Influence of Whole Body Vibration Platform Frequency on Neuromuscular Performance of Community-Dwelling Older Adults

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Abstract

Furness, TP and Maschette, WE. Influence of whole body vibration platform frequency on neuromuscular performance of community-dwelling older adults. *J Strength Cond Res* 23(5): 1508–1513, 2009—The purpose of this study was to progressively overload vibration platform frequency to describe sea-saw whole body vibration influence on neuromuscular performance of community-dwelling older adults. Seventy-three community-dwelling older adults (aged 72 $\pm$ 8 years) were randomly assigned to 4 groups (zero, one, 2, and 3 whole body vibration sessions per week). Quantifiers of neuromuscular performance such as the 5-Chair Stands test, the Timed Up and Go (TUG) test, and the Tinetti test were recorded. Furthermore, Health-related quality of life was qualified with the SF-36 Health Survey. A 6-week whole body vibration intervention significantly improved the quantifiers of neuromuscular performance in a community-dwelling older adult sample. Whole body vibration was shown to significantly reduce time taken to complete the 5-Chair Stands test ($p < 0.05$) and the TUG test ($p < 0.05$). Tinetti test scores significantly improved ($p < 0.05$). as did all components of health-related quality of life ($p < 0.05$). Overall, progressively overloaded frequency elicited more beneficial improvement for the 3 whole body vibration sessions per week group. It was concluded that progressively overloaded frequency was effective in improving quantifiable measures of neuromuscular performance in the sample and that practitioners may confidently prescribe 3 whole body vibration sessions per week with more precise knowledge of the effects of whole body vibration on neuromuscular performance and health-related quality-of-life effects.

Key Words platform dynamics, progressive overload,

Introduction

Whole body vibration (WBV) is a mode of exercise by which one stands on a vibration platform that may be oscillating, therefore creating vertical displacement that affects gravitational forces acting on the whole body (1). During WBV, changes in gravitational conditions are produced by the vibrations of machinery (ie, vehicles and vibration platforms) (1). Gravity is a component of WBV because the product of amplitude and frequency is acceleration (Eq 1). Manipulations of amplitude or frequency can affect the rate of change of the WBV (ie, acceleration) acting on an individual. Thus, the gravitational forces acting on the body are varied in most WBV environments (ie, recreational and occupational). Because the position of the whole body in space is changing, a role of the neuromuscular system during WBV must be to perceive and attenuate changes in body position for optimum performance and/or comfort.

With vibration platforms, WBV improved functional measures of neuromuscular performance such as jump height (1,9), chair rising time (22), health-related quality of life, and gait (4). Specifically, leg press average velocity, average power and average force (2,3), neuromuscular efficiency (3), motor unit recruitment (18), and increased VO_2 to the equivalent of moderate walking occurred after WBV (17,19).

Typically, the WBV was transmitted with vibration platform frequencies between 10 and 40 Hz and vibration platform amplitude between 2.5 and 5.0 mm. The gravitation force created in WBV investigations has been as low as $0.1g$ (21) and as high as $25.7g$ (6). It is known that vibration platform frequency $<$12 Hz and amplitude as high as 3.0 mm caused chronic tendonitis and muscle soreness of the lower limbs in healthy subjects (8,14). Subsequently, the specific vibration platform frequency (Hz) and/or amplitude (mm) to elicit neuromuscular performance benefit from a WBV intervention has not been reported.

It is suggested there is a lack of information on the effectiveness of different WBV platform frequencies on neuromuscular performance (6). Because some benefits of WBV on neuromuscular performance are known, the vibration platform dynamics and subsequent gravitational force needed to achieve specific benefit must be established so that the

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23(5)/1508–1513

Journal of Strength and Conditioning Research

practitioner has boundaries within which to safely advise the clientele. The purpose of this study, therefore, was to investigate the effect of vibration platform frequency on community-dwelling older adults to assess the hypothesis that progressively overloaded vibration frequency and constant vibration amplitude can elicit neuromuscular performance improvements in the target sample.

