emerge (39).

Furthermore, the good feasibility and low-threshold access of WBVT at the workplace, as reported in all the available studies, shows a large potential for a long-term cost-effectiveness of WBVT due to the very low time, personnel, organizational and infrastructural requirements (30-35). In addition to a low requirement of space of devices for WBVT, there is no need for changing clothes, a warm-up or cool-down as well as to take a shower after the training, the WBVT itself has a very low requirement of time (5 to 15 minutes), which allowed the employees to perform the WBVT even during short work breaks (30-35). Moreover, two of the studies demonstrated that WBVT can be performed safely and effectively by employees on their own after a short introduction, without regular supervision (34,35). Thus, these factors seem promising for an estimated easy, resource-efficient feasibility and sustainable integration of WBVT as a WHP intervention without affecting workflows or productivity. Compared to traditional health promotion measures, WBVT, as a minimal preventive intervention, also appears well suited for the implementation in blue-collar workers or occupational areas with special organizational or time challenges such as shift work.

The motivation of the subjects regarding the WBVT was not explicitly recorded in the present studies. However, a high compliance with the training schedule and the training units to be completed was evident across all studies, ranging from 71.6% in Kaeding et al. to more than 100% in the study by Faes et al. in which the subjects completed 29% more units than specified (33,35). It is remarkable that the high compliance values were even recorded in non-supervised interventions, as by Kaeding et al. in 2017 and Kaeding et al. in 2018, as well as in the only partially supervised WBVT by Faes et al., which indirectly suggests a high underlying motivation and adherence of the subjects (33-35). As already mentioned at the beginning, this is considered a key factor for the long-term, health-related and economic success of WHP interventions (13). As WBVT is not intended to replace conventional exercise or an active lifestyle, and multimodal interventions in WHP appear to be more effective according to studies, WBVT should potentially be used as part of multimodal interventions in WHP (1,8-10,30).

To our knowledge, only one other review on the use of WBVT in WHP is published to date. In a narrative review the author comes to the conclusion that WBVT seems to be an effective, safe and suitable preventive workplace-based intervention for white and blue-collar employees (18). The author stated, that WBVT seems to be a promising standalone preventive intervention in workplace-health promotion or is an effective part of multimodal preventive workplace-based interventions (18). This is in line with the results of this systematic review. We underline these statements and recommend the combination of WBVT in WHP with measures to improve the capacity of the cardiovascular system, because WBVT is known not to significantly improve the cardiovascular capacity in healthy humans with an average capacity of the cardiovascular system (40).

Further long-term and high-quality studies on WBVT in WHP, especially in blue-collar workers, are needed to consolidate the scientific evidence of the recent results and advance 16 research in this field. Further studies should focus on a detailed recording of aspects of a possible cost-effectiveness like effects on the sick leave. The optimal combination of all exercise parameters and the optimal mode of vibration of WBVT in WHP in order to be able to derive scientifically based recommendations for practice should also be focused. Despite longer intervention periods, longer follow-up periods are needed to capture possible long-term effects of WBVT.

Strengths of the study

To our knowledge, we performed the first systematic literature analysis on the evidence of WBVT in WHP. The identified six studies are randomized and controlled trials and of a relatively high methodic quality. Two of the studies used a crossover design, which has advantages in the comparison of the INT with each other and with the CONs. Furthermore, the two used modes of vibration in the WBVT interventions show a good comparability due to an almost identical training control. In addition, the WBVT was studied with subject groups of different employment types or work areas, sex distributions and health conditions. The studies were carried out in a real live setting which underlines the practical relevance of the results and provides a good basis for the generalizability of the results.

Limitations of the study

Because searching for relevant literature only in one electronic database, even though it is one of the most extensive databases in medicine, public health, and other related fields, it is possible, that we therefore missed to identify more than the six identified articles. In addition, by the restriction on the languages English and German we might have missed to identify articles published in other languages. The other restrictions, like the restriction on randomized, controlled trials, may have led to the missing of more possibly relevant articles. We also did no separate assessment of the methodological quality of the identified studies.

Moreover, the different subject groups in different settings the studies investigated and the wide range of used methods for data collection as well as a relatively wide range of used exercise parameters and two different used modes of vibration make the interpretation of the results of the studies difficult. The relatively short intervention duration of a few months in the studies should also be noted. Three of the studies were conducted over a period of only four weeks. Thus, only limited conclusions can be drawn about the long-term effects and sustainability of WBVT in WHP.

5. Conclusion:

Answering the afore formulated research question, WBVT appears to be a safe, effective, and well-suited stand-alone intervention in WHP for white-collar and blue-collar workers, especially for unfit employees and employees with preexisting musculoskeletal complaints. In terms of health and performance, a reduction in subjectively perceived musculoskeletal pain and functional limitations, an improvement in musculoskeletal well-being, surefootedness and balance, and initial indications of positive effects on muscular performance can be assumed. In addition, WBVT seems to be able to reduce sick days in employees with pre-existing musculoskeletal complaints and has the potential to be cost-efficient in the long run. In terms of feasibility, WBVT seems to be particularly suitable for different occupational settings and their specific

challenges (e.g., shift work) due to its low time, personnel, organizational and infrastructural requirements. Complemented by a usually high compliance, WBVT proves to be a promising intervention for the field of WHP in terms of positive long-term, health and economic effects. Nevertheless, research is still needed to further consolidate the evidence of the effects of WBVT in WHP, to better differentiate the effects, and to be able to determine long-term effects, sustainability, and the optimal design of exercise parameters for WBVT in WHP.

Conflict of interest

All authors declare that they have no conflicts of interest.

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Narrative Review

Effect of the systemic vibration therapy on functionality in older individuals: narrative review

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Abstract:

Introduction: Aging is associated with a decrease in organic functions. It is a natural phenomenon that is expressed through changes acquired over time. Physical exercise is recommended to improve functional capacity (FC), reducing the risk of falls and mortality in this population. The systemic vibratory therapy (SVT) is promoted through the realization of whole-body vibration exercise (WBVE). The WBVE occurs when mechanical vibration, generated in vibrating platform, is transmitted to the whole body of the individual. This modality of intervention is a recommended as a non- pharmacological approach to improve the FC in older individual. **Aim:** The objective of this narrative review is to provide evidence about effects of the SVT on FC in older individual. **Methods:** This narrative review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Recommendations. Inclusion criteria were randomized clinical trials and original articles about the evaluation of effect of SVT in the FC of older. Exclusion criteria were review articles, journals and magazines, comparison articles, protocol articles, conference abstracts, studies with a population under 60 years of age. **Results:** After searches using the keywords (whole body vibration) and (functional capacity) and (older) in PubMed, Scopus, Cochrane and Embase databases, 103 articles were identified. After considering the exclusion criteria, 5 articles were included in this review. Following the PEDRo scale, the selected papers had an average score of 6 being of regular methodological quality. **Conclusion:** The current narrative review indicates the relevance of SVT to improve the FC of older. However, there is the need of further studies with higher methodological quality.

