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The Effect of WBV on Balance, Mobility and Strength in Aging Adults: A Systematic Review

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Abstract

Whole body vibration (WBV) exposure in elderly adults is found to increase physical activity and so the overall health status. For analyzing effects of WBV on muscle power, balance and overall mobility among elderly adults of age more than 60 years, comprehensive article search was performed from year 2013 till January 2017 on electronic databases of Medley, Google scholar and IEEE (institute of electrical and electronic engineering), search strategy and inclusion criteria was specified initially and then articles were recruited accordingly. Randomized controlled trails targeting WBV effects, compared to control group with some moderate exercise or no intervention at all, on muscle power, balance and mobility were studied and data extracted about author name, publication year, age and number of participants, WBV parameters, protocols of study, vibrating platform, description and comparison among interventions. Initially 656 records were identified in preliminary search through the databases, four studies finally were considered as eligible. Lower body muscle strength (14.8 ± 3.3 to 16.5 ± 3.6) and upper body strength (17.9 ± 4.5 to 20.3 ± 3.6) have shown significant results in all the studies. Improvement in balance and mobility was also significant with $P<0.005$ in comparison with control groups with no interventions. WBV alone or combined with exercise training program seems to improve muscle strength, overall balance and increased mobility among elder adults. Direct comparison among studies was not possible because of differences among parameters and study protocols. More extensive and well-designed research is still needed to establish efficacy and to understand the effects and influences more clearly.

Keywords: Whole-body vibration; Elderly; Balance; Muscle strength; Lower extremity; Musculoskeletal system; Health status; Exercise; Mechanical oscillation; Frail elderly

Introduction

Physical activity plays an important role in delaying age related changes and maintains the overall health of a person by maintaining good balance, stability and improving musculoskeletal health [1]. As age progresses, reduction in physical activity occur, that makes it even more important to exercise so to remain healthy [2]. However, if exercise is not worked out regularly, no potential benefit will be achieved [3]. So, in short, exercise is best alternative for physically inactive people to remain healthy. But, perceived discomfort while exercise is the major factor that reduces the rate of exercise and compliance to exercise in elderly [4,5].

One of the new effective alternative options for physical activity and exercise is the Whole-body vibration (WBV) and as the name implies, it involves application of vibrations to the whole body [6]. Vibrations can be localized or generalized but WBV is different in action from the localized vibrations, as they target a specific body part [7]. Vibratory platform is the ideal place where person stands and vibration is applied. It can be horizontal, vertical or cyclo-vibrations depending upon movement of vibratory platform in specific direction. In addition, several parameters to study includes: vibration frequency (f), amplitude (a), magnitude (m) and time duration (T). Various directions can be focused as per desire like: effect of WBV can be checked for physiological changes [8], reduction in pathologies [9], musculoskeletal health [10-12], pain relief, balance or for macro n micro circulation [13]. The reason behind labeling WBV as an alternative to exercise and physical activity is the working principle of WBV and exercise, to increase exercise intensity the mass (M) is further increased and the working of resistive exercise lies upon M, nevertheless working of WBC lies upon acceleration (A) [14,15] and changes in it and specified by 'Isaac Newton', it works upon 'law of motion' [16]. The overall goal of both is to increase the force (F), and the formula is written here below:

$$F=M*A$$

So, the F can be increased by either increasing M or A. The benefits of using WBV are: it is less time consuming, can be performed easily by elderly and need no physical exertion e.g. an adult of 70 years' age is unable to lift weight of 10 kg or more for long that youngsters can do. As no physical exertion happens with WBV exercising so the compliance rate is much higher than performing resistive exercise.

Whole body vibration (WBV) is training through vibration platform and in broader range is also known as biomechanical stimulation and biomechanical oscillation. Biomedical stimulation (BMS) or biomedical oscillation (BMO) are like WBV as in employing oscillations of low amplitude and frequency to the musculoskeletal structures but a minor difference lies in the fact that BMS is much more specific and targets specific muscles and tendons rather than proving therapy to whole body. Both have a great importance regarding needs, as in the case of stroke patient where the strength of a

specific muscle is required, BMS will be more effective. Furthermore, for improving overall health and fitness as in elderly, the application of WBV is more as it includes much broader area of body.

