Journal of Biomechanics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Controlled whole-body vibration training reduces risk of falls among community-dwelling older adults

Feng Yang [a,*], George A. King [a], Loretta Dillon [b], Xiaogang Su [c]

[a] Department of Kinesiology, University of Texas at El Paso, El Paso, TX 79968, USA
[b] Physical Therapy Program, University of Texas at El Paso, El Paso, TX 79968, USA
[c] Department of Mathematical Sciences, University of Texas at El Paso, El Paso, TX 79968, USA

ARTICLE INFO

Article history:
Accepted 30 June 2015

Keywords:
Fall prevention
Physical medicine
Cutaneous sensation
Range of motion
Fear of falling
Side-alternating vibration
Hip fracture

ABSTRACT

The primary purpose of this study was to systematically examine the effects of an 8-week controlled whole-body vibration training on reducing the risk of falls among community-dwelling adults. Eighteen healthy elderlies received vibration training which was delivered on a side alternating vibration platform in an intermittent way: five repetitions of 1 min vibration followed by a 1 min rest. The vibration frequency and amplitude were 20 Hz and 3.0 mm respectively. The same training was repeated 3 times a week, and the entire training lasted for 8 weeks for a total of 24 training sessions. Immediately prior to (or pre-training) and following (or post-training) the 8-week training course, all participants' risk of falls were evaluated in terms of body balance, functional mobility, muscle strength and power, bone density, range of motion at lower limb joints, foot cutaneous sensation level, and fear of falling. Our results revealed that the training was able to improve all fall risk factors examined with moderate to large effect sizes ranging between 0.55 and 1.26. The important findings of this study were that an 8-week vibration training could significantly increase the range of motion of ankle joints on the sagittal plane (6.4° at pre-training evaluation vs. 9.6° at post-training evaluation for dorsiflexion and 45.8° vs. 51.9° for plantarflexion, $p < 0.05$ for both); reduce the sensation threshold of the foot plantar surface ($p < 0.05$); and lower the fear of falling (12.2 vs. 10.8, $p < 0.05$). These findings could provide guidance to design optimal whole-body vibration training paradigm for fall prevention among older adults.

1. Introduction

Falls among older adults present a significant medical, societal, and economic challenge (Tinetti, 2003). Growing efforts have been directed towards designing and implementing fall prevention programs. Even as traditional strength and balance exercise intervention programs are increasingly adopted to reduce the risk of falls among elderly, several factors restrict their incorporation into fall prevention programs for older adults. First, older adults could get injured or experience a real fall leading to severe consequences while performing physical activities during exercise training. Second, a significant portion of elderly are unable or unwilling to comply with or manage the intensity or duration requirements of a conventional training (Sherrington et al., 2008). Third, exercise programs of sufficient intensity and duration may not be available to all older adults due to cost or the locations of the training programs (Goodwin et al., 2010). Therefore, an alternative to traditional exercise-based fall prevention protocol is pressingly demanded.

Controlled whole-body vibration (CWBV) training has recently emerged as a relatively novel modality to train older adults to reduce their risk of falls (Lam et al., 2012). The transmission of vibrations and oscillations to human body can lead to physiological and neuromuscular changes on numerous levels (Madou and Cronin, 2008). Because the CWBV training is portable, easy to operate, and safe, it is becoming an attractive training approach to reduce the catastrophic consequence caused by falls among older adults. Short-term (6–10 weeks) adequately-controlled programs of CWBV training are reported to reduce fall risk among older adults. For example, a study reported that the a 6-week CWBV training significantly improved the Tinetti body balance score by 3.5 points and reduced the Timed-Up-and-Go (TUG) score by approximately 11 s among nursing home residents (Bruyere et al., 2005). Improvements due to vibration training in balance ability quantified by limits of stability (Cheung et al., 2007) and the behavioral balance test were also found (Elfering et al., 2013, 2014). In another study, after CWBV training, lower limb muscle strength and power were significantly improved by 15% and 19%, respectively, among older women (Roelants et al., 2004).

