ORIGINAL ARTICLE

Functional Performance and Inflammatory Cytokines After Squat Exercises and Whole-Body Vibration in Elderly Individuals With Knee Osteoarthritis

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ABSTRACT. Simão AP, Avelar NC, Tossige-Gomes R, Neves CD, Mendonça VA, Miranda AS, Teixeira MM, Teixeira AL, Andrade AP, Coimbra CC, Lacerda AC. Functional performance and inflammatory cytokines after squat exercises and whole-body vibration in elderly individuals with knee osteoarthritis. Arch Phys Med Rehabil 2012;93:1692-1700.

Objective: To investigate the effects of squat exercises combined with whole-body vibration on the plasma concentration of inflammatory markers and the functional performance of elderly individuals with knee osteoarthritis (OA).

Design: Clinical, prospective, randomized, single-blinded study.

Setting: Exercise physiology laboratory.

Participants: Elderly subjects with knee OA (N=32) were divided into 3 groups: (1) squat exercises on a vibratory platform (platform group, n=11); (2) squat exercises without vibration (squat group, n=10); and (3) the control group (n=11).

Interventions: The structured program of squat exercises in the platform and squat groups was conducted 3 times per week, on alternate days, for 12 weeks.

Main Outcome Measures: Plasma soluble tumor necrosis factor-α receptors 1 (sTNFR1) and 2 (sTNFR2) were measured using immunoassays (the enzyme-linked immunosorbent assay method). The Western Ontario and McMaster Universities Osteoarthritis Index questionnaire was used to evaluate self-reported physical function, pain, and stiffness. The 6-minute walk test, the Berg Balance Scale, and gait speed were used to evaluate physical function.

Results: In the platform group, there were significant reductions in the plasma concentrations of the inflammatory markers sTNFR1 and sTNFR2 ($P<.001$ and $P<.05$, respectively) and self-reported pain ($P<.05$) compared with the control group, and there was an increase in balance ($P<.05$) and speed and distance walked ($P<.05$ and $P<.001$, respectively). In addition, the platform group walked faster than the squat group ($P<.01$).

Conclusions: The results suggest that whole-body vibration training improves self-perception of pain, balance, gait quality, and inflammatory markers in elderly subjects with knee OA.

Key Words: Cytokines; Osteoarthritis, knee; Rehabilitation; TNF receptors.

OSTEOARTHRITIS (OA) IS a slow and progressive disease that is characterized by the degradation of articular cartilage and subchondral bone.[1,2] The degradation of articular knee cartilage in OA causes an inflammatory process (ie, the release of cytokines and the endogenous mediators of inflammatory reactions) that is responsible for the proteolytic digestion of articular cartilage.[3,4]

Studies have shown that OA is associated with high serum levels of inflammatory markers, including tumor necrosis factor-α (TNF-α) and the soluble receptors of TNF-α (sTNFR1 and sTNFR2).[1,2,5] According to Penninx et al,[3] high levels of soluble TNF-α receptors were associated with decreased physical function, increased OA symptoms (eg, pain and stiffness), and worse radiographic scores in elderly, obese individuals with knee OA.

Although the process of articular cartilage degradation is considered to be irreversible, it is known that it can be stabilized or slowed with physical activities that build strength and proprioception in the lower limbs.[4,6,7] The greatest challenge of conservative OA treatment in the elderly is to find physical activities that act within the therapeutic window (ie, the load is high enough to be effective but not high enough to cause joint

List of Abbreviations

BMI	body mass index
g	gravity
IL	interleukin
OA	osteoarthritis
sTNFR1	soluble tumor necrosis factor-α receptor-1
sTNFR2	soluble tumor necrosis factor-α receptor-2
sTNFRs	soluble receptors of tumor necrosis factor-α
TNF-α	tumor necrosis factor-α
TNFR1	cell surface tumor necrosis factor-α receptor-1
TNFR2	cell surface tumor necrosis factor-α receptor-2
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

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deterioration). Within this perspective, whole-body vibration training has been recommended as an efficient and safe tool for building muscle strength[8,9] and proprioception[8] in older women with knee OA.[10] Whole-body vibration training is achieved on a vibratory platform, and the amplitude is varied while the patient is either positioned orthostatically or performing dynamic movements (eg, squats with unipedal or bipedal support, or plantar flexion movements with feet supported over the platform).[11,12]

There is a gap in the literature concerning the capacity of whole-body vibration training to minimize inflammatory components or to prevent functional decline and disease progression in elderly individuals with knee OA. The purpose of this study was to investigate the effects of squat exercises combined with whole-body vibration on the plasma concentration of inflammatory markers and the functional performance of elderly individuals with knee OA. Because the vibratory stimulus strengthens the lower limbs[8,9] and improves proprioception[8] in elderly patients with knee OA by inducing isometric, concentric, and eccentric contractions of the hip and knee extensor muscle groups and the plantar flexors, it was hypothesized that the subjects in the platform group, which involved squat exercise training along with whole-body vibration, would have better control and execution of functional movements, such as those required for balance and gait performance, compared with the control (which did not receive training) and the squat (which involved squat exercise training without whole-body vibration) groups. In addition, the combination of squat exercises and whole-body vibration would improve the stability of the knee affected by OA by reducing the inflammatory joint process and, consequently, the self-perception of pain.