METHODS

Experimental Approach to the Problem

An experimental research design was used to examine effects of vibration platform frequency on WBV and subsequent effects on neuromuscular performance in community-dwelling older adults. The dependent variables (5-Chair Stands test, Timed Up and Go [TUG] test, and Tinetti test) were measured preintervention (before the first WBV bout; week zero) and postintervention (at least 48 hours after the final WBV bout; week 6) to assess chronic neuromuscular performance effects. The amplitude of the vibration platform was constant at 0.5 mm. Sea-saw sinusoidal WBV was delivered using a prototype vibration platform with known reliability while subjects stood with knees at 110° knee extension (Figures 1–2).

Subjects

Seventy-three community-dwelling older adult females and males freely consented to participate in the study (age 72 ± 8 years; stature, 167 ± 8 cm; weight, 77 ± 12 kg) (Table 1). The cohort was drawn from a population of community-dwelling older adults residing in the Chelsea locale, Victoria, Australia. Data, therefore, were collected in the field. The Australian Catholic University Human Research Ethics Committee approved this procedure. The inclusion criteria consisted of any individual aged >65 years and living independently. To draw a cohort of community-dwelling older adults, subjects had to reside in a fully independent residence and be able to complete activities of normal daily function such as nonassisted walking. Subjects who had fallen in the past 12 months or had undergone any form of lower limb joint replacement procedure were not invited to participate in the study. Furthermore, to avoid potential injuries, subjects who had reactive arthritis, vascular disease, vertigo, or were at high risk of thromboembolism were excluded from the study (4,22,20). Additionally, subjects were required to obtain medical permission from their local practitioner. Medical records were not sought for privacy issues; however, subjects who were treated with medicine that affected balance were excluded from the study. The sample was not screened for activity level or acute measures of performance such as heart rate and blood pressure; however, self-reported activity, for both genders, ranged from the performance of daily household activity and chores to regular dedicated exercise (ie, walking the dog and/or golf).

Subjects had to attend at least 90% of all WBV sessions during the 6-week intervention. Compliance was 100% for all 3 WBV sample groups ($n = 55$).

Procedures

Further screening was performed with tests of cognition, vestibular function, and visual acuity. The tests were the Mini-Mental State Examination (MMSE), the Vestibular Stepping test, the Romberg test, the Snellen Eye Chart (6 m), and the Melbourne Edge test. The tests were always conducted in that order for every subject. Subjects unable to pass all tests were not invited to participate further in the study.

Each subject was randomly assigned to one of 4 groups: zero WBV sessions per week, one WBV session per week, 2 WBV sessions per week, and 3 WBV sessions per week. The zero group did not participate in any WBV sessions. The WBV intervention groups attended WBV sessions for 6 weeks (ie, 18 sessions, 12 sessions, or 6 sessions). Each WBV session consisted of 5 1-minute WBV bouts with 1 minute rest between each (4,5,8). A minimum 24-hour rest period was observed between each vibration session (20) (Table 2).

The frequency of the vibration platform was increased in standard with procedures of other WBV studies (4,6,13,24). The frequency of the vibration platform for the first WBV session in week one was 15 Hz ($g = 0.45$) and increased to 25 Hz ($g = 1.26$) by the last WBV session in week 6 (Table 2). The platform delivered sea-saw vibration (Figure 2).

Gravity was calculated with Eq 1 where g = gravitational force; $A.(2\pi f)^2$ = acceleration maximum (product of frequency and amplitude); and 9.81 = the acceleration of gravity. The amplitude is quantified as distance (mm) of a half wave form of vibration (14).

$$g = \frac{A.(2\pi f)^2}{9.81} \quad [1]$$

Subjects stood, in normal flat-soled day shoes, with legs at 110° knee extension and their feet equidistant (16 cm) from the axis of rotation on the vibration platform during each WBV bout (10,11). Subjects were instructed to hold the handlebars for support only. The angle was set using a goniometer and tested at the beginning, after 30 seconds, and at the end of each WBV bout.

