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Possible Benefits of the Whole Body Vibration in the Treatment of Complications in Stroke Patients

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Authors' contributions

This work was carried out in collaboration among all authors. Author SDSF was the corresponding author. Authors SDSF, MOBM, DNP, AA, SP, DCSC, EOGA and GAP selected the papers used in the study and prepared the tables. Author PJM read and corrected the manuscript. Author MBF did the first draft and supervised all the preparation of the manuscript. All authors read and approved the final manuscript.

Review Article

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ABSTRACT

Aims: A stroke is a neurological disorder and muscle weakness is the most prominent impairment. Whole-body vibration (WBV) is a possible modality of exercise that is useful for improving physical capacity, bone mass, balance, proprioception and the quality of life in healthy subjects and in patients with several diseases and among them, the neurological

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disorders. Considering the undesirable clinical conditions of the stroke patients, the aim of this review is to discuss about the benefits of the vibrations generated in the oscillating/vibratory platforms to those patients.
Methodology: A search was performed in the PubMed using the keywords stroke or "cerebrovascular accident" and "whole body vibration". An isolated search was performed with the term “whole body vibration”. Inclusion and exclusion criteria to select the publications were determined.
Results: It is found a limited number of publication involving WBV and the stroke with 16 articles. Of these, 9 publications were rejected for inclusion in this systematic review, due to they did not match the proposed inclusion criteria. Considering the studies that were analysed, about 57% of these have reported an improving in the clinical conditions of the stroke patients with statistical significance. Most probably the reason of the controversial results obtained with WBV findings can be attributed to the diversity of methods to measure the outcomes and the experimental design and the clinical characteristics of the subjects used, as well as the time elapsed post stroke.
Conclusion: Putting together the findings and considering the divergence of the results reported, it is suggested that the use of the vibration generated in the vibratory platform could be suitable to try to improve disorders of the stroke patients. However, it is important to consider the limited number of publications available in the PubMed involving searches evaluating the effect of the WBV in stroke patients.

Keywords: Stroke; whole body vibration; oscillating platform; neurological diseases.

1. INTRODUCTION

Neurological disorders are commonly associated with motor impairment and problems in gait, balance, voluntary muscle control (spasticity) and strength are some of the most important alterations observed in the patients. These clinical conditions contribute to low quality of life [1].

A stroke or cerebrovascular accident or brain attack is a very and serious neurological disorder. It can cause transitory and permanent damages in the brain and the death of the patient. A stroke happens due to disturbances of the blood flow in a part of the brain and the blood supply stops with a rapid loss of the brain function. Several conditions can contribute to the appearance of the stroke. If blood flow is stopped for longer than a few seconds, the brain cannot get blood and oxygen and the cerebral cells can die and in consequence, it occur a permanent damage [2].

High blood pressure, atrial fibrillation, diabetes, family history of stroke, high cholesterol, increasing age, especially after age 55, colour of the skin (black people are more likely to die of a stroke) are risk factors for strokes. Moreover, people who have heart disease or poor blood flow in their legs caused by narrowed arteries are also more likely to have a stroke. The chance of stroke is higher in people who live an unhealthy lifestyle by being overweight or obese, drinking heavily, eating too much fat or salt, smoking and taking cocaine and other illegal drugs [2].

As in other neurological disorders, muscle weakness is a common impairment after stroke. Bohannon [3] considers that for many individuals who have experienced a stroke, muscle weakness is the most prominent impairment. The reduced muscle strength is strongly related to limitations in daily activities, such as gait performance and restrictions in perceived participation [3-5]. Moreover, the prevalence of post-stroke spasticity has been reported to be as high as 39% [6]. Excessive spasticity can limit functional recovery and cause pain or contracture in stroke patients [7]. In addition, a spastic limb can also negatively impact walking ability, physical activities and gait, including a reduction in step length and cadence [8]. Some others possible complications found in the stroke patients are breathing food into the airway (aspiration), dementia, falls, bladder and bowel problems loss of mobility, loss of movement or feeling in one or more parts of the body, poor nutrition, pressure sores, problems speaking and understanding and problems thinking or focusing 2, 9,10].