METHODS

This prospective, randomized, single-blinded study assessed variables immediately before and after a 12-week training program. For the allocation of participants, a 1:1 ratio randomization was performed using opaque envelopes for the concealment of allocation. To minimize the chance of bias, opaque, sealed, and serial-numbered envelopes were used that were opened sequentially (only after the participant's name and further details were written on the envelope) and kept in a locked, secure place. The allocation sequence was concealed from the researcher who enrolled and assessed participants. Only 1 researcher was aware of the group assignments when performing the randomization. This study was approved by the Scientific Ethics Committee of the Federal University of Jequitinhonha and Mucuri Valleys (protocol n° 001/08).

To participate in the study, patients had to be 60 years or older and have a diagnosis of OA in at least 1 knee based on the clinical and radiographic criteria of the American College of Rheumatology[13]: (1) knee pain for most of the days in the previous month; (2) osteophytes at the joint margins on radiographs; (3) synovial fluid typical of OA (laboratory); (4) age 40 years or older; (5) crepitus on active joint motion; and (6) morning stiffness lasting 30 minutes or less. The subjects could only receive a diagnosis of knee OA if the following American College of Rheumatology criteria were present: criteria 1 and 2; criteria 1, 3, 5, and 6; or criteria 1, 4, 5, and 6.

The severity of the knee OA was classified radiographically according to the Kellgren-Lawrence scale (grades 0–4: 0, normal; 4, severe OA). Grade 2 (definite osteophytes and possible narrowing of the joint space) was used as a cutoff to classify knee OA.[14,15] Exclusion criteria were the following: (1) recent knee trauma; (2) use of any device to assist locomotion (eg, walking sticks, crutches, walkers); (3) physiotherapy treatment or any other rehabilitation procedure in the last 3 months; (4) the absence of the minimum clinical and cognitive conditions for performing physical activities; and (5) use of glucocorticoids for at least 2 months before beginning the study. Patients were also excluded if they had the following: orthopedic disease; neurologic, respiratory, or acute cardiac issues that prevented the performance of the required exercises; vestibular disorders; immunosuppression or immunodeficiency; lack of sphincter control (anal and bladder); or cognitive deficits, as determined by a lower score on the Mini-Mental State Examination than obtained by other patients with the same education level.[16] This examination consists of 6 categories, which include memory, spatial orientation, temporal orientation, judgment, problem solving, and reasoning. Each category is scored from 0 to 3. The sum of the scores obtained in each category is determined, and higher scores signify lower cognitive impairment. The cutoff point was 13 for illiterate subjects, 18 for subjects with 1 to 3 years of education, 23 for subjects with 4 to 7 years of education, and 26 for subjects with more than 7 years of education.

A total of 125 elderly patients were evaluated, and 35 (4 men, 31 women) met the criteria for inclusion and participated in the research. Once included in the study, volunteers were randomly distributed into 1 of 3 groups: the platform group (n=12), which involved squat exercise training along with whole-body vibration; the squat group (n=11), which involved squat exercise training without whole-body vibration; and the control group (n=12), in which the members did not receive training and were instructed not to change their lifestyle during the study or engage in any new type of physical activity. To ensure the maintenance of patients in the control group, weekly phone calls were made to each group member to confirm his/her routine activities. Thirty-two of the 35 elderly individuals completed the study and were reassessed after the 12-week training period (fig 1).

Procedures

Clinical and demographic data related to the participants were initially collected, and all study patients (platform, squat, and control groups) underwent a clinical evaluation and blood sample collection before the initiation of the 12-week interven-

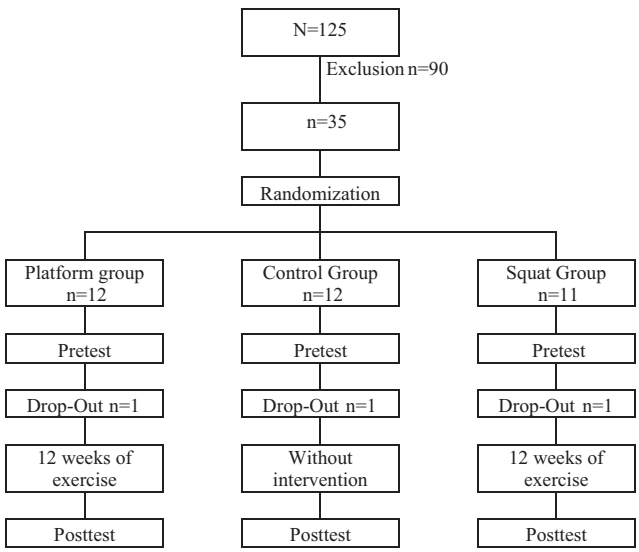

Fig 1. Study flowchart. Pretest and posttest correspond to the periods immediately before and after the training, respectively.