Keywords: Physical exercise, functionality, older, whole-body vibration.

1. Introduction

Aging is a biological process that is associated with a decrease in organic functions accumulated by advancing age. It is a natural phenomenon that is expressed through changes acquired over time, characterized by being a dynamic, progressive and irreversible stage (1). By progressive changes in age, metabolism, and cells, leading to impaired cell regeneration and structural and functional changes in tissues and organs that can present as healthy or pathological aging (2).

The World Health Organization (WHO) and the Pan American Health Organization (PAHO) define the healthy aging as a continuous process of maintaining and improving the physical and mental health, independence, and quality of life throughout the life course, including the functional capacity (FC) (3,4). FC is having the ability to perform actions in relation to autonomy, being referred to as the ability to satisfy your basic needs to learn, grow, make decisions, be mobile, to build and maintain relationships and contribute to society (5).

The pathological process of aging arises with the presence of a physical or mental illness, deteriorating the health of the older, and exposure to extrinsic effects related to the time that harm the level that compromises cellular function and accelerates aging (6). The senility induced due to prolonged or intense exposure to external stimuli results in an increase in the rate of accumulation of senescent cells that amplifies the chance of falling ill (7).

Although advanced age is often associated with a decrease in FC, older individuals also may have reduced muscle strength and gait speed, which results in a progressive loss of lean mass that affects the functionality of the older. Consequently, there is impairment balance, mobility, falls, unintentional body mass loss and dependence to perform activities of daily living (8).

Sedentary behavior is directly linked to factors related to morbidity and mortality of the older (9). On the other hand, adherence to physical exercise (PE) is recommended for any individual regardless of age (10) to promote the quality of life and to improve the FC (11). Aging is also associated with a decrease in the effectiveness of the neuromuscular and sensory systems, directly impacting postural control and balance, making it difficult to maintain an upright posture (12). A modality of PE that might helpolder people with compromised would be the whole-body vibration exercise (WBVE) generated in an individual during the systemic vibration therapy (TVS). TVS is a non- pharmacological and non-invasive intervention that has been considered efficient for older people with reduced mobility (13). Evidence report improvement in balance (14) and in FC (15), being an adequate and efficient intervention, as much as conventional training, improving strength (16) movement speed, and performance in older (13).

SVT occurs when the individual is in contact with the base of a vibrating platform (VP) in operation. Thus, the mechanical vibration (MV) generated in the VP is transmitted to the body of the individual (17), promoting the WBVE. The MV is a physical agent defined by an oscillatory, sinusoidal and deterministic displacement. In the SVT, biomechanical parameters of the MV must be considered, such as frequency (f), peak- to-peak displacement (D) and peak acceleration (Pacel). These parameters are established in the proposed protocols according to the aim of the clinical proposal and the needs of each health condition of the individual. Other parameters would the exposure time of the bouts, rest time between the bouts, type of the VP, posture of the individual on the base of the VP, week periodicity and total time of the SVT (18,19). The SVT can improve balance (14), muscle strength (20), walking speed (21) and functional performance (22) in older adults. Then, the objective of this narrative review is to provide scientific evidence on the effects of SVT on FC in older individuals.

2. Materials and methods

The current narrative review was carried out in accordance with the recommendations of the Preferred Reporting Items For Systematic Reviews and Meta-Analyses (PRISMA)(23). It aimed to answer the question “Is it possible to assess the effects of TVS on functional capacity in the older?” according to the PICOS strategy we have P = older, I =WBVE, C=no comparison, O = functionality and functional capacity and S = Randomized Clinical Trial (RCT).

Searches were conducted in the databases PubMed, Scopus, Cochrane and Embase on April 11, 2023 with the following keywords: (whole body vibration) and (functional capacity) and (older).

The Inclusion criteria were randomized clinical trials, original articles dealing with the older and articles dealing with functional capacity.

The exclusion criteria were Review articles, protocol articles, conference abstracts, studies with populations under 60 years of age.

Assessment of methodological quality

The PEDro Scale was used to assess methodological quality. It has eleven assessment items in which ten are scored. Scoring occurs from the second to the eleventh criterion. The quality of the methodology is evaluated quantitatively: (7-10) high quality, (5-6) fair and if the score is less than or equal to 4 it is considered low quality (24,25).

3. Results

From the searches in the online databases, 103 articles were identified. Thirty-eight were excluded because they were duplicates, resulting in 65 articles for reading. The first analysis was performed by two independent reviewers (AAN; AGVP), reading the titles and abstracts, excluding those that were not the subject for this study and reviewed by a third reviewer (LTJA), totaling 7 articles for complete reading in full. Of the 7 analyzed, one was excluded due to its language and study protocol, totaling 5 articles for inclusion in the current review.

Figure 1- Flowchart with the steps of selection for this study.