Stroke rehabilitation aims to help the patient to understand and to adapt to the clinical difficulties, as well as to prevent secondary complications. It is desirable that the rehabilitation team would be multidisciplinar [11]. The physical therapist has also a relevant hole and non-invasive rehabilitation methods are currently being developed to augment physical therapy to improve motor function of stroke patients, such as transcranial magnetic stimulation and transcranial direct-current stimulation [12] and robotic therapies [13]. Treatment of spasticity related to stroke often involves early mobilizations combined with elongation of spastic muscles and sustained stretching through various positioning [14]. Electrical stimulation to the antagonist muscles or vibrations has also been used with some success [14]. Considering the motor impairment and its consequence in a patient after stroke [6-8], it would be expected important contributions to improve these clinical conditions due to the effect of vibrations generated in oscillating/vibratory platform [15-18].

As reported for several authors [15-18], whole-body vibration (WBV) generated in oscillating/vibratory platform is a possible modality of exercise that is useful for improving physical capacity, bone mass, balance, proprioception and the quality of life in healthy subjects [15,52] and in patients with several diseases and among them, the neurological disorders [18-20].

Most of the studies involving WBV reported increase in myoelectrical activity of the muscles, in muscle strength of the knee extensors, in power production during multijoint movement, as vertical jumps and walking, and reduction in body sway related to acute residual [21-24] and chronic effects of WBV [25-27]. The chronic effect of WBV was tested in athletes [25], in physically active young [21,27] or untrained young [26,28] or adult people [29,30]. Recent researches have demonstrated that WBV can improve the strength and power of elderly people applying several weeks' vibration intervention [16,17,31,32]. However, there are several studies reporting neither acute residual or chronic effects [33-35].

Considering the undesirable clinical conditions of the stroke patients, the aim of this short review is to discuss about the benefits of the vibrations generated in the oscillating/vibratory platforms to those patients.

2. MATERIALS AND METHODS

2.1 Databank Used in This Study

PubMed online database was searched on January 15th 2013. It comprises more than 22 million citations for biomedical literature from MEDLINE, life science journals and online books. Citations may include links to full-text content from PubMed Central and publisher web sites [36].

2.2 Search Strategy Used to Find the Publications

A search was performed using the keywords stroke or "cerebrovascular accident" and "whole body vibration". An isolated search was performed with the term “whole body vibration”. Searches were also done with the keywords related to neurological diseases, as (i) stroke, (ii) “cerebral palsy”, (ii) “Alzheimer disease”, (iii) “multiple sclerosis” and (iv) “Parkinson´s disease”.

2.3 Inclusion and Exclusion Criteria to Select the Publications

Papers were included for review and discussion if (i) they met the search criteria and described a study using whole body vibration generated by an oscillating/vibratory/platform used to treat people with stroke, (ii) they were available in English.

Review manuscripts were excluded, as well as, that have used animals in the investigation. Papers were selected by two independent experts and potential disagreements were resolved through mutual consensus.

3. RESULTS

Fig. 1 shows the process by which the publications were selected for discussion and to be analysed in this investigation. Among some neurological disorders, it is possible to verify an important interest in the investigations about stroke in comparison with “cerebral palsy”, “Alzheimer disease”, “multiple sclerosis” and “Parkinson´s disease”. A scientific interest about the “whole body vibration” is also shown, however, it is only found a limited number of publication involving this vibration and the stroke with 16 articles. Of these, 9 publications were rejected for inclusion in the systematic review, due to they did not match the proposed inclusion criteria. Of these, one was performed with animal [37], 2 (two) were written in languages, Russian [38] and German [39] other than English and one was a revision [1]. Moreover, one publication was involving a combined vibration therapy and strategic balance training was also not considered [40] and another one was about a experimental design (algorithm) [41]. Three papers were performed with health patients [42-44]. A total of seven articles were identified for inclusion in the current systematic review.

