The Knee 21 (2014) 1088–1095

Contents lists available at ScienceDirect

The Knee

Effects of whole-body vibration exercise on muscular strength and power, functional mobility and self-reported knee function in middle-aged and older Japanese women with knee pain

Taishi Tsuji [a,b,*], Jieun Yoon [c], Tatsuya Aiba [d], Akihiro Kanamori [e,f], Tomohiro Okura [e], Kiyoji Tanaka [e]

[a] Gerontology Research Center, University of Jyväskylä, Finland
[b] Japan Society for the Promotion of Science, Japan
[c] Doctoral Program in Physical Education, Health and Sport Sciences, University of Tsukuba, Japan
[d] Doctoral Program in Sports Medicine, University of Tsukuba, Japan
[e] Faculty of Health and Sport Sciences, University of Tsukuba, Japan
[f] University of Tsukuba, Department of Orthopaedic Surgery, Japan

ARTICLE INFO

Article history:
Received 26 May 2013
Received in revised form 23 May 2014
Accepted 21 July 2014

Keywords:
Acceleration training
Knee osteoarthritis
JKOM score

ABSTRACT

Background: Whole-body vibration training using vertical-vibration machines is called “acceleration training” (AT). The purpose of this study was to elucidate the effect of AT on lower-limb muscular strength and power, functional mobility and self-reported knee function in middle-aged and older Japanese women with knee pain.
Methods: Thirty-eight middle-aged and older Japanese women (aged 50–73 years) with knee pain were divided into two groups: (1) the AT group (n = 29) engaged in AT three times per week for eight weeks, and (2) the control group (C group, n = 9). The AT program consisted of flexibility training, strength training of mainly the quadriceps and surrounding muscles and cool-down exercises. The C group was encouraged to perform the same or similar exercises at home without vibratory stimulus. We evaluated knee strength and power, functional mobility (timed up and go: TUG) and self-reported knee function (Japanese Knee Osteoarthritis Measure: JKOM).
Results: No one in the AT group dropped out during the program. All JKOM categories except degree of pain improved significantly post intervention indicating improved knee function, and TUG was significantly shorter in these participants. All knee strength and power parameters except isometric knee extension peak torque improved significantly. The degree of change in JKOM total score and TUG was significantly different between the two groups.
Conclusion: Vibratory stimulus during an eight week AT programme can promote participation and safely improve functional mobility and self-reported knee function better than exercise without vibratory stimulus in middle-aged and older Japanese women with knee pain.
Level of evidence: level 2.

1. Background

As the Japanese population rapidly ages, age-associated diseases of the musculoskeletal system have also increased. Frequent problems include degenerative changes in the knee and the resulting pain. Approximately 60% to 70% of middle-aged and older Japanese women have degenerative arthritis in their knees and approximately 30% to 40% of them experience knee pain [1]. These figures are roughly double the rates experienced by men of the same age [1]. Knee pain has a direct influence on these women's ability to walk, stand up from a chair, ascend and descend stairways and perform other common activities of daily living [2]. Because knee pain is one of the factors that limits physical activity, middle-aged and older women have an urgent need for some way to deal with this problem.

Strength training focused on strengthening the quadriceps muscle has been shown to be an effective, conservative therapy for middle-aged and older women who suffer from knee pain associated with knee osteoarthritis (OA) [3,4]. Recently, whole-body vibration (WBV) has been gaining attention as a new strength training technique that is both safe and effective. WBV training does not rely upon heavy weights or dynamic movements for its effectiveness as a strength training technique. Rather, the participant mounts a platform and statically applies his or her own body weight onto the target site of the body. One major principal behind this technique is the acceleration created by the rapid oscillation of the platform which creates a gravitational field that surpasses gravitational acceleration (9.8 m/s^2). The second major principal is the reflexive mechanism known as the tonic vibration reflex which creates involuntary and sustained muscle contractions [5].

* Corresponding author at: Gerontology Research Center, University of Jyväskylä, P.O. BOX 35 (L), FI-40014, Finland. Tel.: +358 46 622 9068.
E-mail address: tsuji.t.taishi@jyu.fi (T. Tsuji).

http://dx.doi.org/10.1016/j.knee.2014.07.015
0968-0160/

We are aware of three studies that examine the effectiveness of WBV training on knee OA [6–8]. All of them reported significant improvement in objective assessments such as muscular strength and functional mobility performance. However, while two studies [7,8] concluded that WBV improved self-reported knee function (decreased WOMAC pain, stiffness and/or function score), the third study [6] reported no improvement, which illustrates that there is no consistent view on this issue. One reason for these contradictory results might be the difference in training volume (twice a week for eight weeks [6] vs. three times per week for 12 weeks [7,8]). Trans et al. [6] suggested that the applied program may not have the potential to alter physiological mechanisms to an extent that influences self-reported disease status. By increasing training frequency and improving the training exercises, participants may feel improvement in knee function during a limited eight week period. The exercise programs in previous studies [6–8] only included strength training with squat-type exercises. A recent systematic review [9] of exercise interventions for patients with knee OA found that incorporating strength training plus flexibility exercises improved participants' self-reported knee function more than strength training alone (standardized mean difference $= -0.73$ and -0.46, respectively). For WBV training, this combination also might be more effective for improving knee function.