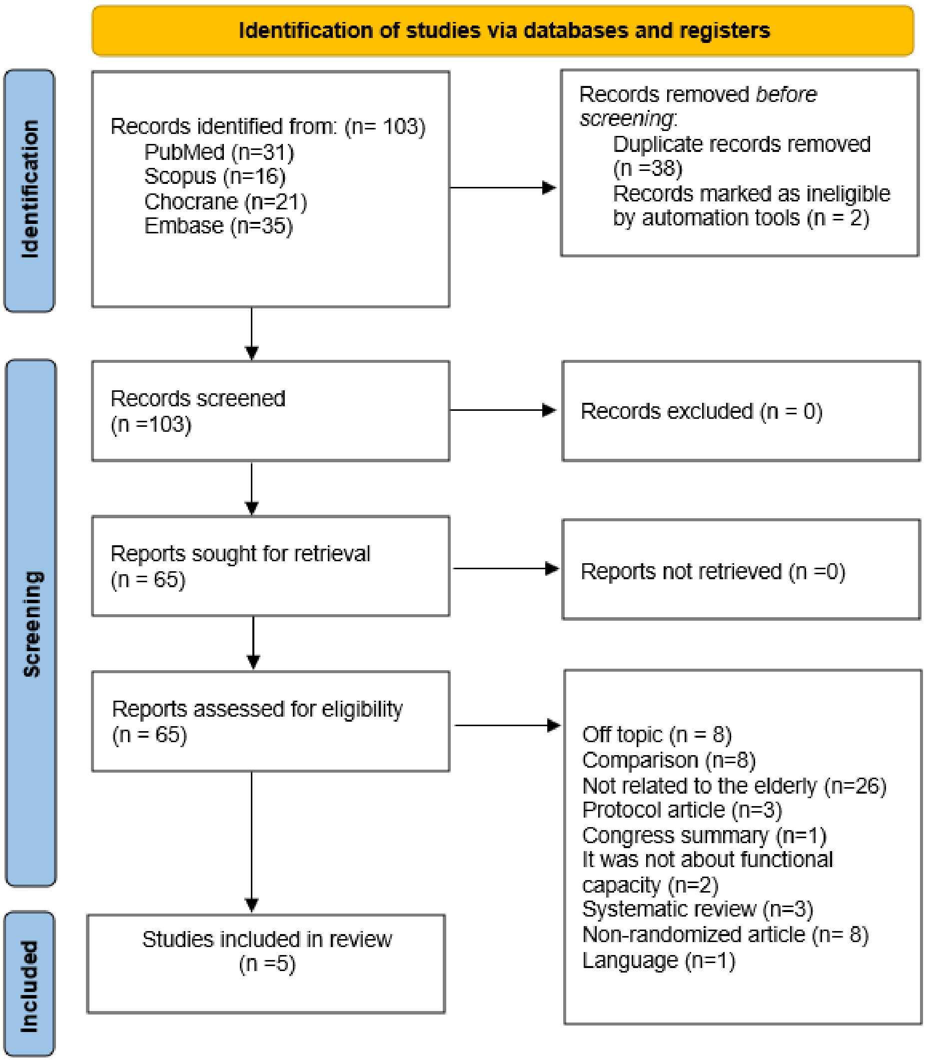

Figure 2- Assessment of the methodological quality of the included studies using the PEDro scale.

Reference	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Score**
Bautmans, et al 2005.	+	-	+	+	-	+	+	-	+	+	07/10
Rees, et al 2008.	+	-	+	-	-	-	+	-	+	+	05/10
Avelar, et al 2011	+	-	+	-	-	-	+	-	+	+	05/10
Buckinx, et al 2014.	+	-	+	-	-	+	-	+	+	+	06/10
Sitjà-Rabert, et al 2015.	+	+	+	-	-	+	-	+	+	+	07/10
	100%	20%	100%	20%	0%	60%	60%	40%	100%	100%	

(2) Subjects were randomly assigned to group (in a crossover study, subjects were randomly assigned to groups according to the treatment received); (3) Subject allocation was secret; (4) Initially, the groups were similar with regard to the most important prognostic indicators; (5) all subjects participated blindly to the most important prognostic indicators; (6) all therapists administered therapy blindly; (7) all raters who measured at least one key outcome did so blindly; (8) measurements of at least one key outcome were obtained in more than 85% of subjects initially assigned to groups; (9) all subjects from whom outcome measurements were presented received the treatment or control condition of key outcomes by intention to treat"; (10) results of intergroup statistical comparisons were described for at least one key outcome; (11) the study presents precision measures as measures of variability for at least one key result. (+) = meets criteria | (-) = does not meet the criteria.

The current narrative review had an average score of 6 being classified in a narrative review of regular methodological quality. With the lowest score of the articles (26,27) and the highest for (28,29)

In the five articles (26–30), 298 older were recruited, the mean age was 71.1 years. The selected studies used described groups of intervention and control. Two studies (26,29) performed a warm-up before the intervention and after a "cooling-down" was performed. One publication used interventions plus exercise and in some studies (29), two (27,28) used a progressive increase in frequency (Hz) and of the duration of work and rest times. In one study (28) the participants were wearing shoes on the feet and another (30) used a pillow to reduce the impact caused by the VP during SVT. The studies reported the use of side-alternating (30) or vertical (26–29) VP. In the selected studies, frequencies ranged from 26-50 Hz, peak-to-peak displacement of 2-8 mm, amplitude of 2-3 mm. On average, 26 sessions were performed lasting from 15 to 80 seconds, rest time from 20 to 80 seconds. The SVT was performed in squat dynamic or static.

Table 1- Main characteristics of the included studies, such as author/year, objective, session protocol, vibrating platform, biomechanical parameters used, evaluation tool used.

Author/year/country	Participants	Objective	Protocol and type of vibrating platform	Assessment tool used
Bautmans, et al 2005. BELGIUM.	24 older, two group WBV+ 76.6y and group CG 78.6y, 77.5 body mass 63.5-66.7 (kg), mean age groups.	Investigate the feasibility of WBV in frail institutionalized older persons, and its impact on muscle performance and functional capacity	VP vertical, Frequency 30-50Hz, amplitude 2-5mm, 6 week 3 sessions/week, VP vertical, wore shoes on his feet.	CSR; BS; SCS; TT; TGUG; GS LE40; LE60.
Rees, et al 2008. AUSTRALIA.	30 older, 66-85y age, two group VIB, EX, body mass 75.3-75.9 (kg).	Investigate the effects of vibration exercise on lower-limb strength in older adults who are healthy.	2-months 3x week, Frequency 26Hz, amplitude 5-8mm, duration 45-80 s, duration/reset 45-80s, knee flex, VP vertical,	CIDII.
Avelar et al 2011. BRAZIL	23 older, 75.5y WBV 71.4y CG, mean age, body mass 72.75- 74.24 (kg).	Evaluate the effects of adding WBVE to squat training on functional performance and self-report of disease in older individuals with OA.	3-month 3x week, frequency 35-40Hz, amplitude 4mm, acceleration 2.78-3.26G, squatting, 6-8 repetitions duration 20-40 s, 20-40 s of reset, VP vertical.	BBS; TUG; CST; 6MWT; WOMAC;
Buckinx et al 2014. BELGIUM	62 older divided into 2 groups WBV and CG mean age 82.2 WBV, 84.2 CG, BMI 25.2-22.5(kg/m²) means grups.	Evaluate the impact of 6-month training by WBVE on functional and motor abilities among nursing home residents observed over a 12-month period.	6-month 3x week, frequency 30Hz, amplitude 2mm, 5 repetitions with 15 s duration 30 s of rest and knees flexed. VP alternating, used foot pad.	Tinetti test; TUG-T; LT.

Sitja-Rabert et al 2015. SPAIN	159 institutionalized older divided into WBV+ and CG mean age of 82 years, body mass 76.15-67.41(kg).	Efficacy of an exercise program on a WBVE in improving body balance and muscle performance and preventing falls in institutionalized older people.	6-month 2x week, frequency 30-35 Hz, amplitude 2 to 4 mm, VP vertical, static/dynamic.	TT; TUG-t; STS; Vmax, HF

Abbrevations: P= Pounds; kg= kilograms; BMI= Body Mass Index; TUG-T= Timed up and go test; STS= sit-To-Stand test; HF= history of falls during the study and study-related**;** TT= Tinetti test; Vmax= Velocidade máxima em m/s; LT= Locométrix test; BBS= Berg Balance Scale; TGUG= Timed Get Up and Go Test; CST= Chair Stand Test; 6MWT= 6-Minute Walk Test; WOMAC= self-report of the status of disease; FRSTS= Five Repetitions of the Sit-To-Stand; CC= Clinical characteristics; NF= Number of falls; CIDII= Cybex II Isokinetic Dynamometer; CSR= Chair sit-and-reach; BS= Back Scratch; SCS= 30-second chair stand; GS= Grip Strength; LE40= leg extension 40 cm/s; LE60= Leg Extension 60cm/s, Y= Years.