* Correspondence to: Department of Kinesiology University of Texas at El Paso, 1851 Wiggins Rd, Rm-452, El Paso, TX 79968, USA. Tel.: +1 915 747 8228; fax: +1 915 747 7522.
E-mail address: fyang@utep.edu (F. Yang).

http://dx.doi.org/10.1016/j.jbiomech.2015.06.029
0021-9290/

Please cite this article as: Yang, F., et al., Controlled whole-body vibration training reduces risk of falls among community-dwelling older adults. Journal of Biomechanics (2015), http://dx.doi.org/10.1016/j.jbiomech.2015.06.029

Additionally, it has been reported that CWBV training can improve proprioceptive function (Cheung et al., 2007; Rees et al., 2009), bone density (Myint et al., 2007), and gait coordination (Bogaerts et al., 2011) of older adults.

However, all aforementioned studies employed dissimilar protocols with wide variations in training parameters, protocol, and intensities (Cochrane et al., 2004; Torvinen et al., 2002). The lack of the commonality of training parameters and intensities among those studies makes it impossible to compare the effect of CWBV training across studies, and limits our capability of designing optimal CWBV-based training protocols. Therefore, a systematic and comprehensive examination of risk factors of falls under the same training parameters and intensity is urgently needed given that CWBV has become increasingly popular (Lam et al., 2012).

Impairment in sensation and reductions in range of motion at lower limb joints occur with aging (Scott et al., 2007). Considerable evidence suggests a link between impaired sensation and the increased likelihood of falls among elderly (Lord et al., 1999). The range of motion, particularly at the ankle joint on the sagittal plane, is critical to the ability of keeping balance during human movement (Spink et al., 2011). Reduced ankle dorsiflexion range has been identified as a significant independent predictor of falls (Menz et al., 2006). To our knowledge, no study has examined the impact of CWBV training on the sensation threshold, particularly the foot cutaneous sensation, and the range of motion at lower limb joints in older adults.

The primary purpose of this study was to systematically evaluate the effects of CWBV training on a battery of risk factors of falls among community-living seniors under the same vibration training protocol. We hypothesized that an 8-week CWBV training course could reduce the risk of falls among older adults by improving their body balance skill, functional mobility, lower-limb muscle strength and power, range of motion, cutaneous sensation level, bone density, and fear of falling. The findings from this study could provide important guidance towards establishing the optimal CWBV training protocol for reducing falls among elderly and contribute to the completeness of the current literature.

2. Methods

2.1. Participants and experimental protocol

Subjects with no known history of cognitive, musculoskeletal, neurological, cardiovascular, or pulmonary impairment that may affect their ability to perform the testing procedures were recruited. An initial recruitment pool of 21 subjects identified 18 (86%) that met the enrollment criteria (Table 1). All 18 subjects gave written informed consent approved by Institutional Review Board. This study used a pretest–posttest longitudinal design to detect the effectiveness of CWBV training on risk of falls among older adults (Fig. 1a). All participants underwent an 8-week CWBV training. Their risk of falls was evaluated and compared between pre- and post-training evaluations.

2.2. Evaluation of risk factors of falls

The fall risk was evaluated for all subjects immediately prior to (in week 1, pre-training evaluation) and after (in week 8, post-training evaluation) the CWBV training (Fig. 1a). The fall risk was characterized by the following commonly-used factors as they have been closely related to falls among older adults (Horlings et al., 2008; Moreland et al., 2004; Patel et al., 2005; Rogers et al., 2003; Rubenstein, 2006).

Table 1
Demographic information for all 18 participants among which 9 were females.

Parameter	Mean	SD	Minimum	Maximum	Median
Age (years)	69.7	3.5	65	79	69
Height (cm)	169.4	9.9	156.5	189.5	168.8
Mass (kg)	78.5	15.5	53.1	111.7	76.2

SD: standard deviation.