Considering the selected articles, in Table 1 are presented the aim of each study, the platform manufacturer, the oscillating frequency and amplitude of the vibration and the main outcome measures. The aims of all the papers are related to the effect of the vibration generated in oscillating platform in stroke patients. The type of the platform is mainly related to a side-alternating way, while the right foot is lower, the left foot is higher and vice versa. The frequencies used in the studies ranged from 12 up to 30 Hz and the amplitudes were from 0.44 up to 5 mm. The main outcome measures were Isokinetic and isometric knee muscle strength (IIKMS) [45-47], Timed Up and Go (TUG) [46,48] and Berg Balance Scale (BBS) [45,46,49], 10-meter walk test (10mWT) [45,48], 6-min walk test (6mWT) [45,46] and electromyography (EMG) of the vastus lateralis [47,50].

Descriptions of the type of platform, the subjects (number, sex, and age), the frequency and the amplitude used in the oscillating platforms used in the 8 selected studies are shown in Table 1.

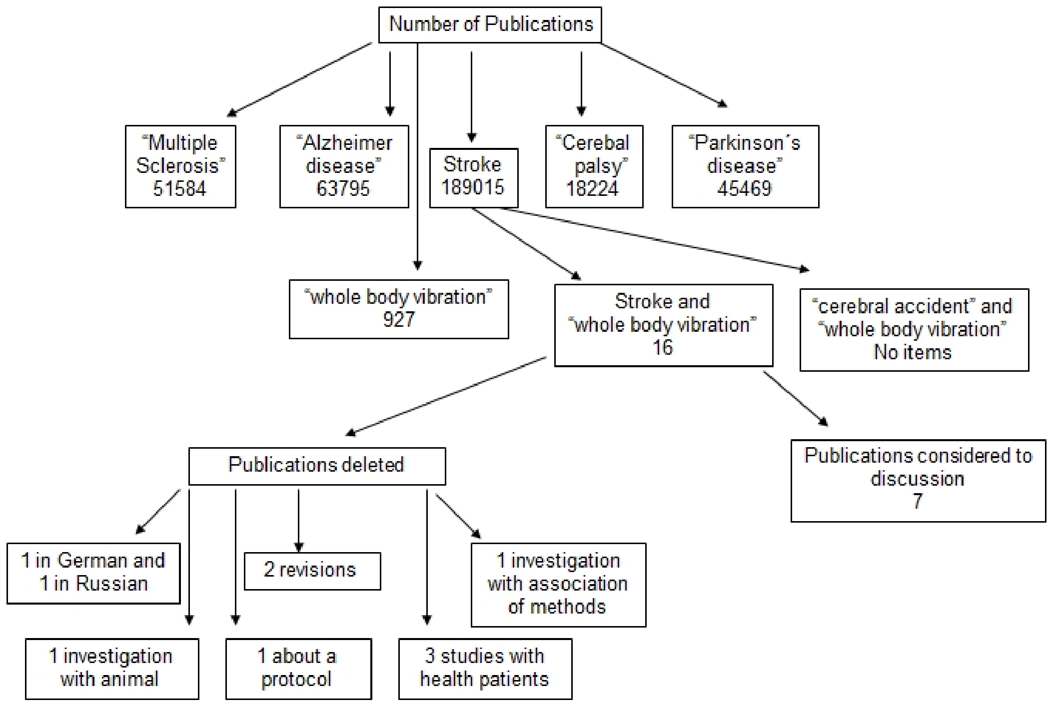

Fig. 1. Process by which the publications were selected to this current investigation

The number of participants, the experimental design used, the main findings and the conclusions of the authors of the selected papers are shown in the Table 2. Putting together the information found in the analyzed papers, the numbers of subjects were ranging from 16 to 82. Moreover, two of the studies had no control groups. An important finding is related to the conclusions of the authors. It is concluded, considering the results obtained in four of the seven papers evaluated, that the WBV may be a promising tool to try to improve some clinical conditions, as the proprioceptive control of posture in stroke patients.

