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Effects of vibration training in reducing risk of slip-related falls among young adults with obesity

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ABSTRACT

This study examined the effects of controlled whole-body vibration training on reducing risk of slip-related falls in people with obesity. Twenty-three young adults with obesity were randomly assigned into either the vibration or placebo group. The vibration and placebo groups respectively received 6-week vibration and placebo training on a side-alternating vibration platform. Before and after the training, the isometric knee extensors strength capacity was measured for the two groups. Both groups were also exposed to a standardized slip induced by a treadmill during gait prior to and following the training. Dynamic stability and fall incidences responding to the slip were also assessed. The results indicated that vibration training significantly increased the muscle strength and improved dynamic stability control at recovery touchdown after the slip occurrence. The improved dynamic stability could be resulted from the enhanced trunk segment movement control, which may be attributable to the strength increment caused by the vibration training. The decline of the fall rates from the pre-training slip to the post-training one was greater among the vibration group than the placebo group (45% vs. 25%). Vibration-based training could be a promising alternative or additional modality to active exercise-based fall prevention programs for people with obesity.

1. Introduction

Falls present a pressing challenge among elderly (Corso et al., 2006). Slip-related falls frequently lead to hip fractures, limitation of mobility, and fear of falling (Stevens et al., 2006). Obesity has been associated with an increased postural instability (Fjeldstad et al., 2008) and reduced lower limb muscle strength relative to body mass (Lafortuna et al., 2005). Both instability and muscle weakness are related to falls (Ding and Yang, 2016; Rogers et al., 2003). Therefore, obesity heightens the fall risk among adults (Himes and Reynolds, 2012). It has been reported that obesity could increase 19 times the likelihood of falls initiated by a standardized slip among young adults after removing the confounding effects from body height and gender (Yang et al., 2017). Obese individuals also suffer a high fall-related injuries rate (Finkelstein et al., 2007). It is imperative to develop effective fall prevention programs towards this population.

Recently, controlled whole-body vibration (CWBV) training has emerged to reduce fall risk among elderly (Yang et al., 2015) and individuals with movement disorders (Sanudo et al., 2013; Yang et al., 2016). During CWBV training, trainees stand on a vibration platform that creates sinusoidal vibrations. The transmission of vibrations to the human body stimulates the primary endings of the muscle spindles, which in turn activates α-motor neurons and results in involuntary muscle contractions. CWBV also increases the synchronization of motor units (Cardinale and Bosco, 2003) and the efficiency of agonist/antagonist pairs (Cardinale and Bosco, 2003; Kossev et al., 2001). The increased synchronization of motor units signifies that more muscle fibers are contracted at once and hence more force can be produced. The enhanced muscular performance could improve the risk factors of fall, which has been shown among older adults (Yang et al., 2015). Given the inherent features of CWBV training, such as portability, safety, and effectiveness, CWBV could be an alternative to traditional exercise-based training.

Previous studies suggested that CWBV training increases the lower limb muscle strength among people with obesity (Milanese et al., 2013). Given that fall risk factors are not equal

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to real-life falls, improved muscle strength (as a fall risk factor) does not necessarily represent a lowered risk of actual falls. Therefore, the effect of CWBV training on reducing real-life falls, particularly slip-related falls, still remains unanswered. An ideal platform to test the effectiveness of CWBV training on reducing slip-related falls in people with obesity would be to expose them to a well-controlled slip perturbation in a laboratory environment.

Dynamic gait stability has been identified as a key risk factor of slip-related falls (Yang et al., 2009). Based on a theoretical framework (the feasible stability region theory) (Hof et al., 2005; Yang et al., 2008), dynamic gait stability is characterized by the relationship between the body's center of mass (COM) motion state and the analytically-derived stability limit (Yang et al., 2009). See Online Supplement for details. The examination of how CWBV training affects dynamic stability control could elucidate the mechanisms through which the training alters the risk of slip-related falls in obese.

Lower limb muscle strength, particularly the knee joint strength, is critical to prevent a slip-related fall. Specifically, after the loss balance following a slip, it is paramount to take a quick and successful recovery step to reestablish the base of support (BOS) and to provide sufficient extensor moment to avoid the limb collapse (Cham and Redfern, 2001; Ding and Yang, 2016; Pai et al., 2006). To determine how vibration training modifies knee extensors moment could also provide insights into the mechanisms of vibration training reducing risk of falls in people with obesity.

The purposes of this study were (1) to examine if a 6-week CWBV training course could improve the knee extensors muscle strength, and (2) to inspect whether the rate of falls and dynamic gait stability in response to a standardized slip induced on a treadmill during gait would be changed by CWBV training program among young people with obesity. Participants with obesity would be randomly assigned to either the vibration or placebo group. Before and after the training, muscle strength, responses to the slip would be evaluated for both groups. We hypothesized that (1) the training group would demonstrate increased lower-limb muscle strength than the placebo group after the training and (2) that vibration training would lower the rate of slip-related falls and improve dynamic stability responding to the post-training slip.

