

THE EFFECT OF WHOLE-BODY VIBRATION ON BALANCE IN ELDERLY WOMEN

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Abstract

Introduction: Injuries resulting from a fall incident have been documented as a leading cause of trauma in elderly adults in the United States. In activities of daily living balance and postural control have significant roles in the elderly population. Anecdotal evidence suggests that there may be a direct relationship between a decrease in balance and sarcopenia in elderly populations.

Objective: To investigate the acute effect of whole body vibration (WBV) on balance measures in elderly women.

Methods: Fifteen women (age 63 ± 5 years) completed two sessions consisting of a familiarization session and pre/post tests on measure of functional balance before and after an intervention of a WBV treatment. Twenty-four *t*-tests compared pre and post measures for Medial/Lateral Root Mean Square (ML-RMS) sway, Anterior/Posterior Root Mean Square (AP-RMS) sway, ML sway velocity, AP sway velocity for each of the six conditions on the Sensory Organization Test (SOT). Six *t*-tests compared pre and post measures for latency on the MCT.

Results: Statistical significance ($P < 0.05$) was found within the participants and main effects for condition were seen in the eyes closed (EC, ECSRS) and the eyes open (EOSRVS) conditions for both anterior/posterior and medial/lateral conditions.

Conclusions: Acute WBV exposure statistically significantly altered sway measures in elderly women. Functional trends were identified with regards to reduced reflex mediated correction. There may be a potential timing effect between the final WBV exposure and balance testing, where a longer time period may be needed.

Key words: elderly women, balance, gait, postural control

Introduction

Balance has a significant role in the activities of daily living in the elderly population. Since falls contribute a significant number of injuries in the elderly [1], the risk of falling is even higher when the elderly have to ambulate a complex and unfamiliar environment [2]. Balance requires a high level of cognitive neural function and an intact neuromuscular system with afferent information from vision, vestibular, musculoskeletal and somatosensory systems [2-4].

Postural sway is induced as result of the constant adjustments and activation of the postural muscles in an attempt to keep the center of pressure (CoP) within the center of the base of support (BoS) [5]. Sway velocity determines the rate of this compensation and root mean square (RMS) gives the amount of compensation needed to maintain the CoP within the center of the BoS and thereby effectively maintain balance. Higher values of velocity and RMS indicate decreased postural stability and balance as they imply larger angular changes in the location of the CoP [5]. These two measures are used as they provide different characteristics of postural sway. An increase in postural sway can be an indicator for impairment of postural control

as a result of functional instability [6] and it has been shown that an increased sway is strongly associated with increased frequency of falls [7,8]. The age related decline in impairments in physical functioning [1] and an increase in cases of chronic health problems such as sarcopenia, cardiovascular disease, osteoporosis, and neuromusculoskeletal disorders is well known.

The integration and organization of the visual, vestibular, somatosensory systems, a higher level of cognitive control and an intact musculoskeletal system is responsible for the maintenance of balance [3,4]. Static postural stability refers to the control of the center of mass relative to the base of support under unperturbed conditions, whereas dynamic postural stability is the same under perturbed conditions. Balance declines with age due to reductions in both the available muscle mass and neurological adaptations to aging [1,9]. Musculoskeletal components, such as strength, flexibility, range of motion, tone, timing and coordination have been reported to decrease with age. The decline in cognitive control and sensory systems combined with the impaired musculoskeletal system renders the postural control system less effective among the elderly [10-15]. Therefore, static and dynamic postural stability may

be impaired and maintenance of balance in activities of daily living may be compromised.

Whole-body vibration (WBV) has been used as a facilitator of muscle activation with mixed success. Some studies have shown acute enhancement, while others have reported no improvement or a reduced performance [16-20]. Nevertheless, WBV has been shown to activate the tonic vibration reflex, a polysynaptic reflex resulting in many small reflex contractions of the targeted musculature [16,17,19-22]. In relation to balance, WBV may aid in spindle reflex responses, where dynamic stability is predominately dependent on the somatosensory system. The main mechanisms cited for acute improvements in ballistic type performance following vibration exposure are an increased sensitivity of the stretch reflex coupled with an increased synchronization of higher threshold motor units [15-17,19,20,22-24]. Increases in force, power output, and RFD have previously been reported following acute exposure to WBV [16-20,25] and these increases may be related to better maintenance of dynamic balance among older adults. With higher values of RFD, the latency time to maintain dynamic balance may be lowered, thus helping in a faster recovery from an external perturbation, resulting in better balance.