It is assumed that because of WBV 'tonic vibration reflex' occurs [16]. The mechanism is as: Vibration evokes muscle contractions by activation spindles of muscles that are basically activated by neurophysiological mechanisms. This activates muscles, increases the electromyography (EMG) even when the person is not actually in motion [17]. Consequently, WBV can improve stability, strength and power of aged adults as exercise can do [18]. Furthermore, Nishihira et al. have documented that with vibration myotactic stretch reflex started that acts upon muscle spindles and so consequently muscle contraction [19]. In another study by Abercromby et al., the participants performed squats on vibration platform and also the same movements without vibration platform, the EMG activity was measured and was much enhanced after vibrations [20].

Some of the previous studies have briefed in some outcomes as: improvement in balance [21], increases in bone mineral density [22], increased blood circulation [23], reduction in pain level [24], increased muscle strength and power [25] and in special cases like in knee osteoarthritis [26], scoliosis [27], spinal problems [28], cardiovascular issues, stroke cases, multiple sclerosis [29], Parkinson's disease [30], osteopenia, diabetes mellitus [31], rewardingly improvement in overall health of the person. Furthermore, for inactive and elderly, it is the best solution to improve health and quality of life.

More recently, the trend toward studying the effect of WBV for aged adults is increasing and the highlighted parameters of study are: balance, solving musculoskeletal issues, improving bone health especially after menopause in females, bone density, mobility and improving general health status [21,25,32,33]. The basic purpose of this systematic review is to search current literature about WBV for elderly, cautions about using intervention and to highlight positive outcomes.

Methods

Data sources and searches

Comprehensive article search was performed in January on electronic databases of Medley, Google scholar and IEEE (institute of electrical and electronic engineering), the keywords included: 'Whole body vibration (WHO)', 'elderly', 'aging adults', 'randomized controlled trials', 'balance', 'mobility' and 'muscle power'. The articles published from 2013 till now are included in the review. Search strategy and inclusion criteria were specified initially and then article were recruited accordingly.

Randomized controlled trials (RCT) were given more preference and out of four full text articles assessed, three are RCT and only one is case study. All those RCT were considered eligible that addressed the effect of WBV on mobility, balance ability, muscle power and reduction in fear of falling. The primary outcomes considered here are: balance, mobility and muscle strength plus the secondary outcomes are also considered that includes: general health condition, reduction in fear of falling and overall physical fitness. The inclusion criteria were studies that included WBV exposure to intervention group, human studies, time duration of >5 weeks, exercise and WBV together, participants were aged adults, where mobility balance and muscle power were targeted and worked upon. The exclusion criteria were studies that included young participants, individuals with stroke, diabetes mellitus, cerebral palsy and severe musculoskeletal disturbances like scoliosis and the studies that are unreliable.

Study selection

All studies identified and considered after the search strategy were screened by two reviewers (independent to each other), screening was done for titles and abstracts of all studies. A standard was followed for final recruitment of all studies that was based on eligibility criteria and the studies that do not meet the screening checklist standard were excluded. For the second review the full text versions of studies were retrieved and secondary selection was made. The opinions of both reviewers were same.

Data extraction

Reading by the both reviewers independently and for extraction of data, initially a data extraction form was made and the data included the following parameters: author name and year of publication, no of participants, parameters and time duration, intervention and comparison groups, gender and age, description of intervention plus comparison among intervention and control group, the outcomes and results of all studies included. Large sample size studies were given more preference than the small sample size studies, the studies fulfilling the data extraction form were considered with maximum one or two parameters missing (Figure 1).

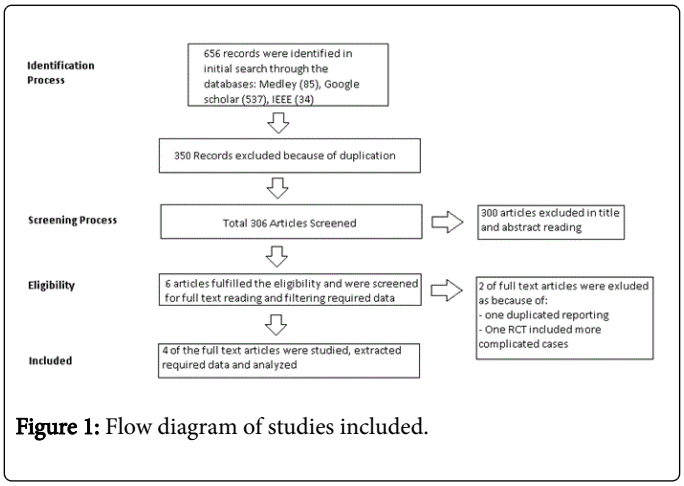

Figure 1: Flow diagram of studies included.