2.2.1. Body balance

Participants' body balance was assessed using the Berg Balance Scale (BBS) test (Berg et al., 1992). Participants performed a series of functional balance tasks of increasing difficulty and the degree of success in achieving each task was scored.

2.2.2. Functional mobility

The functional mobility was evaluated using the TUG test (Podsiadlo and Richardson, 1991). During the test, subjects stood up from a chair, walked forward 3 m, turned around, walked back, and then sat back down in the chair. The time in seconds required to complete the task at normal pace was used for analysis.

2.2.3. Muscle strength

The isometric strength capacity was assessed on right knee via an isokinetic dynamometer (Biodex System 3, Shirley, NY). During tests, subjects performed maximal voluntary isometric contractions of knee extensors and flexors three times each. The contractions lasted 7 s each and were separated by a 2-min rest interval. The greatest torque normalized to body mass (Nm/kg) was recorded as isometric strength performance. The average maximum torque across the three trials was used for analysis.

2.2.4. Chair-rise test

The chair-rise test was used to quantify the lower limb power performance (Hardy et al., 2010). The chair-rise movement was repeated for 5 cycles of rising from a chair and then sitting down again at subjects' faster speed (Rees et al., 2008). The time taken to finish the 5 repetitions was recorded.

2.2.5. Range of motion

The active range of motion in degrees was assessed for hip extension, flexion, adduction, and abduction, knee flexion, and ankle dorsiflexion and plantar-flexion on right leg by using a goniometer (Clarkson, 2013).

2.2.6. Cutaneous sensation on foot

All subjects received the sensory assessment via a Semmes–Weinstein nylon monofilament touch-test kit (NC 12775-14, North Coast Medical, CA) applying

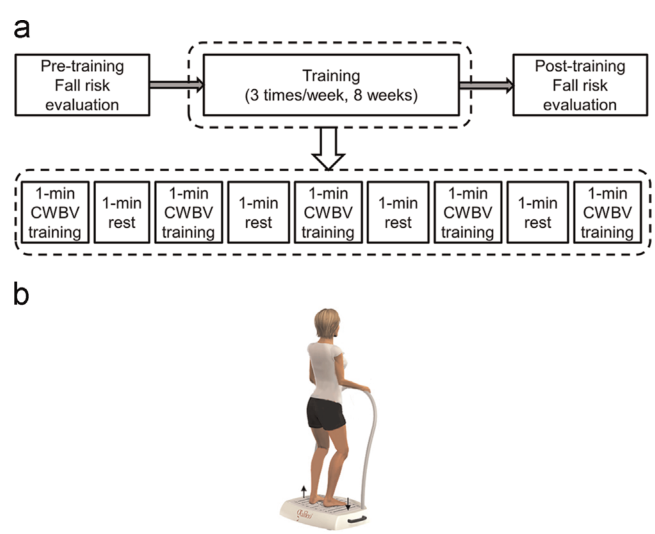

Fig. 1. Schematics of (a) the experimental protocol and (b) the side alternating vibration platform used to produce controlled whole-body vibration training. Vibration was delivered in an intermittent way: five repetitions of 1-min vibration followed by a 1-min rest. The same training was repeated 3 times a week, and the entire training lasted for 8 weeks (weeks 1 through 8) for a total of 24 training sessions. During training, participants held handlebars for balance and looked directly ahead with standing on the vibrator platform barefooted over clearly marked foot positions corresponding to the vibration amplitude during the training. They were also required to stand on the platform with 20° knee flexion but with a straight trunk to allow the transmission of vibration to the lower limbs but not the spinal cord or brain. They were instructed to try to distribute their body weight evenly over the forefoot and hindfoot bilaterally. Immediately prior to (or pre-training) and following (or post-training) the 8-week training course, all participants' risk of falls were evaluated in terms of the body balance, functional mobility, muscle strength and power, bone density, range of motion, cutaneous sensation level, and fear of falling.

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