Sitja et al. 2015 (29) reported that SVT associated with an exercise program is a safe intervention, and that there benefits to body balance, gait, functional mobility and muscle strength are similar to those of isolated exercise in institutionalized older. However, Buckinx et al. 2014 (30) showed that SVT does not seem appropriate to improve functional and motor skills among residents of nursing homes. Avelar et al. 2011(27) have shown that the addition of TVS to squat training may represent a viable and effective way to improve the self-perception of stiffness and physical function, mobility and muscle condition in older people with knee osteoarthritis. Ress et al 2008 (26), demonstrated that a protocol with 8 weeks of SVT results in a significant improvement in the strength and power of the plantar flexors for a group of healthy older. It is reported that the gain in strength after the vibratory training appears to dissipate distally through lower limb muscle groups and that different SVT protocols should be used to target upper leg muscles. Bautmans et al. 2005 (28) have shown that the 6-week protocol is feasible in institutionalized older who present limited functional dependence and can be beneficial for balance and mobility. It is not yet clear whether WBV has an additional benefit in muscle performance and flexibility compared to classical exercise in these people.

1. Discussion

Sitja et al. 2015 (29) described the SVT as a physical exercise in which individuals perform several exercises in a squatting position on a VP. Buckinx et al. 2014 (30) reported that SVT has gained ground in rehabilitation, and that it favors the increase of power and muscle strength. It is also described that these effects contribute to improve the muscle performance and body balance, these physiological responses are relevant to the older. Simão et al. 2019 (31) also recommend SVT as an effective alternative for strength rehabilitation in older, and the intervention with VP would be a safe, effective and adequate training method. In consequence SVT would be a viable intervention for individuals who are unable to participate in conventional physical exercises.

Sitja et al. 2015 (29) showed that after SVT, the Tinetti total score revealed a significant global improvement over time in both groups at 6 weeks and at 6 months, with no significant differences between groups. Buckinx et al. 2014 (30), in the TVS group, observed an increase in balance and a decrease in gait after 6 months, which represents a total decrease of Tinetti. In the control group, balance and gait scores in the total of Tinetti were reduced, one showing that there was an improvement in the balance of individuals exposed to TVS. Considering gait, the results were not very promising, not showing significant differences in both groups. Beaudart et al. 2013 (32), demonstrated that the Tinetti test, for the WBV group, in balance, in gait showed an increase, representing a better response in the total Tinette. In the control group an increase was also observed for balance and gait where that represented a total increase of Tinetti.

Sitja et al. 2015 (29) revealed that there was no significant improvement over time in either group at 6 weeks or at 6 months. However, Qiu et al. 2022 (33) showed improvement in relation to the TUG-Test with a protocol of 4 to 24 weeks of SVT. Avelar et al. 2011 (27) evaluated the effects of SVT within groups, before starting the interventions and after the interventions, following a 3-month protocol, to assess the functional performance of individuals. Berg Balance Score (BBS) tests were used during the BBS analysis, in the exercise group without vibration showed improvement in its performance, the same results were shown for the distance covered in 6 min (6MWT). Sade et al. 2019 (34) have shown a relevant difference in the same test for the intervention group (35), while Lai et al. 2019, regarding the results of the distance covered in 6 min by the participants in both groups there was not a significant increase (35).

Sitja et al. 2015 (29) in the stand and sit five times test, showed a significant improvement in both groups at 6 weeks, but there were no differences between groups at 6 weeks or 6 months. Paineiras-Domingos et al. 2018 (36) did not obtain an improvement in the STS test. In the sit and reach chair test, Bautmans et al. 2005 (28) described a significant improvement for the SVT group, with no significant difference between groups. However, Merriman et al. 2011 (37) have shown that there was a significant improvement during the WBV intervention between the groups in muscle performance tests such as the Chair stand test (CST). Avelar et al. 2011(27) described that only in the group in which vibration was added to the squat training that the performance of the participants improved after the SVT intervention, however, when compared between the groups, there were no differences. Nawrat-Szołtysik et al. 2022 (38) when comparing the results in relation to the groups, showed that the SVT group showed a significant improvements in the CST(38).

The aging process presents as one of the factors that contribute to the loss of FC the decrease in the lean mass of the lower limbs older. Ress et al. 2008 (26) used the Cyber II dynamometer to assess lower limb muscle strength, showing that the TVS group had significant improvements in ankle plantar flexor torque and power compared to the group without vibration. The mean amount of change in ankle plantar flexor torque was 18% and 5% for the vibration and no vibration groups, respectively. However Broekmans et al. 2010 (39) did not show improvements in the FC of the lower limbs in a 20-week protocol (39).

The current narrative review has some limitations. Although four known databases were used, including more data sources could improve amount of literature included in the review. The same is true for search keywords which, although inclusive, could have provided different results if a broader search strategy had been used, and therefore, not all relevant studies could have been identified. Furthermore, among the included studies, limitations are also present in terms of study design, heterogeneity of protocols for SVT, heterogeneity of control groups, cohorts, and the clear definition of the validation guideline to each of samples tested in the studies. This heterogeneity makes it very difficult to compare studies and interpret the effects of SVT use on individuals' functional capacity. Moreover, the results could also be stratified considering the age of the participants and the type of functional loss.

The strengths of this study is related to the use of SVT in the older as prevention and treatment for the organic changes caused by aging, thus favoring the elaboration of the theme for this review. The strengths of this study are related to the use of SVT in the older as prevention and treatment for the organic changes caused by aging, thus favoring the elaboration of the theme for this review.

Facts and perspectives

The objective was to demonstrate the relevance of SVT in the functional capacity of older individuals, related to balance, gait and muscle strength, and an increase in its use in the studied population has been described due to the ease of application and performance of the exercise. In addition, it is relevant to consider the results analyzed because they do not have a constant value, each result is characterized by the properties of the variable and the physiological condition that the individual is in. It is important to consider the biomechanical parameters of VP, as each study used different adjustments. Furthermore, in the future, it would be desirable to perform a complete comparison of the results obtained with data obtained using previously reported methods.