Table 1. Type of platform, the aim, the frequency and the amplitude used in the oscillating platforms used in the 7 selected studies

Reference	Aim	Platform manufacturer	Oscillating frequency and amplitude	Main Outcome Measures
Brogårdh et al, 2010 [46]	To evaluate the effects of WBV training in individuals after stroke.	VP (Xrsizeb; vertical vibrations).	25 Hz an amplitude of 3.75mm.	IIKMS, balance (BBS), muscle tone (Modified Ashworth Scale), gait performance (TUG, comfortable gait speed, fast gait speed, and 6mWT), and perceived participation (Stroke Impact Scale).
Tihanyi et al, 2010 [47]	To investigate the chronic effect of low frequency WBV on IE strength of knee extensors with different force exertion capacity.	VP called Nemes Bosco-system (OMP, Rieti, Italy).	12 up to 20 Hz, and the amplitude of 5 mm	IIKMSK and myoelectrical activity (EMG) of the vastus lateralis.
van Nes et al, 2006 [49]	To study the effects of 6-weeks WBV on postural control and daily activities compared with 6 wk of exercise therapy on music of the same intensity in the postacute phase of stroke.	Galileo 900, Galileo 2000, Enschede, The Netherlands	30-Hz frontal plane oscillations of 3-mm amplitude	BBS, Trunk Control Test, Rivermead Mobility Index, Barthel Index, Functional Ambulation Categories, Motricity Index, and somatosensory threshold at 0, 6, and 12 wk follow up.
Chang et al, 2012 [48]	To investigate the effects of a single session of WBV training on ankle Plantar flexion spasticity and gait performance in SP.	Vertical WBV (AV-001, Bodygreen, Taiwan)	12 Hz and an amplitude of 4 mm.	The spastic changes were measured clinically and neurophysiologically. Subjective evaluation of ankle spasticity was performed via a visual analogue scale. Gait performances were evaluated by the TUG test, 10mWT and cadence.
Lau et al, 2012 [45]	To examine the efficacy of WBV in optimizing neuromotor erformance and reducing falls in chronic SP.	Vertical (synchronous) WBV signals were delivered by the Jet-Vibe System(Danil SMCCo. Ltd., Seoul, South Korea).	frequency from 20 up to 30 Hz and amplitude from 0.44 up to 0.60 mm,	Balance (BBS), mobility (10mWT and 6mWT), IIKMS, and fall-related self-efficacy (activities-specific balance confidence scale) were assessed at baseline, after the 8-wk training and at 1-month follow-up.
Tihanyi et al, 2007 [50]	To determine the effect of WBV on IE torque and EMG of knee extensors on the affected side of SP	Nemes–Bosco vibration platform (OMP, Rieti, Italy).	20 Hz vibration and amplitude of 5 mm	Maximum IE torque, rate of torque development, root-mean-squared EMG, median frequency of vastus lateralis, and co-activation of knee flexors.
van Ness et al, 2004 [51]	Tho verify the effects of WBV on postural control in SP.	(Galileo 900, Galileo2000, Enschede, The Netherlands)	30-Hz oscillations at 3 mm of amplitude in the frontal plane.	Postural control and symmetry were assessed in terms of center-of-pressure movement.

Whole body vibration- WBV, Electromyography – EMG, Timed Up and Go – TUG, 10-meter walk test – 10mWT, 6-min walk test – 6mWT, Berg Balance Scale- BBS, IIKMS - Isokinetic and isometric knee muscle strength, Stroke patients – SP, IE - isometric and eccentric

Table 2. Number of participants, the experimental design used, the main findings and the conclusions of the authors of the selected papers