When WBV is used as a training modality to elicit chronic adaptations, older participants appear to respond more favorably when compared to their younger counterparts, possibly due to their lower relative training state or decreased motorneuron activity prior to incorporating WBV training [10-14]. The majority of acute research using WBV has been performed using younger males and females with increasingly variable responses seen with older subjects [10-14,16-21,25]. Acute exposure to WBV in older subjects may ultimately stimulate key elements of central and peripheral nervous system control. This may result in positively altered force/velocity characteristics, reflex control and proprioceptive regulation, leading to improvements in walking gait and functional balance. These elements may be altered since static and dynamic postural control requires less cognitive control and becomes challenging during dual tasks where they are competing for the same information processing pathways, resulting in a decrement in performance. Therefore, the purpose of this study was to determine the effect of acute WBV in elderly women on balance.

Methods

Participants

Fifteen post menopausal women (age: 68.3 ± 5 years) with no history of clinically significant or disabling muscular, orthopedic, cardiovascular, metabolic, or neurological conditions, who have the ability to walk and stand independently, and who are not taking any CNS-depressant drugs completed the

study. Participants were screened and deemed eligible to participate in the study if they were able to complete the American Academy of Neurology's up and go test 3 times successfully (less than 8.5s) [26].

Testing and Procedures

Participants were asked to visit the lab on 2 separate occasions, separated by 48 hours. The first session was considered the qualifying and familiarization while the second visit was the testing session.

Lab visit one

Visit one served as a screening and familiarization session. Each participant read and signed the intuitively approved informed consent document. Anthropometrics were recorded followed by a five-minute cycle ergometer warm-up at a self-selected pace followed by a seated three-minute rest. Following warm-up the qualifying up and go tests were recorded; upon qualification participants were then familiarized with WBV protocol and balance protocol.

Lab visit two

Following at least 48 hours, participants returned for their second visit. Participants again warmed up on a cycle ergometer for five minutes. Following a three-minute seated rest, the participants were tested for each of the balance measures (described below in Functional Balance Assessment section). The participants then had five minutes of seated rest before they were exposed to the vibration protocol treatment. Immediately following the last vibration treatment, the participants performed the same functional balance measures as pre-treatment measures.

Whole Body Vibration

The treatment utilized the AIRdaptive (Power Plate, Inc.), composed of a 33" x 33" flat platform fixed to a stable handle. The vibration platform produces tri-axial accelerations with a primary emphasis upon the z-plane. Participants were instructed to stand in a quarter squat position with their feet flat, positioned shoulder width apart with their toes pointing slightly outward. Their knee joint angles were corrected to $135 \pm 5^\circ$ of flexion for optimal vibration exposure to the lower-body. Participants maintained this position by holding on to the central support handles. For each experiment participants underwent 3 trials of 20 seconds each of WBV exposure at a frequency of 30 Hz and low amplitude of 2-4 mm, with a 60 seconds rest period between each exposure.

Functional Balance Assessment

Balance assessment was done on the NeuroCom® Equitest System™ (NeuroCom, Inc., Clackamas, OR). The system utilizes a dynamic 18" x 18" dual force plate