2. Conclusion

SVT can improve the FC of the older, thus contributing to greater independence to carry out daily activities, self-care and quality of life, considering it safe and that its benefits are similar to conventional exercise for older population. Older people who used the SVT showed an improvement in the self-perception of stiffness, muscle function, mobility, balance, strength and power of the plantar flexors. In addition, studies suggest adding more sessions and increasing the duration of interventions with protocols that use varied frequencies, avoiding stimulus accommodation. of the additional benefits in muscle performance and flexibility. However, more studies are needed with a high level of methodological quality and a specific investigation of the mechanisms that point to the increase in strength after SVT in an older population, it is also essential to standardize a SVT protocol in elderly people with reduced FC.

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Conflicts of Interest:

The authors declare no conflicts of interest or personal relationships that could influence the findings reported in this article.

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Narrative Review

Efficacy of whole-body vibration exercise on inflammatory biomarkers, clinical, functional and biological aspects in women with fibromyalgia: A narrative review

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Abstract

Introduction: The whole-body vibration (WBV) exercise has been widely applied in clinical practice. Thus, the current review aimed to provide an updated investigation of the current literature on the effects and efficacy of WBV on clinical, functional, and biological parameters in women patients with fibromyalgia (FM). **Methods:** For the purpose of this study, databases on PubMed, Cochrane Central Register of Controlled Trials, and Physiotherapy Evidence Database (PEDro) were identified and selected. Articles including single or multiple WBV sessions were recognised. **Results:** Five papers were included in this review (2 case-control studies and 3 RCTs). The sample size ranged from 17 to 20 participants, involving only women diagnosed with FM. The identified outcomes were pain, balance, quality of life, fatigue, disability, and FM- related inflammatory biomarkers. **Conclusions:** Despite the fact that WBV treatment appears to be safe and feasible, there is limited evidence to support the application of WBV in clinical practices in patients with FM. We emphasized on the importance of further studies addressing mechanobiomodulation in FM.

Keywords: Systemic vibratory therapy, fibromyalgia, inflammatory markers.

1. Introduction

The cause of the chronic illness fibromyalgia (FM) is yet unknown. The FM is defined by widespread inflammatory pain and tenderness which can last up to three months or more, and the presence of the at least 11 out 18 listed tender spots. About 2- 3% of people in the general population have FM, and 90% of them are women (1). Fatigue, disturbed sleep, decreased cognition, reduced functional ability, headaches, arthritis, muscle spasms, tingling, and balance issues are just a few of the impairments and activity limits linked to FM (2). Ankylosing spondylitis and rheumatoid arthritis are two conditions often linked to FM (3-5).

Finding evidence indicating responses triggered by inflammation is becoming genuine, thereby giving opportunities to potential explanations for the clinical condition of FM patients. As advanced information emerges, it provides a crucial avenue for investigating FM and its biological aspects (6-10). In this regard, numerous biological markers that may contribute to this illness have been extensively studied (10).

The development of laboratory tests that enable accurate diagnosis can stem from the isolation of an infectious agent or toxin responsible for the disease. However, until further investigation to uncover the disease's root cause, specific treatments may not be feasible. In the meantime, the management of FM involves a combination of pharmacological and non-pharmacological strategies (11, 12).

Non-pharmacological therapies for FM include physical interventions such as yoga, tai chi, walking, and whole-body vibration (WBV) exercises (13, 14). In WBV exercises, individuals are positioned on a platform to which stimuli are transmitted throughout the body. The intensity of the stimulus is determined by factors such as peak-to-peak displacement, amplitude, frequency, and acceleration of the oscillation (15–17). There are some action mechanisms to justify the effects of the WBV exercise, such as vibratory tonic reflex and mechanobiomodulation (18-22). Although there have been seven reviews on the effects of WBV exercise on FM-associated symptoms, current studies published in the last five years have highlighted the need for an updated analysis of the available evidence (23, 24). Furthermore, due to the limited methodological quality of previous studies, the effectiveness of WBV in the FM population is still not well established due to the limited methodological quality of previous studies. Yet, research findings support the hypothesis that WBV therapy may improve balance, discomfort, and fatigue (25-28) (Figure 1).

Bear in mind that we stress the importance of evaluating studies that address the effects of biological parameters related to the inflammatory profile in FM and the relationship with WBV. Therefore, in an effort to bridge the existing gaps, the present review aimed to invistigate recent evidence and provided an up-to-date analysis. These analyses were on the effects and efficacy of WBV, either alone or combined with exercise, in patients with FM.

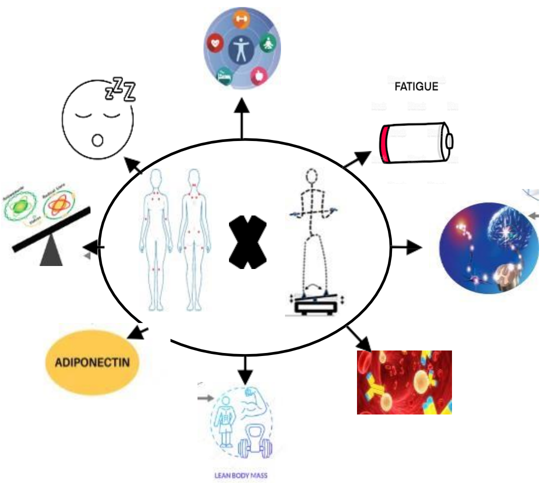

Figure 1 - Exploring the potential benefits of whole-body vibration exercise for fibromyalgia management.

2. Methods

Electronic database searches and selection strategy

A search was conducted over the last five years as new studies published over the have highlighted the need for an up-to-date review of available evidence in the Cochrane Library, the Physiotherapy Evidence Database (PEDro), and the PubMed database up till June 2023. The search strategy utilized keywords such as "fibromyalgia" and "whole body vibration". Experts in the field of WBV in FM supervised these activities. Our search strategy was structured using the P.I.C.O.T components (Patients/Population, Intervention, Comparison, Outcomes) to establish the elements. The inclusion criteria for the articles were: (a) focus on WBV therapy, (b) inclusion of a study cohort comprising solely people with FM, and (c) no language restrictions. One of the authors manually removed duplicate articles. A flow chart depicting the complete selection process was included in the systematic review (Figure 1). Two independent evaluators carried out the selection process. The search was concluded on June 20, 2023, with no submission deadline imposed.

Types of participants

We included research that examined adults with FM and performed WBV exercise. n addition, we selected articles that used published criteria for diagnosis (orclassification) of FM. Until the year 1990, the American College of Rheumatology (ACR) criteria served as the standard for classifying individuals having FM. That was once they experienced widespread pain lasting longer than three months and when pain can be elicited at 11 out of 18 specific tender points on the body with 4 kg tactile pressure (29). The newer preliminary diagnostic tool — ACR 2010 — does not rely upon the physical tender point examination and is available as both a clinician-administered tool and a survey questionnaire (30).