Reference	Participants and time after the stroke	Experimental design	Results	Conclusions
Brogårdh et al, 2010 [46]	Participants (N=31; age 62±7y) were divided in intervention group (IG) (13 man and 3 woman) or a control group (CG) (12 man and 3 woman).	WBV training (2 sessions/wk for 6wk; 12 repetitions of 40–60s WBV per session). IG trained on a VP (amplitude 3.75mm) and the CG on a placebo" VP (0.2mm amplitude). Frequency was 25Hz on both VP.	There were no significant differences between the 2 groups after the WBV training. Significant but small improvements ($P<0.05$) in body function and gait performance were found within both groups.	WBV training on a VP was not more efficient than a placebo VP. The use of WBV in individuals with chronic stroke and mild to moderate disability is not supported.
Tihanyi et al, 2010 [47]	The subjects were randomly assigned into two groups, i.e. IG (n=10) and CG (n=10). Each group with 4 female and 6 male. Age was 58.0±4.9 years (IG) and 57.7±8.2 (CG).	IG received WBV with 20 Hz frequency 3 times/wk standing on a VP (half squat position) meanwhile flexing and extending the joints and placing the weight from one leg to the other. Knee extensor strength was determined under IE contraction before and after WBV intervention. Myoelectrical activity (EMG) of the vastus lateralis muscle was measured.	Significant improvement was in the IG only. Maximum isometric torque and EMG activity increased significantly for both paretic and non-paretic leg, but the improvement was threefold greater in the IG. No significant alteration was found in rate of torque development. Maximum eccentric torque and EMG increased significantly for the paretic leg only. Mechanical work enhanced significantly in the paretic side only.	Low vibration frequency intervention can increase the strength in weak muscles due to neuromuscular impairment and restricted physical activity.
van Nes et al, 2006 [49]	Fifty-three patients were in WBV group (n=27, 16 male and 11 female) or the ETM group n=26, 14 male and 12 female).	Patients were treated with either WBV or exercise therapy on music (ETM) during 6 wk. Treatments consisted of 4 sessions of 45 seconds stimulation with a 1-min break. ETM was a "sham" treatment.	At baseline, both groups were comparable in terms of prognostic factors and outcome measures. Both at 6 and 12 wk follow up, no statistical differences in outcome were observed in the groups.	Daily sessions of WBV during 6 wk are not more effective in terms of recovery of balance and activities of daily living than the same amount of ETM in the postacute phase of stroke.
Chang et al, 2012 [48]	Thirty subjects were randomized into either a CG (n = 15, 10 men and 5 female) or an IG (n=15, 11 male and 4 female).	IG was treated with WBV while CG was treated with placebo. The subjects were positioned on the platform in a semi-squatting position. The time included two 10-min periods of vibration with a 1-min rest interval. In CG, the vibration machine was not turned on.	Changes between IG and CG were significantly different in Modified Ashworth Scale. The Hmax/Mmax ratio and visual analogue scale were significantly decreased. WBV could significantly improve gait velocity, timed TUG test and 10mWT. The uneven body weight posture on bilateral feet was also improved after vibration.	The results suggest that a single session of WBV training can reduce ankle plantarflexion spasticity in chronic SP, thereby potentially increasing ambulatory capacity.

Table 2. continued ....

Lau et al, 2012 [45]	82 chronic stroke patients were randomly assigned to either the IG or CG.	IG received 9–15 min of WBV while performing a variety of dynamic leg exercises on the vibration platform. The CG performed the same exercises without vibration. The subjects underwent their respective training three times a week for 8 wk.	Intention-to-treat analysis revealed similar significant improvement in all balance, mobility, muscle strength, and fall-related self-efficacy measures in both groups after the 8-wk treatment period (P<0.001), and these were maintained at the 1-month follow-up. The incidence of falls did not differ between the two groups (P> 0.05).	The addition of the presently used WBV on paradigm to a leg exercise protocol was no more effective in improving neuromotor performance and reducing the incidence of falls than leg exercises alone in chronic SP who have mild to moderate motor impairments
Tihanyi et al, 2007 [50]	Sixteen patients (age 58.2 ±9.4 years)	8 patients assigned to the IG were standing on a vibration platform for 1 min six times in one session. Patients in the CG also stood on the platform but did not receive vibration.	IE knee extension torque increased in the IG. Vibration increased EMG amplitude and the median frequency in the vastus lateralis in IG. Vibration improved the ability to generate mechanical work during eccentric contraction and reduced biceps femoris co-activation during IE contraction.	These results suggest that one bout of WBV can transiently increase voluntary force and muscle activation of the quadriceps muscle affected by a stroke.
van Ness et al, 2004 [51]	23 ischemic SP (13 men, 10 women; age 58.1± 11.4 yrs) with a poststroke interval of at least 6 mos (mean interval 23.3 ±11.4 mos). 23 healthy controls (age 63.9 ± 9.3 yrs) were in the CG.	All patients were subjected to one series of four consecutive assessments of 45-sec WBV with a 1-min pause between administrations.	Results indicated a stable baseline performance from the 1st to the 2nd assessment for all tasks. After WBV, the 3rd assessment demonstrated reduction in the RMS center-of-pressure velocity in the anteroposterior direction when standing with the eyes closed (persisted during the 4th assessment). Patients showed an increase in their weight-shifting speed at the 3rd balance assessment while precision remained constant.	It is concluded that WBV may be a promising candidate to improve proprioceptive control of posture in SP.

