ORIGINAL ARTICLE

Improvement of Stance Control and Muscle Performance Induced by Focal Muscle Vibration in Young-Elderly Women: A Randomized Controlled Trial

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ABSTRACT. Filippi GM, Brunetti O, Botti FM, Panichi R, Roscini M, Camerota F, Cesari M, Pettorossi VE. Improvement of stance control and muscle performance induced by focal muscle vibration in young-elderly women: a randomized controlled trial. Arch Phys Med Rehabil 2009;90:2019-25.

Objective: To determine the effect of a particular protocol of mechanical vibration, applied focally and repeatedly (repeated muscle vibration [rMV]) on the quadriceps muscles, on stance and lower-extremity muscle power of young-elderly women.

Design: Double-blind randomized controlled trial; 3-month follow-up after intervention.

Setting: Human Physiology Laboratories, University of Perugia, Italy.

Participants: Sedentary women volunteers (N=60), randomized in 3 groups (mean age ± SD, 65.3±4.2y; range, 60–72).

Intervention: rMV (100Hz, 300–500μm, in three 10-minute sessions a day for 3 consecutive days) was applied to voluntary contracted quadriceps (vibrated and contracted group) and relaxed quadriceps (vibrated and relaxed group). A third group received placebo stimulation (nonvibrated group).

Main Outcome Measures: Area of sway of the center of pressure, vertical jump height, and leg power.

Results: Twenty-four hours after the end of the complete series of applications, the area of sway of the center of pressure decreased significantly by approximately 20%, vertical jump increased by approximately 55%, and leg power increased by approximately 35%. These effects were maintained for at least 90 days after treatment.

Conclusions: rMV is a short-lasting and noninvasive protocol that can significantly and persistently improve muscle performance in sedentary young-elderly women.

Key Words: Aged; Rehabilitation; Women.

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THE PROBLEM OF maintaining body stance is crucial in motor control and becomes particularly relevant as people age because of the increasing risk of falls reported with aging.[1] Among the elderly there is a physiologic progressive deterioration involving both the musculoskeletal and nervous systems, leading to biomechanical limitations, reduced strength, delayed reactions,[2] and proprioceptive and balance impairment.[2-4] Therefore, many protocols have been developed to improve body balance by combining sensory and muscle training.[5-9] Unfortunately, however, these training protocols are often difficult to apply among older people because of their extended duration and/or required compliance.

Another way to improve motor performance is to apply a mechanical muscle vibration to the whole body (WBV) because it can activate proprioceptors and is a powerful input to motor control networks.[10] WBV parameters are commonly set at relatively low frequencies (~10–50Hz) and large amplitudes (~1–5mm).[11] This technique has been shown to enhance leg motor performance in untrained older people.[12] In particular, short-lasting stimulation induces a transient increase in electromyography activity, power output,[11,13] and blood circulation.[14] Long-lasting stimulation also improved gait, body balance, and functional capacity in the elderly.[15]

Although WBV seems to be a promising method to improve motor performance, there are pathological conditions, such as low back pain, joint damage, and circulatory problems, that could be worsened by WBV.[11,16,17] Moreover, it has been shown that significant effects can only be achieved after several weeks of treatment.[18] Last, WBV—by definition—does not permit targeted action on specific muscles, and the applied stimulus parameters change profoundly during their diffusion through body tissues,[19] reaching frequency and amplitude values that can become dangerous.[11,20]

Consequently, another vibratory technique has been proposed,[21,22] consisting of low-amplitude and high-frequency vibratory stimulation applied repetitively to a limited area of the body (rMV). This focal stimulation represents selective intervention that does not have negative effects and permits the use of higher frequencies (100Hz) than WBV, which are more specific and powerful for primary (Ia) spindle afferents.[23,24] Nonetheless, focal vibration has been shown to induce aftereffects lasting 30 to 60 minutes consisting of exacerbation of muscle fatigue[25] as well as postural shift.[26] Conversely, studies in patients presenting a hemispace deficit (neglect) show that rMV can induce sustained changes in their body representa-

List of Abbreviations

ACL	anterior cruciate ligament
COP	center of pressure
rMV	repeated muscle vibration
WBV	whole-body vibration

tion.[27,28] More recently, studies performed by our research group on young subjects[21,22] showed that long-term improvement of motor performance can be induced using a particular vibratory protocol. These enduring effects were achieved by applying rMV (100Hz) to contracted quadriceps in three 10-minute sessions for 3 consecutive days. As a result, knee extension performance (fatigue resistance, time of force development, strength) was enhanced in healthy young people for at least 2 weeks.[22] Moreover, by using the same protocol, stance and leg extensor muscle force were improved for several months in young subjects who underwent reconstruction of the ACL.[21] These positive results in young people convinced us to extend the rMV protocol to young-elderly subjects in an attempt to increase their motor performance and balance control. In these subjects, asthenia is an important issue limiting an active lifestyle and causing loss of balance, thus augmenting the tendency towards sedentariness and triggering a vicious circle that is potentially responsible for the increased risk of falls.