Measure includes a Widespread Pain Index (19 areas representing anterior and posterior axes and limbs) and a Symptom Severity Scale containing items related to secondary symptoms such as fatigue, sleep disturbance, cognition, and somatic complaints. Scores on both measures are used to determine whether a person qualifies as meeting a "case definition" of FM. This tool has been used to classify 88.1% of cases that meet ACR 1990 criteria and it permits ongoing monitoring of symptom change in people with a current or previous diagnosis of fibromyalgia (1). Although measurements focusing on tender point counts have been widely applied in clinical and research settings, methods described by Wolfe 2010 and Wolfe 2011 promise to classify people with fibromyalgia more efficiently. This occurs while allowing improved monitoring of disease status over time. Desoite the facts that differences among published fibromyalgia diagnostic/classification criteria are known, we considered all published criteria to be acceptable and comparable for the purposes of this review.

Types of interventions

We examined trials that studied WBV exercise interventions (e.g., moving or holding a standing position while on an oscillating platform) regardless of the frequency, duration, or intensity of exercise sessions. Appendix 2 provided an example of a WBV exercise intervention. We categorized interventions by the duration of the program (e.g., “short” < seven weeks; “intermediate” seven to 12 weeks, “long” > 12 weeks) and by frequency of training per week (e.g., once per week, twice per week, and three or more times per week). Comparative interventions included control (e.g., placebo or sham intervention).

Data extraction

Data were extracted from the selected articles by one of the authors. A second author checked this extraction. Any disagreement was discussed and ultimately resolved by a third author if contact with the original author of the article could not be established.

For each selected article, the following data were extracted: (a) the sample and protocol characteristics, namely, the sample size, age, and activity of the control and WBV groups (Table 1), and (b) the vibration therapy details, namely, the device and its oscillation (acceleration, frequency and amplitude), the duration of the intervention, the number of WBV sessions, the number of vibration series, the rest period, and the exposure duration in each series (Table 2).

Table 1- Studies characteristics.

Study, Type of study and Recruitment	**Participants Characteristics**			**Inclusion criterion**	**Exclusion criterion**	**Findings**	**Conclusion**
	Sample size and groups	**Age (years)**	**Exercise type**				
Santos et al 2023 RCT	40 participants FM (20 WBV 20 Control)	WBV 57.15±6.80 CT 55.5 ± 7.9	Dynamic squatting	Diagnosis of FM, based on criteria the ACR.	Any concomitant disease that could be exacerbated by physical activity, pregnancy, inflammatory diseases and degenerative, joint, respiratory or cardiovascular diseases, or participation program psychological, physical therapy program, or regular physical exercise more than once a week for 30 min or longer over a 2-week period in the last 5 years.	Modulation of the inflammatory profile in women with FM.	Six weeks of WBVT improves blood redox status markers, increases irisin levels and reduces visceral adipose tissue mass, favoring less cell damage and more marked oxidative balance in women with FM.

Ribeiro et al 2021 RCT	40 participants FM (20 WBV 20 Control)	WBV 56.2 ± 3.2 CT 58.1 ± 2.3	Dynamic squatting	Diagnosis of FM, based on criteria the ACR.	Any concomitant disease that could be exacerbated by physical activity, pregnancy, inflammatory diseases and degenerative, joint, respiratory or cardiovascular diseases, or participation program psychological, physical therapy program, or regular physical exercise more than once a week	Modulation of the inflammatory profile in women with FM.	WBVT promotes increased blood levels of BDNF, with concomitant improvement in lower limb muscle strength, aerobic capacity, clinical symptoms and quality of life in women with FMS.

					for 30 min or longer over a 2-week period in the last 5 years.		
Mingorance et al 2021 RCT	20 participants (20 WBV 20 Control)	WBV 52.5±8.3 CT 53.5 ± 8.9	Dynamic squatting	Women diagnosed with FM according to the ACR.	Severe trauma, peripheral nerve compression, inflammatory rheumatic diseases, presence of neurological or oncological disorders, osteoporosis, pregnancy, severe cardiovascular disease, pacemaker, hip and knee implants, participation in a psychological or physiotherapeutic program, participation in physical exercise more than once a week over a 2 week period for the last 5 years.	Quality of life, pain, sensitivity measures (pressure pain thresholds, vibration thresholds), motor function tasks (Berg scale, 6-minute walk test, isometric back muscle strength), and static and dynamic balance.	Improve physical, functional and emotional aspects in the intervention group, in contrast to the control group that did not present alterations. These improvements were not maintained at follow-up.
Santos et al 2019 Prospective paired case control	40 participants (20 WBV 20 Control)	WBV 53.0±12.0 CT 52.4±10.8	Dynamic squatting	Diagnosis of FM, based on criteria the ACR.	Any concomitant disease that could be exacerbated by physical activity, pregnancy, inflammatory diseases and degenerative, joint, respiratory or cardiovascular diseases, or participation program psychological, physical therapy program, or regular physical exercise more	Modulation of the inflammatory profile in women with FM.	A single trial of WBV exercise improved all oxidant and antioxidant parameters for greater adaptation to the stress response in women with FM.

					than once a week for 30 min or longer over a 2-week period in the last 5 years.		
Ribeiro et al 2018 Prospective paired case control	40 participants (20 WBV 20 CT)	WBV 52.16±1.81 CT 51.05±1.90	Dynamic squatting	Women diagnosed with FM according to the ACR.	Any concomitant disease that could be exacerbated by physical activity, pregnancy, inflammatory diseases and degenerative, joint, respiratory or cardiovascular diseases, or participation program psychological, physical therapy program, or regular physical exercise more than once a week for 30 min or longer over a 2-week period in the last 5 years.	Modulation of the inflammatory profile in women with FM.	A single acute short and short WBV session might improve the inflammatory state in FM patients, reaching values close to those of healthy mates in their baseline state.

Studies characteristics using the PICO (Patients, Intervention, Control, Outcomes, and Study design) approach. ACR: American College of Rheumatology.

Table 2 - Details of vibrating therapy

Study	WBV type and commercial name	Type of treatment	Frequency Amplitude Acceleration	Series times	Posture	Comparison protocol	Additional treatment
Santos et al 2023	FitVibe Synchronous	Session Multiple 6 weeks (3x weeks)	40 Hz 4mm 25.7 g	8x40 seconds Rest: 40 seg	Dynamic squattin	Yes	None
Ribeiro et al 2021	FitVibe Synchronous	Session Multiple 6 weeks (3x weeks)	40 Hz 4mm 25.7 g	8x40 seconds Rest: 40 seg	Dynamic squattin	Yes	None
Mingorance et al 2021	Galileo Fitness Vibration Side-alternating way	Session Multiple 12 weeks (3x weeks)	30 Hz 3 mm 14.5 g	6x30 seconds Rest: 30 seg	Dynamic squattin	Yes	None
Santos et al 2019	FitVibe Synchronous	Session acute	40 Hz 4mm 25.7 g	8x40 seconds Rest: 40 seg	Dynamic squattin	Yes	None
Ribeiro et al 2018	FitVibe Synchronous	Session acute	40 Hz 4mm 25.7 g	8x40 seconds Rest: 40 seg	Dynamic squattin	Yes	None

Details of vibrating therapy including acceleration: frequency and amplitude of oscillation, duration of intervention, number of Whole-Body Vibration (WBV) sessions and number of vibration series, rest period and duration of exposure in each series.

