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ORIGINAL PAPER

Whole-body vibration on lower limb flexibility and extensibility – a randomized clinical trial

Carla Cristina da Silva Morais, Gabriele Favaro Misiak, Ligia Maria Santin, Alberito Rodrigo de Carvalho, Gladson Ricardo Flor Bertolini

Universidade Estadual do Oeste do Paraná, Paraná, Brasil

ABSTRACT

Introduction and aim. The whole-body vibration has become known for optimizing the production of muscle power due to mechanical oscillations that are dependent on vibration frequency. However, the effects of varying the vibration frequency on flexibility have still been little explored. Compare the effects of two frequencies of whole-body vibration on flexibility and extensibility of the lower limbs.

Material and methods. Randomized clinical trial with a sample of 42 young adult volunteers of both sexes, who performed squatting sessions with individualized load on a platform and distributed into three groups of vibration frequency: control group (CG), with the platform off; low frequency group (LF), with a frequency of 30 Hz; high frequency group (HF), with a frequency of 45 Hz. In total, the intervention was carried out in 12 sessions and lasted 6 weeks, with 2 sessions per week. Flexibility, evaluated before and after the intervention by the sit and reach test (Wells bench) and by evaluating the extensibility of the ischiotibials by goniometry.

Results. No statistical differences were observed for any of the outcomes evaluated.

Conclusion. None of the proposed frequencies produced gains in flexibility and extensibility of the lower extremities and there was no superiority of one frequency over another.

Keyword. musculoskeletal abnormalities, physical therapy modalities, range of motion

Introduction

The term fascia refers to flat layers of dense tissue, such as aponeuroses, joint capsules, dura mater, periosteum, neurovascular sheaths, epimysium, perimysium, and endomysium among others.[1] Taking into account the muscle fascia, the epimysium is the external layer that covers the muscle, making it an individual organ. Internally, the division into fascicles is performed by a continuous connective tissue network called the perimysium; and finally the endomysium encompasses the fibers individually, and these structures connect and coordinate muscle elements through cellular signaling that involves connections between the sarcolemma and the fascia through integrins.[2,3]

In view of its thickness and rigidity characteristics, the main restrictor of passive stretching is the perimysium and, to a lesser extent, the endomysium, which are tissues that undergo adaptations to muscular exercise, disuse, and injury, that is, they limit muscle extensibility and, in this way, flexibility. Joint flexibility is characterized by the range of motion available for the joint to move effectively without producing injury; stretching exercises are generally used for this purpose.[2,4] There are several exercises that can influence flexibility, thus gen-

Corresponding author: Gladson Ricardo Flor Bertolini, e-mail: gladsonricardo@gmail.com

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erating benefits such as reducing the risk of falls, preventing pain and injuries especially active and passive stretching exercises.[5,6]

Physical exercise produces an increase in local blood flow, leading to an increase in temperature, an important factor for the gain of muscle extensibility.[7–10] One of the forms of physical exercise is whole-body vibration (WBV); the modality has shown improvement in physical performance due to improved synchronization of motor units, potentiation of the stretch reflex, increased activity of synergist muscles and inhibition of antagonists.[11–16] The WBV is an electronic device that generates real possibilities of muscle strength gain and even indicated for flexibility gains.[11,12,17,18] And, despite being controversial, some authors point out that WBV promotes flexibility gains.[18–26]

Aim

Since fascia remodeling can occur due to the stress imposed by physical exercise, the objective of this study was to compare the repercussions of two frequencies of WBV on the flexibility and extensibility of the lower extremities, in nonathletic individuals over the long term.

Material and methods

Study design and recruitment

This study was classified as a blind (participant), parallel, randomized, placebo-controlled clinical trial following the recommendations of the Consolidated Standards of Reporting Trials (CONSORT), was published in the Brazilian Registry of Clinical Trials (ReBEC – RBR-4rrn7cf). The study was approved by the Ethics Committee on Research Involving Human Beings of the Universidade Estadual do Oeste do Paraná and registered under protocol number 5.269.114. All volunteers signed an informed concept for their participation in the study.