2. Methods

2.1. Participants

Only those who were obese were enrolled. For a male (female) participant, his (her) body mass index must be at least 30 kg/m^2 and the body fat percentage should be no less than 25% (35%) (Wu and Madigan, 2014). Participants must also be free of any musculoskeletal disorders, neurological disorders, orthopedic conditions, and cardiovascular conditions. Twenty-eight young adults were initially screened. Twenty-three of them were qualified and randomized into two groups (vibration vs. placebo, Table 1). All participants gave their written consent for participation in the experiment approved by the Institutional Review Board.

Six more participants were excluded from the study due to incomplete training ($n = 3$) or no valid slip trial during post-training test ($n = 3$) (Fig. 1). Nine from the vibration group and eight from placebo group were included in the final analysis. Of the remaining 17 participants, all successfully completed the intervention with a compliance rate of 100% (number of sessions = 18). None of the participants reported any major discomfort or adverse effect during the training. Itching of legs ($n = 3$), which are typical for vibration intervention, were reported in the vibration group. These effects were mild and diminished after approximately 3–5 training sessions.

2.2. Study design

This study adopted a two-arm, randomized controlled design (Figs. 1 and 2a). The vibration and placebo groups respectively received a 6-week vibration and placebo training on a vibration platform. Before and after the training, muscle strength, fall rate and dynamic stability during a treadmill-induced slip were assessed. Participants had no knowledge about their group assignment and the investigators who performed the two evaluations were also blinded to participants' group assignment.

2.3. Evaluation of risk factors of slip-related falls

2.3.1. Muscle strength

Strength capacity of the right knee extensors was assessed via an isokinetic dynamometer (Biodex, NY). While they were seated in the dynamometer chair, participants performed maximal voluntary isometric contractions of knee extensors three times with the knee joint flexed at 35°. The contractions lasted seven seconds each and were separated by a 2-min rest interval. The peak torque was recorded during each of the three repetitions. The average value of the three peaks across the three repetitions, normalized to body mass (Nm/kg), was calculated to represent the knee extensors strength capacity.

2.3.2. Slip perturbation

Following the muscle performance assessment, all subjects took a 10-min break. After five overground walking trials on a 14-m walkway, all subjects stepped on a regular treadmill over which each participant's comfortable walking speed was determined. They also walked five minutes to get acquainted with treadmill walking. They were then moved to the ActiveStep treadmill (Simbex, NH) and wore a safety harness attached to an overhead arch through ropes (Fig. 2b). A load cell connecting to the ropes measured the force exerted on it at 600 Hz. Participants were instructed that "the following trials will be normal walking ones without any perturbation." After walking 3–5 times at their self-selected gait speed as determined above, they walked three times at the speed of 1.2 m/s. They were then told that "from the next trial on, you may or may not experience a simulated slip in each trial. If a slip happens, try to recover your balance and to continue walking."

Following the instructions, participants walked two trials at the speed of 1.2 m/s without perturbation on the treadmill. They were then exposed to the slip perturbation. After 10–12 regular steps in the slip trial, approximately 80–120 ms later than the touchdown of the leading foot, without participants' knowledge, the belt suddenly accelerated forward 1.2 m/s within 0.2 s, which induced a forward displacement of the subjects' BOS relative to their COM, creating an unexpected slip perturbation (Yang et al., 2013). The perturbation level was the same for all subjects (Fig. 2c). Full-body kinematics from 26 retro-reflective markers placed on the participants' body were gathered using an 8-camera motion capture system (Vicon, UK) which was synchronized with the load cell measurement.

2.4. Vibration and placebo training

A side-alternating vibration platform (Galileo, German) was used in this study (Fig. 2d). Participants stood over clearly-marked positions on the platform during training (Fig. 2d). They were required to maintain stance on the platform with knees at 20° flexion and the trunk held upright (Mikhael et al., 2010). The vibration frequency and amplitude were 25 Hz and 3.9 mm, respectively. Each training session was comprised of five repetitions of 1-min vibration exposure followed by a 1-min rest (Fig. 2a). The same training was repeated three times a week over six weeks for a total of 18 training sessions (Fig. 2a). The vibration group experienced the vibration training while standing on the platform. The placebo group stood on the same platform which did not vibrate (Fig. 2a). Other than the vibration, participants in both groups followed the identical procedures.

Table 1
Comparisons of the demographic information (in mean ± standard deviation) between vibration and placebo groups.

Groups	Age (years)	Gender (female)	Height (m)	Mass (kg)	BMI (kg/m^2)	Body fat (%)
Vibration ($n = 12$)	26.00 ± 7.29	4	1.72 ± 0.08	102.1 ± 9.4	34.44 ± 1.94	36.58 ± 6.66
Placebo ($n = 11$)	23.72 ± 2.97	4	1.69 ± 0.11	103.7 ± 24.1	35.85 ± 5.36	38.16 ± 5.26
p value	0.375	0.879[a]	0.487	0.828	0.403	0.537

BMI: body mass index.
[a] Fisher's exact test was used.

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