Quality assessment

Level of evidence was used for assessing the methodological quality of all 4 articles included in this review, Sackett scoring was used here [34]. The goal of this assessment was to analyze the quality of articles selected. Both reviewers assessed independently the quality and documented. A specific level is assigned to every article, as per Sackett scoring that states from 1A and end up till 5. These are different types of study protocols followed by different studies

Results

Description of studies

The search strategy generated 656 records, out of them first, second and third round analysis was done, some were excluded in initial stage after analyzing the title names and reviewing the abstracts, 8 articles were retrieved for detailed analysis and full text reading. After

reviewing these, 4 were excluded after full text reading and the remaining 4 were selected and recruited for the review [21,25,32,33]. Figure 1 demonstrates the flow diagram of the studies included and their characteristics and parameters are summarized in Tables 1 and 2.

Studies	Year of publication	Study type	Level
Zhang et al. [32]	2014	RCT	1B
Osugi et al. [33]	2014	RCT	1B
Gómez-Cabello et al. [21]	2014	RCT	1B
Shim et al. [25]	2014	Case series	1C

Table 1: Quality assessment.

Level	Criterion
1A	Systematic Review of RCT*
1B	RCT with narrow confidence intervals
1C	all or none case series
2A	systematic review of cohort studies
2B	cohort study of low quality
2C	outcomes research
3A	systematic review of case-controlled studies
3B	case-controlled study
4	case series, poor cohort case controlled study
5	expert opinion
	* RCT=Randomized Controlled Trial

Table 2: Level of quality assessment.

A total of 138 participants were assessed, the year of publication of studies ranged from 2013 to 2017. All the studies included elderly participants, aged more than 60 years. Both males and females were included in the study and a comprehensive result upon adult population is targeted. In addition, all studies randomly allocated the participants in to groups the Intervention group (IG) and the Control group (CG), the intervention group was exposed to whole body vibration (WBV) alone or with any exercise training and the control group was given no intervention at all. Least minimum range of frequency started from 6 Hz as used by Zhang et al. [32] and the maximum was 40 Hz as practiced by Gómez-Cabello et al. [21]. Overall range was among 6 to 40 Hz.

The technical details of vibration platform and time duration of intervention is given in the table below (Tables 3 and 4).

Author, year	Platforms	Frequency (Hz)	Amplitude (mm)	Time duration in wks	Time duration of intervention	intervention
Zhang et al., 2014 [32]	Galileo machine (Novotec, Pforzheim, Germany).	6–26 Hz	1–3 mm;	8 weeks	4–5 bouts × 60 s; 3–5 times weekly	IG: WBV CG: exercise+usual care
Osugi et al., 2014 [33]	Galileo machine (G-900; Novotec, Pforzheim, Germany)	20 Hz	---------	24 weeks	Squat training was done in 4 min WBV session, 2 times per week	IG: WBV+Squat training CG: WBV alone
Gómez-Cabello et al., 2013 [21]	Pro5 Power plate (London, Uk)	40 Hz	2 mm (peak to peak)	11 weeks	10 repetitions in squat position of 45 s duration, with a rest period of 60 s.	IG: WBV in squat position. CG: no training
Shim et al., 2014 [25]	Extream 1000; AMH International Co., Ltd., Incheon, Republic of Korea)	18–27 Hz	30 mm (anterior to posterior)	6 weeks	3 times per week, WBV session while knees and hips flexed and applied for 15 min, 3 times per week	IG: WBV alone

Table 3: Technical details of vibratory platforms.