Synthesis and data analysis

Studies published in the last five years (2018 - 2023) exclusively in adults with a clinical diagnosis of FM were included. A descriptive analysis of WBV effect measures was performed on each selected outcome.

3. Results

Article Selection

A total of 31 articles was found in the electronic search of Cochrane (8 articles), PubMed (11 articles), and PEDro (12 articles) databases. After checking for duplicates, eleven articles remained and were selected, of which five were reviews and one article was excluded (the study clearly did not meet the inclusion criteria). Finally, five articles were included in our review, with two different study designs (e.g., randomized or control case), and two types of intervention (e.g., single session or multiple sessions) (Figure 2).

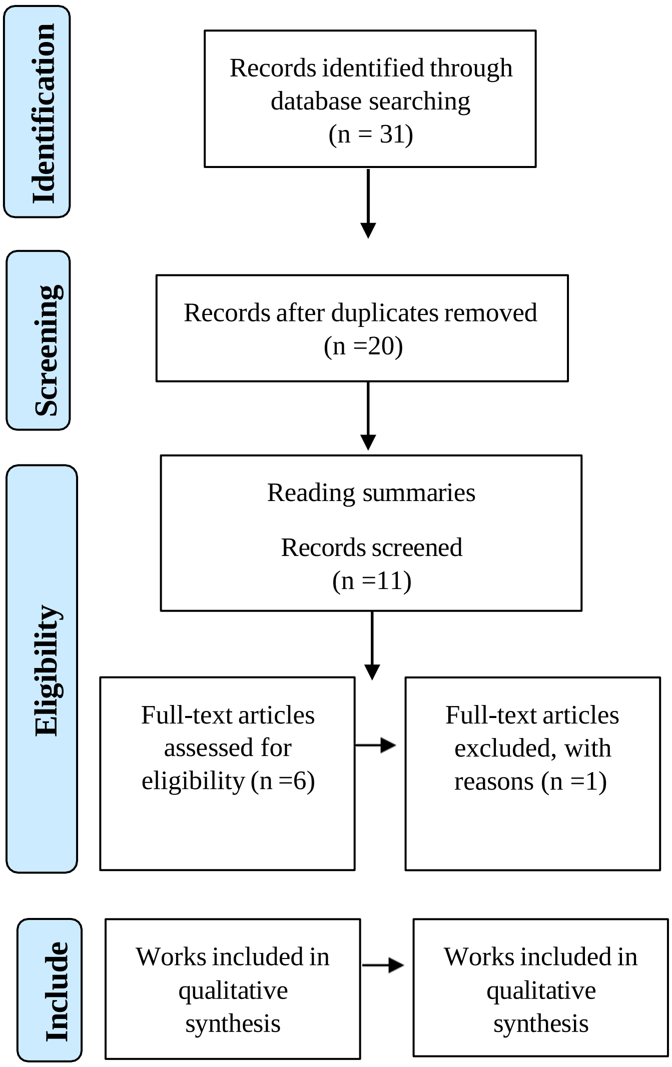

Figure 2 - Flow Diagram: phases of the systematic review.

Study Characteristics

The characteristics of the studies using the PICO (Patients, Intervention, Control, Outcomes, and Study design) approach are summarized in Table 1. All five studies were performed with adult women with FM and the sample size varied from 20 to 40 participants.

WBV Parameters

WBV Equipment

One study used the Galileo vibratory platform (32), and four studies used the FitVibe platform (23, 24, 33, 34). The Galileo vibratory and FitVibe platforms produce a vertical sine-wave vibration.

Frequency and Amplitude

The studies differed in terms of amplitude and frequency of vibration. Four studies used vertical synchronous stimulus vibration employing an amplitude of 4 mm and a frequency of 40 Hz, and one study used vertical synchronous vibration stimulus employing an amplitude of 3 mm and a frequency of 30 Hz. (Table 1).

Performance on the Platform

In the five studies, the subjects maintained a dynamic posture on the platform during the vibration. All works specified that both feet were always supported on the platform during the vibration. The knee angle varied between 90º and 180º (Table 1).

Key Measurements and Effects

The outcomes with the highest level of conclusion were pain, quality of life and biological aspects related to FM that characterize the modeling of the inflammatory profile (Table 2).

Pain

Pain is the most important symptom in FM, but it was specifically assessed in only one study, which reported improvement in pain (Effect Size = 0.97%), in the post-treatment (32).

Balance

One study evaluated the effects of WBV therapy on balance, specifically dynamic and static balance. In the study it was shown that WBV significantly improved the dynamic balance (Effect Size = 0.57%) and the static balance (Effect Size = 0.87%) in the WBV group (32).

Inflammatory profile

Four studies examined the biological aspects associated with FM, specifically focusing on the modeling of the inflammatory process.

Two studies demonstrated that a single session of WBV resulted in the modulation of the inflammatory profile in women with FM. One study reported a decrease in plasma levels of adiponectin and sTNFR1, along with an increase in levels of sTNFR2. Significant interactions were observed in plasma levels of adiponectin (p=0.0001), sTNFR1 (p=0.000001), and sTNFR2 (p=0.0052) (33). In the second study,improvements were observed in all oxidant and antioxidant parameters, indicating a greater adaptation to stress response in women with FM. This was evidenced by a reduction in TBARS (p<0.001), an increase in FRAP (p<0.001), and CAT (p=0.005), and an increase in SOD levels (p=0.019) (34).

Two studies revealed that multiple WBV sessions led to modulation of the inflammatory profile in women with FM. In one study, WBV therapy was found to increase blood levels of BDNF (p=0.045), accompanied by improvements in aspects related to the biological rhythm (23). Another study demonstrated that WBV therapy resulted in increased levels of irisin (p=0.01) and reduced levels of TBARS (p=0.001) and visceral adipose tissue mass (p=0.001) in women with FM. These findings indicate a reduction in cellular damage and a more pronounced oxidative balance (24).

Effects of a single WBV session

Researchers investigated the acute effects of a single WBV session (Figue 3), on inflammatory biomarkers in FM patients and matched healthy people using experiments with 40 participants (33, 34). Thus, with just one vibration session, the data showed an improvement in the inflammatory profile. As a result, FM patients attained results equivalent to those of healthy people who shared the same anthropometric traits. Exercise-induced regulation appears to be the mechanism underlying this neuroendocrinological response, resulting in improved stress response in FM patients.