Volunteers were recruited in a non-probabilistic and consecutive way. Young adults aged between 18 and 30 years, not practicing systematic physical activities, of both genders were included. The dissemination of the study was done by digital means and personal approaches in the surroundings of the University where the research was developed. Volunteers with neurological and cognitive problems, cardiorespiratory diseases, and a history of joint or muscle injuries in the last six months were not included. The exclusion criterion for data analysis was the withdrawal of the volunteer's authorization to participate in the study.

Randomization and blinding

Volunteers were randomly assigned to three intervention conditions according to the frequency imposed by the WBV. The distribution between the intervention frequencies was paired with respect to sex.

In all, 42 volunteers were randomly separated into 3 interventions, according to the frequency applied on the vibration platform: 30 Hz group (LF), 45 Hz group (HF), and control group (CG).

The randomization process was performed by a researcher not involved in any other stage of the study and assigned to this process only. The randomization list was generated electronically using GraphPad QuickCalcs software.

Outcomes

The endpoints of the study were posterior chain flexibility and hamstring extensibility.

To evaluate the flexibility of the posterior chain, the Sit and Reach test (Wells bench) was applied, and to evaluate the extensibility of the hamstrings, goniometry was performed.

In the evaluation with the Wells bench, the volunteer sat on an EVA tatami with knees extended and bare feet, leaning his entire plantar surface on the Wells bench. After the command, with arms extended, the left one above the right, and the chin close to the chest, the trunk flexion was performed in an attempt to reach the greatest possible distance indicated on the ruler of the Wells bench. The individual performed three trunk flexions without destabilizing or compensating for knee flexion. At the moment of maximum reach, the volunteer held the position for two seconds and returned to the initial posture, repeating the act two more times with a 10 s interval between them. The best reach result among the three was considered.

A universal double arm goniometer was used to analyze the muscle extensibility of the tibial ischii. The goniometer is a valid and highly reliable tool in measuring the range of motion (ROM) of the knee joint. The inter-tester reliability of the goniometer is 0.977–0.982 and the intra-tester reliability is 0.972–0.985.[27] The extensibility of the ischiotibial muscles was measured by the degree of limitation in the ROM of knee extension. Volunteers were placed in the dorsal decubitus that supported the hip joint in 90° flexion. After that, they were asked to extend the knee actively until their maximum fitness, keeping the hip joint fixed at 90°. The goniometer axis was positioned at the lateral epicondyle of the femur, the fixed arm toward the greater trochanter of the femur, and the mobile arm parallel to the fibula toward the lateral malleolus.

Methodological procedures

The evaluations took place on three occasions over time: (EVA1) familiarization, (EVA2) pre-intervention; (EVA3) post-intervention.

Familiarization (EVA1): On the first visit, an interview was conducted to record the physical and functional history of the volunteers, as well as their anthropometric measurements. The following measurements and information were recorded: age (years), body mass (kg), height (m), lower limb length (m), sex, body mass index (BMI), and self-reported level of physical activity. Volunteers were familiarized with the evaluation procedures to minimize the learning effect. The familiarization data was not computed for the statistical analyses. The first visit preceded the second visit by a minimum of 72 h and a maximum of 120 h.

Pre-intervention (EVA2): the volunteers were re-evaluated, in relation to the measures corresponding to the study outcomes, in the same way as during familiarization, between 72 h and 120 h of the latter and before the beginning of the intervention.

Post-intervention (EVA3): the volunteers were evaluated in an identical manner as practiced at familiarization, between 24 h and 48 h after the end of the intervention.

Intervention

In total, the intervention was carried out in 12 sessions and lasted 6 weeks, with 2 sessions per week. Each session lasted an average of 20 minutes, at the same hour of the day.

Squat

The intervention common to all groups was the squat. In the familiarization session the volunteer was asked to perform as many squats as possible, up to the point of fatigue (the goal was for individual protocol planning of training exercises), within a hip range that varied from 180° in the standing position to 70° in the squatting position, delimited by a band attached to two cones.

The volume of squats during the interventions was based on the percentage of the maximum number of squats obtained, individually, in the familiarization assessment. The percentage was increased in the program throughout the 12 sessions. With changes in the percentage of maximum squats from 50% to 80% between sessions one through eight and 80 to 90% for the last four sessions. The rhythm of the movement was controlled by a metronome. In each session a series of squats was performed.