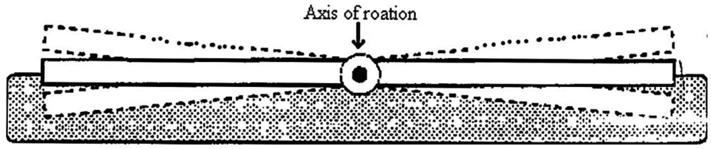

Figure 1. Sea-saw sinusoidal vibration platform.

Data Collection

Subjects performed the 5-Chair Stands test, the TUG test, and

Figure 2. Prototype whole body vibration platform.

Table 1. Mean ± *SD* of age, stature, and body mass of the sample.

Gender	*n*	Age (years)	Stature (cm)	Mass (kg)
Female	38	74 ± 8	163 ± 4	67 ± 14
Male	35	70 ± 8	171 ± 9	86 ± 10
Cohort	73	72 ± 8	167 ± 8	77 ± 12

the Tinetti test (in that order) for preintervention and postintervention. To ensure chronic data collection, the preintervention battery was completed before the first vibration session, whereas the postintervention battery was completed at least 48 hours after the final vibration session (7). Subjects were also asked to complete the SF-36 Health Survey before the first WBV session and at least 48 hours after the final WBV session.

A minimum 24-hour rest period was observed between each vibration session (20). Subjects assigned to the one WBV session per week group completed a WBV session on the same day every week. Participants of the 2 WBV sessions per week group completed WBV sessions on Tuesday and Thursday. Participants of the 3 WBV sessions per week group completed WBV sessions on Monday, Wednesday, and Friday.

The 5-Chair Stands test. Each subject was asked to sit in a standard height (46 cm, including backrest) chair with their arms crossed. The subject was then asked to stand and sit 5 times. The test began when the investigator said "go" and ended when the subject sat with their back against the backrest of the chair. Subjects were told their back must make contact with the backrest for all 5 chair stands. The time taken was recorded. Subjects were told the procedure to complete the test and were given one familiarization test.

The Timed Up and Go test. The subject was asked to sit in a standard height (46 cm) arm (63 cm) chair. The subject was then asked to stand, walk 3 m to a marker on the floor, turn, return, and sit on the chair. The test began when the investigator said "go" and ended when the subject sat with their back against the backrest of the chair. Subjects were told their back must make contact with the backrest to complete the test. The time taken was recorded. Subjects were told the procedure to complete the test and were given one familiarization test.

For both tests, the timed test occurred 5 minutes after the familiarization test to ensure recovery. Subjects were asked to complete the test as they felt comfortable. The instruction was stated as such because it was the intention to measure data while older adults were performing simulated activities of daily living.

The Tinetti test. The Tinetti test was used to assess body balance and gait. Specifically, each subject was assessed on their ability to, for example, rise from a chair, turn 360°, and walk in a straight line. A score of zero was awarded if the subject was at the lower end of ability, whereas a score of 2 was awarded if the subject showed no signs of inconvenience. A global score of 28 was awarded for 12 measures of gait and 16 measures of body balance.

The SF-36 Health Survey. The SF-36 Health Survey was used to assess health-related quality of life (HRQOL) of all subjects. The survey consisted of 8 health concepts of life: physical functioning, bodily pain, role limitations resulting from physical health problems and personal or emotional problems, emotional well-being, social functioning, energy or fatigue, and general health perceptions. Subject scores were graded on a Likert scale.

Statistical Analyses

A mixed-design (between-within) multivariate analysis of variance with post hoc analysis was calculated to view effects of the independent variables (test occasion and WBV group)

Table 2. Vibration platform frequency for the 6 week WBV intervention.