Sr. no.	Author Nam Year	Participants	Intervention and Comparison Group	Gender IG%/CG%	Age of participants (years, mean ± SD	Description of intervention	Description of comparison	Outcomes	Results
1	Zhang et al., 2014 [32]	44 Aged adults meeting the Fried Frailty Criteria	Intervention group (IG): Whole-body vibration exercise (WBV) n=22 control group (CG): Usual care +exercise, n=22	IG: 17 Male (M) 2 Female (F), CG: 15 M+3F	IG: 85.84 ± 3.58 CG: 84.67 ± 3.68	IG: 4–5 bouts of WBV × 60 s, 3–5 times weekly	IG: 4–5 bouts of WBV × 60 s, 3–5 times week CG: 8 weeks exercise +usual care	The Timed Up and Go Test (TUG), 30s chair stand test, lower extremities muscle strength, balance function, balance confidence and General Health Status	Significant improvement with WBV group in TUG Test, improved posture stability and General Health Status.

2	Osugi et al., 2014 [33]	28 aged adults reporting problems of knee osteoarthritis Kellgren-Lawrence grade 1, 2, or 3 & spondylitis	WBV alone(WBV): n=14, WBV + squat exercise training (WBVST): N=14	WBV: 6 M +8F, WBVST: 6M +8F	WBV: 72.5 ± 4.6 WBVST: 72.3 ± 6.5	WBV: A 4 min WBV exercise was performed 2 days per week WBVST: During a 4 min WBV session, squat t training (20 times per min) is added	WBV: only WBV is applied; WBVST: Squat training is added with WBV	body balance, walking velocity, tandem gait step number, chair-rising time, muscle power	WBV: improved body balance and walking velocity. WBVST: improved tandem gait step number and chair-rising time
3	Gómez-Cabello et al., 2013 [21]	Forty-nine non-institutionalized elderly	IG: WBV+squat, n=24. CG: no intervention, n=25	Total 20 men and 29 women participated in the Study	WBV+No intervention group Aged: 75.0 ± 4.7 years)	WBVST Includes 10 repetitions in squat position on vibration platform for 45 s with rest period of 60 s. The interventionist given 3 times per week for 11 weeks.	IG: In intervention group WBV was applied and squat positions was maintained while training, CG: no intervention was applied in control group	Balance, lower- and upper-body strength and flexibility, agility, walking speed and endurance	Increase in muscular strength and walking speed was found. Balance performance have shown no significant changes with intervention.
4	Shim et al., 2014 [25]	17 elderly individuals	IG: WBV alone, n=17	IG: 7M +10F	75.8 ± 6.3	Participants performed whole body vibration exercise in the horizontal direction using a whole body vibration device for 15 min a day, 3 times a week, for 6 weeks.	IG: only the intervention group was there in the study and no control was included in the study	Balance, Timed Up and Go test and fear of falling	Improvements in balance and fear of falling

Table 4: Characteristics of included studies.

Balance

Research on effects of WBV on balance in elderly is somehow more extensive. Several studies have documented significant improvements in balance by WBV [35,36], controversial result was documented by Marín et al., in 2013 where no improvement in balance was found [37]. For balance analysis, systematic review was performed and data was included form four different trials with varying vibratory platforms, and a total of 138 participants. The control group have not contributed in any intervention or have performed some usual care. There was an improvement imbalance of participants (surface area ellipse: 404.58 ± 177.05 to 255.95 ± 107.28) that favors WBV intervention [32]. These values of four weeks and eight weeks 'exposure were documented and both have shown improvements from the baseline value.

The 24 weeks program of WBV plus squat training have shown same results in improving balance as that by only exposing to WBV and the values are (122 ± 94 103 ± 92, p<0.001) [33]. Improvements in balance were also found in a study that has shown the variation before and after as (24.5 ± 20.2 to 34.3 ± 22) [21]. A research study on elderly individuals exposed to WBV has documented significant results for balance from52.9 ± 2.1 to 53.8 ± 2.0 [25].

Muscle strength

Muscle strength is one of the major factors that contribute to overall health of an individual. For this muscle strength analysis is also made and effect of WBV regarding muscle strength is taken in to account. A total number of 138 participants were analyzed by four trials included here, it seems that much more improvement in muscle strength was found in a study by Zhang et al. [32], that targeted on knee extensor muscles and resulted in improvement from (6.96 ± 1.70 kg to 11.26 ± 2.08 kg, P<0.05).