and a visual surround, both with rotational and transitional capabilities to measure the vertical forces exerted by the subject's feet as balance is challenged. The Sensory Organization Test (SOT) was used to assess static balance and the Motor Control Test (MCT) for assessing dynamic balance. The SOT is based on the sensory conflict hypothesis, in which the individuals are challenged with conflicting unreliable visual and proprioceptive sensory information using the sway referencing visual surround and support of the Neurocom Equitest and thereby creating six sensory testing conditions. 1) eyes open (EO) and 2) eyes closed (EC) with no sway reference of the support and the visual surround, 3) eyes open with sway referenced vision (EOSRV) and 4) sway referenced support (EOSRS), 5) eyes closed with sway referenced support (ECSRS) and 6) eyes open with sway referenced vision and support (EOSRVS). The experimental conditions used the Sensory Organization Test (SOT) incorporating the sway-referencing capabilities of the platform (support) and the visual surround (vision) to produce six balance testing conditions: standing with 1) eyes open (EO) and 2) eyes closed (EC) with no sway reference of the support and the visual surround, 3) eyes open with sway referenced vision (EOSRV) and 4) sway referenced support (EOSRS), 5) eyes closed with sway referenced support (ECSRS) and 6) eyes open with sway referenced vision and support (EOSRVS). The MCT was performed following the SOT, which based on automatic postural responses in response to an external perturbation. This consisted of sequences of small, medium or large platform translations which were scaled to the patient's height, in forward and backward directions to elicit automatic postural responses. The SOT lasted for 3 trials of 20 seconds each and the MCT lasted for 10 seconds for each of the translations. Forces were recorded to estimate center of pressure for sway analysis during the testing conditions. A harness system was used to prevent injury from falling during all testing [5,27].

Data processing

SOT: The values of the dependent sway variables were derived from the Center of Pressure (CoP) movement, which were calculated from the raw data from the NeuroCom Equitest Balance Master. The average sway velocity and the root-mean-square (RMS) of the CoP were used to characterize the postural sway in the AP and the ML directions during the 60-second testing period. Sway velocity in particular is a measure of the peak-to-peak change of the CoP per unit time. The RMS sway, which is used as a rectifying measure, estimates the amplitude of sway and the overall amount of movement of the CoP. The Sway RMS and velocity were calculated using the following equations respectively.

MCT Data Processing: The MCT assesses the ability of the automatic motor/postural response system to quickly recover following an unexpected external disturbance. The external disturbances are administered by forward and backward translations scaled to the height of the participant and this measurement allows for a dynamic measure of balance. MCT records latency responses, which is a measure of how long it takes to restore normal balance following an unexpected perturbation. While static stability is a measure of balance under un-perturbed conditions, dynamic stability tests are under external perturbations, similar to those that normally arise from the external environment and with failure to restore balance, potentially lead to an increased risk of fall rates.

Statistical analysis

All statistical procedures were conducted using the PASW 18.0 (SPSS, Inc., Chicago, IL). An *a-priori alpha* was set at 0.05 to determine statistical significance. Twenty-four paired sample *t*-tests were performed to determine if differences existed between the pre and post measures for each of the six conditions (RMS sway, sway velocity in the A/P and M/L direction) during the SOT. Six paired sample *t*-tests were performed to determine if differences existed between the pre and post measures of latency during the six MCT conditions. Bonferroni correction of alpha was not used for each *t*-test since each test was an independent measure of balance.

Results

Statistically significant differences ($P < 0.05$) were found in the main effects of balance dependant variables. Significant differences existed in the EC, ECSRS and EOSRVS among the six SOT balance conditions for RMS sway and sway velocity in both the anterior-

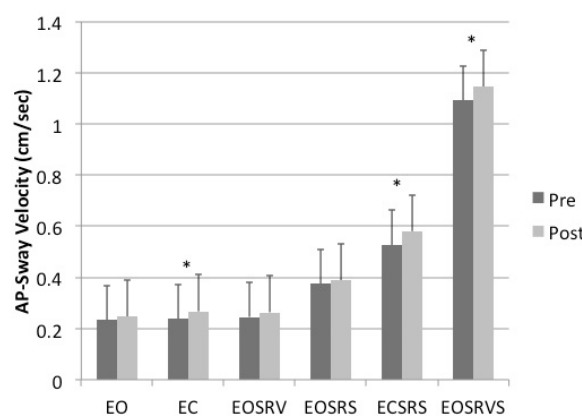


Fig. 1. Means and standard error for anterior/posterior sway velocity between pre and post in all six conditions. Eyes open (EO), eyes closed (EC), eyes open with sway referenced vision (EOSRV), eyes open with sway referenced support (EOSRS), eyes closed with sway referenced support (ECSRS) and eyes open with sway referenced vision and support (EOSRVS). Significant differences between pre and post are indicated by an *.