Group	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Zero	5 × 15 Hz	2 × 15 Hz 3 × 20 Hz	5 × 20 Hz	2 × 20 Hz 3 × 25 Hz	5 × 25 Hz	5 × 25 Hz
1/Week	5 × 15 Hz	2 × 15 Hz 3 × 20 Hz	5 × 20 Hz	2 × 20 Hz 3 × 25 Hz	5 × 25 Hz	5 × 25 Hz
2/Week	5 × 15 Hz	2 × 15 Hz 3 × 20 Hz	5 × 20 Hz	2 × 20 Hz 3 × 25 Hz	5 × 25 Hz	5 × 25 Hz
3/Week	5 × 15 Hz	2 × 15 Hz 3 × 20 Hz	5 × 20 Hz	2 × 20 Hz 3 × 25 Hz	5 × 25 Hz	5 × 25 Hz

All WBV bouts were 60 seconds, interspersed with 60 seconds rest. For the Zero group, amplitude was 0.00 mm. For all other groups, amplitude was 0.05 mm.

for both the 5-Chair Stands test and the TUG test. A one-way analysis of variance with post hoc analysis was also calculated using the difference scores of the 5-Chair Stands tests because the groups were different at the pretest occasion. Paired-sample tests were calculated to determine within-group differences. Test–retest correlation (intraclass correlation) was calculated within the zero group, in which $r > 0.90$ is considered high reliability (15,25). Ordinal data were analyzed with nonparametric statistical methods. Ordinal data from the Tinetti test and the SF-36 Health Survey were analyzed with Friedman's 2-way analysis of variance. Between-group comparison was not conducted for the SF-36 Health Survey because the subject:dependent variable ratio was too low for statistical power. Data were imported to a SPSS 14.0 for Windows (SPSS Inc, Chicago, IL). The level of statistical significance was set at $p \leq 0.05$.

Results

For the cohort, the mean time to complete the 5-Chair Stands and the TUG test significantly reduced after the WBV intervention (Table 3). There was a 10.1% reduction for 5-Chair Stands test time and an 8.7% reduction for the TUG test time. Tinetti test total score significantly increased after the WBV intervention as did all variables of the SF-36 Health Survey (Table 3).

For the 5-Chair Stands, TUG, and Tinetti tests, significant neuromuscular performance improvements were found within the 2 and 3 WBV sessions per week groups (Table 4). After between analysis, for the 5-Chair Stands test, the 3 group was significantly faster than the zero group. For the TUG test, the 3 group was significantly faster that the 2 group. For the Tinetti test total, the 3 group was significantly better than all other groups. Intraclass correlation for the zero group were

Table 3. Statistics of the dependent variables for all subjects.

Variable	Pre	Post	SF-36 Health Survey	Pre	Post
5-Chair Stands test (seconds)	14.67 ± 3.25	13.19* ± 2.41	Physical functioning	64 ± 22	70 ± 18*
Timed Up and Go test (seconds)	9.26 ± 2.05	8.45* ± 1.74	Limitation resulting from physical health	70 ± 32	77 ± 23*
Tinetti test total	24 ± 2	25 ± 2*	Limitation resulting from emotional health	75 ± 33	84 ± 21*
Tinetti test gait	11 ± 1	11 ± 1	Energy	63 ± 17	69 ± 12*
Tinetti test balance	13 ± 2	14 ± 1*	Well-being	75 ± 16	78 ± 12*
			Social functioning	84 ± 20	87 ± 14*
			Bodily pain	73 ± 20	81 ± 14*
			General health	69 ± 17	72 ± 11*

*Significant difference; n = 73.

Table 4. Statistics of the 5-Chair Stands test, Timed Up and Go (TUG) test, and Tinetti test for each sample group.