The equipment used for WBV training can be divided into two types: the rotational vibration (RV) machine and the vertical-vibration (VV) machine [10]. RV machines have a vibrating platform mounted on a central axis so that the platform can rock right and left (like a seesaw). VV machines have a platform in the shape of a slab that can vibrate in all three spatial dimensions. The difference in the effectiveness of these two types of machines has not been established, but it is easier for users to maintain the correct training posture [10] when using VV machines rather than RV machines. This makes the VV machines well-suited to middle-aged and older persons suffering from knee pain. In recent years, training methods using the VV machines, which can produce vibrations in all three spatial dimensions, have come to be called "acceleration training" (AT) [5].

The objective of this study was to elucidate the effect AT with strength and flexibility exercises has on lower-limb muscular strength and power, functional mobility and self-reported knee function when used by middle-aged and older Japanese women who suffer from knee pain. A secondary objective was to investigate the effectiveness of AT on deformities as categorized by severity. This study hypothesized that AT can improve all aspects of knee function for all levels of severity.

2. Methods

2.1. Participants

The study was a single-blind, prospective, controlled study. A flowchart showing the progress of participants from recruitment and selection to the end of the study is shown in Fig. 1. The power analysis with settings at $\alpha = 0.05$, power $(1 - \beta) = 0.80$ and effect size $= 0.58$ [3] showed that a group of 26 participants was the required sample size in the AT group. Participants were recruited via advertisements placed in local information magazines with responses handled over the telephone. Inclusion criteria were 1. Post-menopausal women, 2. Age between 50 and 75 and 3. Suffering from knee pain. We received 80 responses. The exclusion criteria were 1. Use of a pacemaker, 2. In the acute phase of a disease, 3. Suffering from severe diabetes, 4. Suffering from rheumatic disease, 5. Unable to walk without support, 6. Being seen regularly at a hospital due to knee pain, 7. Engaging in strength training three or more times per week and 8. Unable to attend the study briefing or continuously attend the training.

There were 47 women interested in participating who fit the criteria: 32 were chosen for the three times per week AT training (AT group) and 15 were placed in the control group (C group) in which they would perform an exercise protocol at their homes. However, after these 47 women were examined by a physician, only 29 women in the AT group and nine women in the C group were found to be free of rheumatic disease and able to participate in the training. Table 1 shows their descriptive data. There were no significant differences in any category between the AT group and C group at the time baseline measurements were taken. This study was conducted with the approval of the ethics committee of the University of Tsukuba. All participants received both oral and written explanations of this study and their written consent was obtained. The nine participants in the C group were given the same post-study program as the participants in the AT group.

2.2. Study protocol

One month before participating in this study, participants were examined by an orthopedic surgeon, and one week before participating, we evaluated their lower-limb muscular strength and power, functional mobility and self-reported knee function. We also obtained radiographs on the 29 participants in the AT group to assess the degree of knee degeneration. One week after the study ended, all of the above tests were repeated.

Participants in the AT group participated in their training program three days per week with at least one day between each session for eight weeks (total of 24 times) (January 16, 2012 to March 9, 2012). Each session was 50 min long which included a 10-minute warm-up and flexibility training period, a 25-minute period of strength training with participants using their own weight and a 15-minute cool-down period. All exercises were performed on VV machines (POWER PLATE, POWER PLATE International, London, UK). The training program is detailed in Table 2 and Fig. 2. Six types of flexibility exercises and four types of cool-down exercises were performed in each session. The strength training exercises were designed to strengthen mainly the quadriceps (e.g. squats and lunge exercises) and surrounding muscles. The numbers of sets and exercises were gradually increased as the program progressed. Exercises were performed at a frequency of 30 Hz, vibration amplitude of 2.5 mm and for 30 s/set, which was well below the WBV training level (30 Hz, 4.0 mm, 10 min/day) suggested by Abercromby et al. [11] as the level which could pose physical danger to the participant. Except for the up-and-down exercise, all exercises were muscular-exertion types involving isometric muscular contractions. Each part of the up-and-down exercise was performed for 4 s in the following order: hip flexion, knee extension, knee flexion and hip extension.

During the eight weeks of the AT group's intervention, the participants in the C group were encouraged to perform exercises at home. Explanatory materials containing instructions on how to perform the exercises were distributed after the pre-test (week 0) and at the end of week 4. The goal was to perform exercises which were the same or similar to those performed by the AT group (Fig. 2) for the same amount of time and number of sets while standing, lying down and seated. Participants in the C group kept a record of their exercises which was submitted to the researchers after the study ended.

2.3. Outcomes

2.3.1. Muscular strength and power

A Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY, USA) was used to test the isometric (0 deg/s) knee extension peak torque and isokinetic (60 deg/s) knee extension/flexion peak torque and average power. Participant positioning for the knee extension and flexion trials has been described previously [12]. Participants performed maximal isometric knee extensions of 3-s duration at a knee joint angle of 120 deg (180 deg = full knee extension) [13]. Isokinetic knee extension and flexion trials were performed separately with angle of the knee joint ranging from approximately 90 deg to 180 deg. For each trial, participants performed two submaximal and two maximal contractions before testing. They then performed three maximal voluntary contractions each separated by a 5-s pause. A rest