In cases in which the volunteers did not reach the range that delimited the amplitude stipulated for the squat or did it out of the tempo determined by a metronome three consecutive times, it was determined that the volume of squats stipulated for the following week would remain the same during the current week, in order to control the external load.

Vibratory platform

The vibrating platform, the Power Plate® model, was used so that the vibration ran through the entire body of the volunteers during squatting movements, which were performed on the platform.

The volunteers performed a series of squats at an angle of 70º, identical to the baseline evaluation. To adapt to the desired angle, two cones were placed next to the vibration platform, with a strip connected to the top of each, indicating that squatting could not exceed this limit, which was adjusted for each individual, with respect to their body differences. The parameters set for the whole body vibration were an amplitude of 2 mm, at a frequency of 30 Hz for the LF and 45 Hz for the HF. The CG performed the same squatting protocol on the platform, but with it turned off.

Statistical analysis

The SPSS 20.0 software (IBM, Chicago, USA) was used for statistical analysis, with data presented as mean and standard error, and inferential analysis using a mixed univariate ANOVA and ANOVA model, the level of significance adopted was 5% ($\alpha=0.05$). Cohen's effect size d was also analyzed, based on EV1 and the last assessment (EV3).[28]

Results

Volunteer recruitment took place from March to May 2022, and during those 8 weeks 42 positive responses were obtained. Seven of these volunteers were excluded, 2 due to external musculoskeletal injuries, 1 due to SARS-COV-2 contamination, and 1 due to dropout. The remaining 38 volunteers were distributed in HFD group (n=14; 8 women); in LF (n=13; 8 women) and CG (n=11; 7 women). No significant differences were found in age or BMI. The sample characteristics are presented in Table 1.

Table 1. Sample characterization data (mean and standard deviation values)

	High-Frequency	Low-frequency	Control	p
Age (years)	20.8 ± 0.4	21.2 ± 0.4	21.5 ± 0.4	0.518
BMC (kg/m²)	26.5 ± 1.4	25.1 ± 1.4	24.9 ± 1.5	0.687

No statistical differences were observed for any of the evaluated outcomes (Wells bench – $F(1,453; 50.8)=1.358$, $p=0.189$ (Fig 1A); goniometry – $F(2; 70)=1.652$, $p=0.6$ (Fig 1B)) (Table 1). The effect sizes observed for the Wells bench were: null for HF (ES=0.07) and CG (ES=0.08), very small for LF (ES=0.14). For goniometry the values were: very small for HF (ES=0.17), null for LF (ES=-0.06), and small for CG (ES=0.39). The mean values can be seen in Figure 1.

Discussion

The present study examined the effects of the vibrating platform on the flexibility of the posterior chain and the extensibility of the ischiotibial muscles in healthy young people. The hypothesis of the study was that the use of

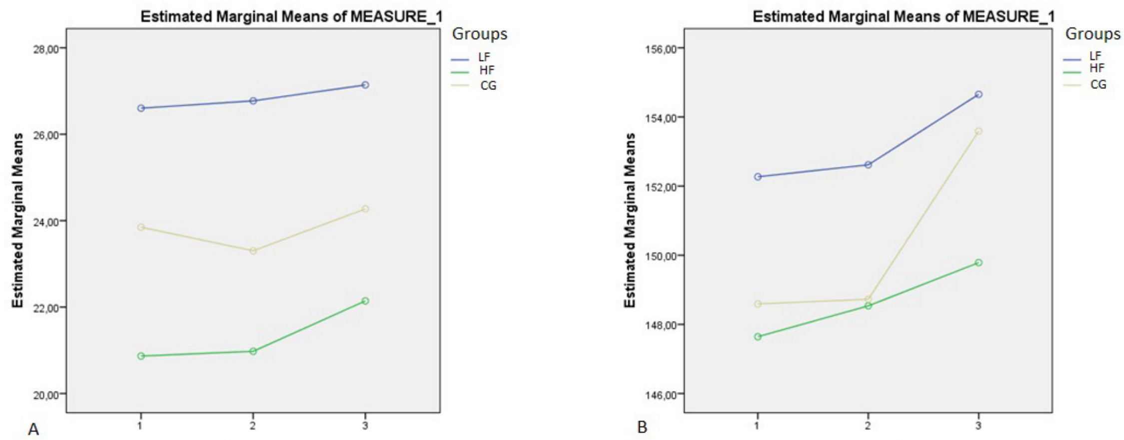

Fig. 1. Graphic representation of the values observed for the different groups (LF, HF, and CG) at the different evaluation times (1, 2, and 3), for the Wells bench (A) and goniometry (B)