Sample group	5-Chair_{Pre} (seconds)	5-Chair_{Post} (seconds)	TUG_{Pre} (seconds)	TUG_{Post} (seconds)	Tinetti $total_{Pre}$	Tinetti $total_{Post}$
Zero (n = 18)	14.86 ± 3.45	13.35 ± 1.12	8.92 ± 1.65	8.07 ± 0.89	24 ± 2	25 ± 1
1/week (n = 18)	13.64 ± 2.79	13.79 ± 3.01	9.37 ± 1.59	8.91 ± 1.83	24 ± 2	25 ± 1
2/week (n = 18)	15.35 ± 4.13	13.27* ± 2.92	10.29 ± 2.98	9.17* ± 2.52	23 ± 2	25* ± 2
3/week (n = 19)	14.86 ± 2.47	12.35* ± 1.95	8.47 ± 1.41	7.65* ± 0.92	23 ± 3	26* ± 2

*Significant difference.

significant for test–retest reliability, in which r was between 0.90 and 0.95 ($p < 0.05$) for all dependent variables.

Discussion

Frequency and amplitude are the crucial components regarding a beneficial or contraindicated outcome for muscular strength from vibration exercise (12). This study showed that WBV with controlled amplitude and manipulated frequency elicited beneficial neuromuscular adaptation in a community-dwelling older adult sample, particularly within the 3 WBV sessions per week group. The maximum gravitational force (1.26g) generated by the vibration platform of this study, although not as large as other studies, elicited neuromuscular performance improvement. Furthermore, the vibration platform dynamics were such that no injuries were associated with the 6-week WBV intervention.

Body balance, gait, and HRQoL also improved after a 6-week WBV intervention. Using a similar method, Bruyere et al (4) also found a significant intervention effect with the Tinetti test and the SF-36 Health Survey.

These findings are similar to other studies of muscular strength and muscular power after WBV. Using varied methods, researchers reported that WBV effects neuromuscular performance (2,18,24). The improvements may be attributed to neurogenic adaptation because other studies reported similar trends (7,13,16). Other possible explanation for the observed neuromuscular improvements was, as had been suggested in the literature, increased synchronous motor unit recruitment. WBV increased muscular fatigue quantifiers (rating of perceived exertion and blood lactate levels) (18). Such process caused enhanced neuromuscular excitability and greater motor unit recruitment (23). Relative improvements in neuromuscular performance are expected in those circumstances.

Furthermore, the synchronous activity of synergist muscles of the lower limbs or increased inhibition of the antagonistic muscles caused by the activation of the stretch reflex may also explain the observed findings (23). For this study, subjects stood with knee flexion (110°), thus promoting additional quadriceps group (agonist) activation, possibly through elicitation of the stretch reflex during WBV.

The gravitational forces used in pervious investigations are difficult to calculate due to inconsistent nomenclature (2,6,9,24). Amplitude has been described synonymously as displacement, peak-to-peak amplitude and, peak-to-peak displacement. One study, for example, initially reported vibration oscillation magnitude as amplitude of 2.5 mm to 5.0 mm, only later to describe vibration oscillation magnitude as peak-to-peak displacement of the same magnitude (9). Inconsistent calculations of gravitational force have been reported because the definition of amplitude had not been standard. For this study, with Eq 1, gravity was accurately calculated.

Practical Applications

Researchers used a 3 WBV sessions per week method for an intervention and found improvement in neuromuscular performance of younger and older adults (9,22,24). This study, however, specifically investigated the number of WBV sessions per week required to affect neuromuscular performance for the target population using fixed amplitude and progressively overloaded frequency. The influence of platform frequency and associated gravitational forces acting on the body of the 3 WBV sessions per week intervention elicited significantly larger gains in neuromuscular performance.

Whole body vibration research findings drew attention to the importance of WBV as a research area of exercise science. WBV may be an alternative mode of exercise for community-dwelling older individuals who are, for example, less inclined to participate in gym classes or individuals who have trouble walking. Progressively overloaded vibration platform frequency, initially 15–25 Hz, and platform amplitude controlled at 0.5 mm (between 0.45 and 1.26g) was well tolerated and sufficient to elicit neuromuscular performance improvement in the target sample while avoiding injuries. The practitioner may confidently use these boundaries for a community-dwelling older adult.

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