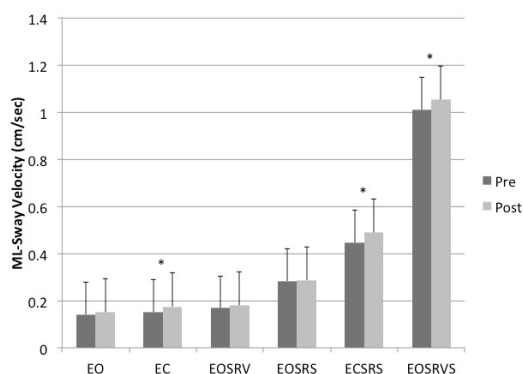


Fig. 2. Means and standard error for medial/lateral sway velocity between pre and post in all six conditions. Eyes open (EO), eyes closed (EC), eyes open with sway referenced vision (EOSRV), eyes open with sway referenced support (EOSRS), eyes closed with sway referenced support (ECSRS) and eyes open with sway referenced vision and support (EOSRVS). Significant differences between pre and post are indicated by an *.

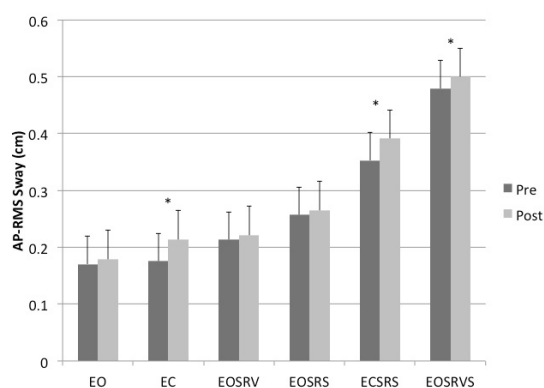


Fig. 3. Means and standard error for anterior/posterior RMS sway between pre and post in all six conditions. Eyes open (EO), eyes closed (EC), eyes open with sway referenced vision (EOSRV), eyes open with sway referenced support (EOSRS), eyes closed with sway referenced support (ECSRS) and eyes open with sway referenced vision and support (EOSRVS). Significant differences between pre and post are indicated by an *.

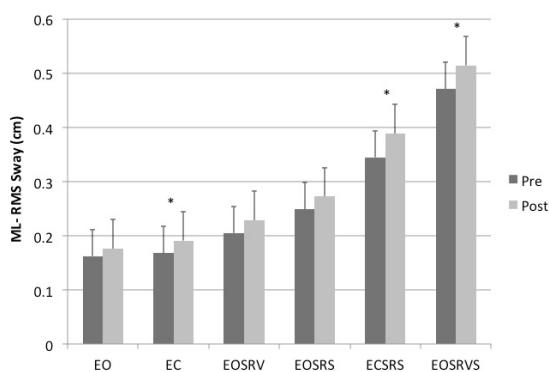


Fig. 4. Means and standard error for medial/lateral RMS sway between pre and post in all six conditions. Eyes open (EO), eyes closed (EC), eyes open with sway referenced vision (EOSRV), eyes open with sway referenced support (EOSRS), eyes closed with sway referenced support (ECSRS) and eyes open with sway referenced vision and support (EOSRVS). Significant differences between pre and post are indicated by an *.

posterior and medio-lateral directions (AP & ML RMS and AP & ML sway velocity). There were no statistically significant ($P > 0.05$) differences found for the pre and post test measures between all other conditions in the SOT (Fig. 1-4). There were no statistically significant ($P > 0.05$) differences found between the pre and post test scores among the lactency measures for dynamic stability.

Discussion

This study investigated balance in elderly women following WBV exposure. The major findings were that following WBV there was an increase in AP and ML RMS sway and sway velocity for EC, ECSRS, EOSRV conditions from pre to post. To our knowledge, this study is the first study to illustrate possible adverse effects in balance immediately following WBV. This may be a concern for elderly populations as it could be an obstacle in administration of WBV. A recent study by Carlucci et al. found no difference between pre and post measures in balance following vibration [28]. However, their balance assessment did not test multiple systems, they used a posturographic protocol, whereas our study that utilized the NeuroCom Balance Master which tested somatosensory, vision and vestibular systems to determine balance. This may explain the contradictions in results, as Carlucci et al. only assessed static balance. Another consideration for our study is that in the pre condition, we did not have participants perform static squats with no vibration for a better comparison, however previous research has shown no difference in balance measures following static squats alone [29].