Direct comparison between different studies was somehow difficult because of heterogeneity, varying exposure time, frequency, amplitude. Nevertheless, the individual results of studies included in the literature have shown significant results for improving muscle strength among elderly. In a 24 weeks' study by Osugi et al. [33], participants were exposed to two different modalities that involves WBV plus squat training and the other one with only WBV, non-significant results were found among both modalities and have proved that WBV alone even can give the strengthening effect to muscles with aP<0.0001 and value of improving strength are 10.7 ± 2.8 12.2 ± 4.5 [33]. After the 11 weeks' program for upper and lower body muscle strength exposed to WBV, participants of intervention group have shown improvements in both regions as; lower body strength (14.8 ± 3.3 to 16.5 ± 3.6), upper body strength (17.9 ± 4.5 to 20.3 ± 3.6) [21].

Mobility

Regarding primary outcomes, data of four studies were evaluated completely and more studies were also considered. Total of 138 participants participated in different studies with varying parameters like vibration frequency, amplitude, time duration and course of intervention. Comparison group was not given any training. After 8 week program of WBV in elderly, significant improvement was found

in mobility level from (40.47 ± 15.94 to 21.34 ± 4.42) [32]. In this 24 weeks research, two interventions were done, first one was WBV plus squat training and the other was WBV alone, significant result was found among no intervention and intervention group. Although, no significant results were found among both intervention groups and have shown the same results for WBV both squat and without squat with P<0.0001, the values of both intervention groups are as: 8.8 ± 2.1 9.6 ± 3.0 [33]. So, both interventions differ significantly from control but not from one another. A study of 17 participants with WBV alone as intervention have shown significant improvement in mobility 11.02 ± 1.14 to 9.70 ± 1.77 [25].

The papers selected in the review have shown various effects of WBV for elderly adults, regarding acute and chronic effects, the least time span of intervention was 6 weeks and the maximum time was 24 weeks. Shim et al. [25], demonstrated that with a frequency of 18-27 Hz and 30 mm amplitude and therapy given three times a week, there is an improvement in the balance and the decrease in fear of falling. Overall, a six-week therapy have shown significant results (P<0.05). Given these facts, a six-week therapy was also beneficial for improving fitness in the elder adults [25]. Furthermore, an eight-week study by Zhang et al. [32], illustrated a comparison between control and intervention group, control group n=22 was assisted with usual care and exercise whereas the intervention group n=22 was given 4 to 5 bouts for 60 s of whole body vibrations for three to five times a week have shown similar improvements [32]. Although a study by Osugi et al. [33], that included the elder adults showing some knee problems symptoms and exposed them to vibration therapy for a maximum time span of 24 weeks, on Galileo machine (G-900; Novotec), with a frequency of 20 Hz have shown improvement in body balance, walking velocity, improvement in tandem gait step numbers and chair-rising time. Hence, both the short term and long term therapy was advantageous for elder adults nevertheless a continued training is valuable for maintaining physical fitness just like exercise, and because of much higher compliance rate of whole body vibration, it is a best alternative for physically inactive patients and elder adults [33].

Discussion

Summary of evidence

In this review, three parameters were studied for influence of WBV on them that includes balance, mobility and muscle strength. The targeted age group was elder adults, having no complicated disease or disability. It seems that the least therapy duration of 6 weeks was also sufficient for improvements in balance that highlights the importance and significance of WBV [25]. In contrast, an 11 week WBV intervention resulted in non-significant results [21]. Maximum time span of studies was 24 weeks WBV intervention exposure that also has shown significant results for improving balance among elderly. In all the studies, aged adults were exposed to WBV; exposure was different regarding parameters like varying platforms, protocols of study, time span and frequency of exposure [32]. Out of all four different clinical trials included, three exposed elderly adults with WBV only and the control group was not exposed to any specific intervention, analyzed for results but in the fourth one, that was a 24 weeks trail, two modalities were compared that includes WBV plus squat and WBV alone, the analyzed differences between modalities were non-significant with a P<0.001 in case of balance and even more less P<0.0001 for mobility and muscle strength [33].

Muscle strength was also targeted as primary outcome of this study, direct comparison among studies was not possible because odd varying parameters and protocols followed by every study but indirect comparison and results of all the included studies have shown significant improvement in muscle strength with a p<0.05, minimum time span of progressive exposure was 6 weeks and maximum of 24 weeks, analysis have shown significant results for all studies [21,32,33].