Whole body vibration- WBV,Intervention group – IG, root mean square (RMS), control group- CG, week – wk, vibration platform – VP, IE - Isometric and eccentric

4. DISCUSSION

Several training procedures have been used with the expectance to improve lower-extremity function in patients after stroke. WBV exercises have been suggested to be an alternative form of training to these patients and it has been hypothesized that the vibrations generated in vibration platform could initiate muscle contractions by stimulating the muscle spindles and the alpha motor neurons.[4]. Although these WBV exercises have been used successfully to treat several disorders [3,18,32,42] and among them, neurological diseases [19,20], the number of the publications involving WBV and stroke is strongly limited. In the PubMed only seven papers are found involving WBV and stroke (Fig. 1).

Following, the findings of the selected papers are discussed, however, there are some study limitations and it is extremely difficult to compare investigations involving such a variability of methods of inclusion, assessment and therapeutic. Moreover, it would always be preferable, if and when possible of course, to compare studies homogeneous in terms of types of patients included, rating scales and treatment protocols. In addition, the main findings of the selected papers are indicated, trying to show the importance of the vibrations generated in oscillating platform in improving the clinical conditions of the stroke patients.

Considering the studies that were analysed, about 57% of these have reported an improving in the clinical conditions of the stroke patients with statistical significance. Most probably the reason of the controversial results obtained with WBV findings can be attributed to the large diversity of the methods to measure the outcomes and the experimental designs and the clinical characteristics of the subjects used, as well as the time elapsed post stroke. Furthermore, the length of training, intensity, frequency or amplitude setting has been different among the selected papers. Naturally, the number of the patients used in the investigations has also contributed to the results in the analysed papers.

Important improvements related to the musculoskeletal system in the stroke patients were reported. Some of these improvements have reached a significant difference between the patients of the investigated group in comparison to the patients of the control group. Tihany et al [50] have reported that the vibrations generated in the vibratory platform have increased the Isometric and eccentric knee extension torque. This increase has been also found to the EMG amplitude and the median frequency in the *vastus lateralis* in the stroke patients. In addition, the vibration improved the ability to generate mechanical work during eccentric contraction and reduced biceps femoris co-activation during isometric and eccentric contractions. Tihany et al [50] have described significant improvement in the stroke patients treated with WBV. The maximum isometric torque and EMG activity (as previously published by Tihany et al [50] increased significantly for both paretic and non-paretic leg. Maximum eccentric torque and EMG increased significantly for the paretic leg only. Mechanical work enhanced significantly in the paretic side only. Studies published by Lau et al [45] have revealed similar significant improvement in all balance, mobility, muscle strength, and fall-related self-efficacy measures in both groups after the 8-wk treatment period. Moreover, these improvements were maintained at the 1-month follow-up. Chang et al [48] have reported that the WBV could significantly improve gait velocity, timed TUG test and 10mWT. Moreover, the uneven body weight posture on bilateral feet was also improved after vibration.

Physical inactivity is associated with an increased risk of stroke and an increase of the physical activity may decrease the risk of stroke [51]. Furthermore, the physical activity is also known to have a positive effect on control of blood pressure and diabetes, two highly relevant risk factors for stroke. Considering the effects of the WBV exercises, it would be interesting to consider these exercises, as physical activity, to aid in the prevention of stroke.

5. CONCLUSION

Putting together the findings described in this study and considering the divergence of the results in the publications, it is possible to conclude and to suggest that the use of the vibration generated in the vibratory platform could be suitable to try to improve some disorders of the stroke patients. However, it is important to consider the limited number of publications available in the PubMed involving searches evaluating the effect of the WBV in stroke patients

CONSENT

It is not applicable in our paper.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Not applicable.

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