In this study, we performed a double-blind study in which a group of young-elderly women underwent rMV of the quadriceps muscle. Stance and leg muscle power were investigated at different times after the intervention to test the possible long-term efficacy of the rMV in young-elderly people.

Fig 1. Focal vibratory device and application site: vibrator tip was applied near the vastus medialis and the quadriceps tendons and pushed against the tissues to assure the propagation of mechanical stimuli into the muscle.

METHODS

We used a double-blind parallel-group study design. The study was conducted on a pool of 60 women randomized into 3 groups corresponding to the 3 different interventions; group assignment was performed by block randomization (Random Allocation Software,[a] free share).

Research Participants

The double-blind, randomized, controlled trial was conducted on 60 sedentary women volunteers over the age of 60 years who were recruited from the University of the Third Age of Perugia. The experimental protocol was designed according to the Declaration of Helsinki (1964) and was approved by the local ethics committee. All study participants provided informed consent. Three teams respectively performed intervention, data collection, and evaluation. The intervention team, the assessors, and those performing the analysis were all unaware of the research expectations and were masked from the study assignment; each subject was identified exclusively by a computer-assigned numerical code.

Exclusion criteria were the presence of cardiovascular, respiratory, neurologic, or musculoskeletal pathologies and/or other chronic conditions. Subjects on drug therapy that could alter their movement or spatial perception were also excluded from the study.

Participants were randomly assigned to 3 groups, each composed of 20 women: (1) the first group of participants underwent rMV on contracted quadriceps (vibrated and contracted group); (2) the second group of participants underwent rMV on fully relaxed quadriceps (vibrated and relaxed group); (3) the third group of participants, used as a control group, underwent false (placebo) vibratory treatment while the quadriceps was kept contracted (nonvibrated group). In this group, the vibrator was positioned close to the extensor tendon but without touching the skin. In this condition, the patients were subjected only to the faint buzzing sound of the vibrator. Like the subjects from the other groups, however, they were told that they were being treated with a vibrating electromagnetic device.

The intervention was not repeated during the 3-month follow-up period, and all the subjects continued their normal daily activities without introducing any extra type of physical training; this condition was monitored through periodic phone interviews.

Six subjects (10% of the study group: 2 from the vibrated and relaxed group, 1 from the nonvibrated group, 3 from the vibrated and contracted group) dropped out of the study at the second and third measurements because of personal problems. Statistical analysis was performed by including all available data or by excluding the dropout subjects' data. Because we did not find significant differences in the 2 statistical evaluations, the Results section reports only evaluations obtained by including all data.

Intervention

Vibration was applied simultaneously on the 2 legs close to the quadriceps tendon insertion (fig 1). Vibratory stimulation was applied to the quadriceps using a specific device[b] that consisted of an electromechanical transducer, a mechanical support, and an electronic control. The support was rigidly anchored to the floor to guarantee good mechanical contact with tissue. A mechanical arm allowed the transducer to be placed on the distal end of vastus medialis and the common tendon of rectus and intermedius femoris at about 2cm from the medial edge of the patella (see fig 1), as also described in previous studies.[21,22] Soft tissues were compressed to ensure better transmission of vibrations to the quadriceps muscles. The transducer applied perpendicular to the muscle, near its distal tendon insertion, generated a 0.2-mm to 0.5-mm peak-to-peak sinusoidal displacement. Vibration frequency was set at 100Hz. Vibration amplitude was evaluated using a light X-Y infrared sensor detecting the displacement of an infrared light emitting diode placed orthogonally on the lateral face of the vibrator tip.

During vibratory stimulation, the participants were supine and contracted the quadriceps. To maintain this contraction, the subjects were asked to keep the popliteal cavum in contact with the bed because, based on previous experiments,[21,22] specific contraction intensity during vibratory application does not appear to be important. The assessors monitored muscle contraction throughout the entire series of applications.

Mechanical stimulation was applied over 3 consecutive days. Each of these applications lasted 30 minutes; for every 10

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