Because mobility is the output of combined effect of increased balance and improvement in muscle strength, mobility was also analyzed for observing complex movement, among all studies p<0.005, that have shown positive effect of WBV in improving mobility among elder adults [21,25,32,33].

A closer look on the results gathered from literature indicates the importance and clinical significance of Whole body vibration but because of the novelty of therapy, only 1 out of 10 elder adults can approach the therapy and the ratio is even lesser in the developing countries. Its clinical applications cover a wide range and helps not only the elder adults in retaining their potentials that are unable to do strenuous exercises but also aid patients with debilitating conditions such as victims of stroke [38], multiple sclerosis, Parkinson's disease [39], pain management, wide range of arthritis, overstressed joints and for improving lymphatic drainage. It's not only useful in regaining health but also assists in prevention of injuries and illness by maintaining strength and balance [35]. Due to its great importance, its acceptance is evidenced by major medical and rehabilitation centers of the world and universities as Universities of Cologne, Ghent, Weimar, Aberdeen and 'The European Space Centre' (as because of lack of gravity in space, astronauts exhibit muscle atrophy, so Whole body vibration is being used to improve muscle fitness and more and more experimentation is in progress).

Regarding debate about exercise, its health benefits are highly evidenced but focusing on special cases like elder adults, stroke cases, exercise is not a practical solution, therefore Whole body vibration provides a best alternative for exercise that saves time, improves compliance and additionally benefits in regaining strength, promoting circulation, pain control, improving mobility, increasing muscle strength so, overall, it helps to improve the quality of life. The attendants will not have any hurdle in practicing this therapy, as it is home based, time saver and the patient compliance rate is 100% as evidenced by hospital based trials all the subjects have completed their therapy duration and the follow up [21,25,32,33].

Being more specific, Whole body vibration machines are properly designed, verified, validated and are of international quality following "ISO 9001:2000 EN 46003:1999 quality assurance system". Moreover, strict protocols provided by "European Directive 93/4/ECC of medical devices" are followed.

According, to the authors' opinion of the studies included, elderly adults were exposed to a wide range of therapy, with varying protocols and time span ranging from 6-24 weeks, the outcomes have indicated improvement in the muscle strength (10.7 ± 2.8 12.2 ± 4.5, P<0.0001), balance (122 ± 94 103 ± 92, p<0.001) and mobility (8.8 ± 2.1 9.6 ± 3.0) of elderly adults. So, the studies have indicated that therapy with whole body vibration have no negative effects and is an alternative for exercise in elderly adults.

Limitations and Conclusion

This is the second and advanced systematic review to search literature (2013-2017) about WBV exposure for elderly after work by Harold Merriman and Kurt Jackson 2009 on "The Effects of Whole-Body Vibration Training in Aging Adults: A Systematic Review". This review is focused on latest research work of recent years and summarized and because of day to day new inventions the previous review was outdated. Analysis was somehow limited because of less number of articles available. Furthermore, heterogeneity among studies was found, so results should be analyzed and implemented in practice with caution. Various protocols were followed and with different time spans and parameters of WBV like frequency, amplitude and time of exposure. Regarding more accuracy, homogeneity and reproducibility of WBV, minimal items for intervention should be reported clearly as frequency and type of vibration, type of amplitude and so on. Failure in reporting such important minimal parameters results in impairing comparison between studies. Despite getting significant and positive results for balance, mobility and muscle strength for elderly after exposure to WBV, caution should be taken to extrapolate these results in to clinical or home practice of therapy. Studies have shown great compliance and adherence of elderly with this intervention and maximum patients have participated in follow-up and have not skipped the sessions. No, adverse effects were found in participants exposed to WBV and it seems to be more convenient, safe, feasible way of improving health among elderly and is less time consuming also. So, this method of WBV is great to help improve physical fitness and upgrading general health in elderly as an alternative of physical activity and exercise. However, because of heterogeneity among study protocols and differences in parameters, well designed research is still required for strengthening more current evidence. In conclusion, elderly patients and their family can benefit through use of WBV therapy for improving balance, mobility, muscle strength and broadly speaking the overall health.

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