In our study, acute WBV exposure significantly altered sway measures in this population immediately post vibration exposure. The statistically significant results for AP and ML sway velocity and sway RMS was found in EC, ECSRS and EOSRVS conditions. The EC is tested with absent vision and is a measure of the vestibular and somatosensory systems to maintain balance. The ECSRS is tested with absent vision and conflicting somatosensory information, which measures the vestibular system in maintaining balance. The EOSRVS condition measures the vestibular system in maintaining balance with conflicting somatosensory and visual information. Therefore results suggest a decrement in balance performance when vision is compromised and when the vestibular system alone works to maintain balance following WBV. A possible explanation for this may be that the WBV affects the vestibular system, which is why conditions 5 and 6 of the SOT were compromised. It is possible the vestibular system was affected by transmission of vibration to the head [30] however, not likely since participants knees were flexed, allowing for vibration exposure to be disbursed throughout the musculature in the body.

Although the current study found a decrement in balance following WBV, these results are in contrast with other studies where balance was found to be significantly better for the WBV group when compared to the control group [3]. Researchers also concluded that benefits of WBV may be obtained after longer or more intensive training programs [10]. This was also supported by an investigation showing beneficial effects in the elderly population with WBV exercise in addition to muscle strengthening, balance and walking exercises on walking ability [14]. Acute WBV has previously been shown to improve power output, muscle strength and flexibility, which are all important components of postural control, but not analyzed in the current study [16-20,31].

Previous research also investigated the effects on balance following WBV as a training intervention and no differences were found between the vibration and control group on postural sway at 2 and 4 month test sessions [32]. Another study examined pre balance assessed by RMS and peak-to-peak amplitude of postural sway both in the AP and ML direction did not differ after 6 months of WBV training [33]. Although the current study did not investigate WBV chronic training intervention, it is important to note that WBV training over an extended period of time may not affect balance measures in the same way as acute WBV training. This indicates that there may be different effects of acute WBV compared to chronic WBV exposure. In chronic WBV training, individuals usually are exposed to a larger training volume over an extended period of time and tested in weekly intervals where acute WBV training balance is assessed immediately or within a short time frame. This ultimately suggests that acute and chronic WBV training likely elicit different responses.

Recovery time between WBV exposure and balance tasks also needs to be addressed and investigated further, as existing theory currently suggests that longer rest times are necessary to result in participants' improvement balance tasks such as the SOT and MCT. Performing multiple balance assessments at distinct time points following WBV exposure may provide additional helpful data concerning residual effects of WBV as recovery time is a key variable especially to this population. For instance, if an older individual utilized WBV for other known benefits previously mentioned, a sufficient time after exposure may be necessary to prevent slips or falls due to an increase in AP and ML sway velocities. If sway velocities are increased, this may increase instability, indicating that older women may want to take precautions immediately following WBV.

WBV has been shown to cause a tonic vibration reflex, which in turn leads to an increase in the recruitment of motor units through activation of muscle spindles and polysynaptic pathways [34]. A potential mechanism to explain our findings may relate to the

increase in muscle spindle activation induced by the tonic vibration reflex (TVR) mediated by the neural signal of the Ia afferents [35] and activation of muscle fibers via large alpha-motoneurons. Following WBV, a decrease inhibition from the alpha motoneuron may occur, increasing muscle spindle activation. The increase in muscle spindle activation may potentiate an increase in force production causing an increase in sway velocity. If an individual's sway velocity is increased from exerting too much force, this may make it difficult to maintain proper balance.

Future research should investigate the interaction between balance and muscle spindles, which play a part in both ankle and hip strategies of postural control. Also, research is needed with respect to varied frequencies, amplitude, durations, rest intervals and platform type, of WBV exposures in combination with multiple balance assessments to track the "residual" effects of WBV upon functional balance. More research is also warranted in chronic interventions utilizing static and dynamic exercises performed on the WBV platform with and without additional loading to improve; strength, power output, rate of force production and functional balance.

Declaration of interest

The authors report no conflicts of interest.

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Accepted: March 18, 2014

Published: March 27, 2014

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Authors' contribution

A – Study Design

B – Data Collection

C – Statistical Analysis

D – Data Interpretation

E – Manuscript Preparation

F – Literature Search

G – Funds Collection