Effects of multiple WBV sessions

Three studies, involving 60 participants, examined the effects of multiple WBV sessions (Figure 3), with a training period lasting approximately 6-12 weeks. Significant findings from these studies included improvements in dynamic balance and static balance (32), reduction in pain, improvement in disability and quality of life assessed through QIF (23, 32), enhancement of muscle strength and functional performance (23, 32), as well improvements in balance and reduction of the inflammatory profile (23, 24).

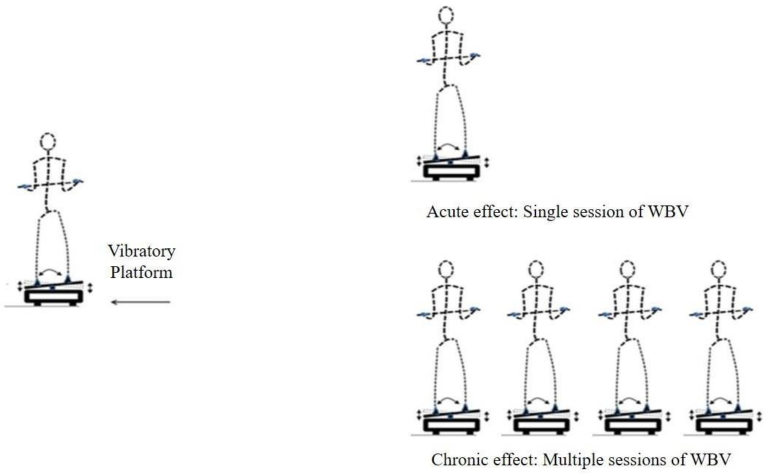

Figure 3 - Possible position adopted during the whole-body vibration exercise.

4. Discussion

This review aimed to assess the potential benefits of WBV for women with FM. Five studies, encompassing 100 participants, were analyzed and exhibited a sound methodological foundation. It is worth noting that all participants had a confirmed FM diagnosis by a Rheumatologist, which enhances the reliability of the results. The findings of this review indicate that WBV therapy has the potential to improve various FM symptoms, including inflammatory parameters, disability, pain, quality of life, and balance issues (23, 24, 32-34).

Scientific evidence supports the benefits of WBV in FM, including improvements in muscle power and strength, sleep quality, peripheral blood circulation, functionality, balance, postural control, quality of life, and body composition, as well as decreased pain and muscle fatigue and risk of falling, in conjunction with increases in bone mineral density and muscle fiber recruitment. Moreover, remains a gap in the association between WBV and inflammatory markers in FM (35-37). In this analysis, we discovered four papers that discussed how WBV led to patient adjustments and modulation of the inflammatory profile. According to a recent narrative review, it is imperative to research on the application of systemic vibration therapy to mechanobiomodulation components as potential biological effects. Considering current findings about biological responses to mechanical vibrations (38).

Recognizing that diffuse and persistent pain is a primary symptom of FM, often leading to limitations in daily activities for patients (2, 5), exercise and physical activity have been found to play a crucial role in promoting analgesia. This occurs through modulation of the immune system, both locally and systemically, as well as within the central nervous system. Such modulation triggers the release of anti-inflammatory cytokines, which reduce the activity of nociceptors and the central nervous system to alleviate pain. Regular exercise has been shown to increase the levels of anti-inflammatory cytokines in the spinal cord while decreasing glial activation and inflammatory cytokines in the central nervous system. It further enhances the transcription of factors that regulate IL-1 (interleukin 1 beta), NFk (nuclear factor kappa beta), and NLPP3 (NOD-type receptor with pyrin domain 3), all possibly known to be reduced with regular exercise. By restoring neuroimmune signaling in the central nervous system, exercise can help prevent the development of hyperalgesia. These mechanisms contribute to importance of therapeutic improvements and positively influence the quality of life for individuals with FM (39).

Importantly, a recent study has revealed that central sensitization and inflammation, despite having distinct physiological mechanisms, exhibit numerous similarities. This includes the notion that multiple biomarkers, rather than a single gold standard, are required to explain the diverse clinical and biological manifestations. Furthermore, both central sensitization and inflammation display crucial roles in various clinical conditions and diseases, with their clinical presentations varying significantly among patients (40). Given this overall context, the significance of research that comprehensively examines the adaptive responses to different exercise modalities becomes even more pronounced. Such research considers both the biological context related to biomarkers and the somatosensory context to enhance our understanding of the complex interplay between exercise, the body's adaptive responses, and the broader clinical implications.

According to the review (42), the choice of protocol and exercise modality can have an impact on the evaluation of the effects of WBV on FM symptoms. Therefore, itis crucial to conduct a comprehensive and systematic analysis to determine the appropriate protocol for each study. Additionally, standardized language is imperative in WBV investigations as different studies utilize various concepts and terminologies, such as the platform and the mode of vibration (synchronous, asynchronous, and alternating). This variation in terminology makes it challenging to understand and replicate the protocols employed in different studies (28, 29).

Finally, this review has provided valuable insights into the benefits of WBV for FM. We highlighted the potential connection between mechanobiomodulation and disease-related biological responses. These perspectives suggested that a comprehensive understanding of mechanobiomodulation will contribute to unraveling the underlying mechanisms behind the biological effects of WBV in FM. The research findings discussed in this review, encompassing both functional and biological factors, can significantly enhance the utilization of WBV in FM. Ultimately improve the quality of life for patients affected by this clinical approach.

While this review provides valuable insights, it is important to acknowledge its limitations. These include: (i) the limited number of studies available on the use of WBV in FM, (ii) the significant variation in vibration protocols across the included studies, and (iii) the diverse range of outcomes evaluated. Additionally, the literature search was conducted in three electronic databases (the Cochrane Library, the Physiotherapy Evidence Database (PEDro and PubMed), which may have resulted in the omission of some relevant studies. It is worth noting that we periodically update the search to ensure comprehensive coverage.

5. Conclusion

WBV therapy indeed shows promising potential as a primary treatment for FM based on the mentioned benefits, such as regulating the inflammatory profile and improving quality of life, balance, functional limitations, and fatigue (as shown in Figure 4). The positive effects of WBV on FM patients have sparked optimism among researchers. However, the use of WBV in FM is still an emerging field, and studies investigating its efficacy over the past five years have been limited. Specifically, there is a need for further research to understand the underlying biomechanomodulation mechanisms and to develop more effective treatment strategies. Despite the current limitations in research, the authors remain hopeful about the potential benefits of WBV for FM patients, especially when tailored to individualized treatment approaches.

Interest conflicts

The authors declare no conflicts of interest.

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