WBV, using two frequencies of intervention (30 Hz and 45 Hz), combined with squatting exercise, would contribute to the improvement of the outcomes investigated; however, this hypothesis was not supported because no differences were observed in any of the groups.

The study by Cochrane et al. was positive toward the acute effect of the vibrating platform on flexibility, improving in 8.2% the sit and reach test.[19] The authors justified that the vibration effect promotes the stimulation of the primary endings of the muscle spindles, which in turn activate the stretch reflexes of the motor neurons of the agonist muscle and thus inhibit the antagonist muscle (hamstrings). The authors believe that activation of inhibitory interneurons of the hamstrings decreased the braking force of the hip and lumbar joints, thus facilitating greater reach. Another possible explanation is that vibration can cause muscle heating, which generates an increase in muscle extensibility, so that thixotropism and vasodilation together decrease blood viscosity, and thus increase its displacement. Finally, they mention that vibratory waves reduce the muscle and tendon pain threshold, generating increased tolerance to muscle stretch, allowing greater amplitude. It should be taken into account that the frequency used was 26 Hz and the amplitude was 6 mm, yet the exercises were in different ways, including actively stretching the ischiotibial muscles, i.e., different parameters from those presented in this study.

Dallas et al. analyzed the short-term acute effect of WBV in young gymnasts and observed gains in the sit and reach test (similar to the Wells bench).[29] In another study, Dallas and Kirialanis, again verified gains in flexibility when associating and even without associating WBV with muscle stretching.[23] Dallas et al. verified the effect in divers and again verified flexibility gains at 30 and 50 Hz.[24] Despina et al. used WBV exercises or only resisted exercises in rhythmic gymnasts (30 Hz, 2mm of amplitude) and also reported gains in flexibility.[25] Similarly, Fagnani et al., in a protocol of 8 weeks (three times a week) of WBV (35 Hz and 4 mm of displacement) with 26 competitive athletes of different sports, observed improvements in strength, jumping, and flexibility, evaluated by the sit-and-reach test.[20]

Of the studies cited above, it should be taken into consideration, that the volunteers were athletes, unlike the present study in which the volunteers were not athletes, which may be a factor that led to different results. In healthy, but elderly individuals, Tseng et al. report gains in flexibility after three months of treatment and even in the segment in six months, but it is worth mentioning that it is a population with characteristics of loss of amplitude (elderly), that is, they have greater possibilities of gaining still within the flexibility considered normal.[22] Still, analyzing nonathletes without underlying diseases, Gerodimos et al. analyzed the acute aspect of WBV (15, 20 and 30 Hz, 6 mm amplitude) on flexibility, indicating immediate advantages that lasted up to 15 minutes, but the gap of the long-term effects remained.[26] In the study by Marmitt et al., with three volunteers using WBV (30 Hz) aiming to increase muscle mass and flexibility, during 60 days, twice a week, performing: squat, back squat, sumo squat, bridge over the shoulders, and toe lifting.[21] They did not observe differences between the initial and final time, similar to what was found in this study.

Although some studies show that resistance exercise combined with the vibration platform can help increase flexibility, the present study did not show improvement. Therefore, we speculate that the WBV parameters, such as frequency, amplitude, exercise protocol, and even previous conditioning of volunteers, can interfere with the gain of muscle extensibility that would reflect in joint flexibility, noting that in this study there was no stretching before or after the application of the vibration resource. We suggest that future studies not only evaluate the association with stretching, but also analyze whether different frequency ranges can interfere with disease processes such as osteoarthritis.

Conclusion

None of the proposed frequencies produced gains in lower limb flexibility and extensibility, and there was no superiority of one frequency over another. However, one must take into consideration limitations such as the study population, the performance of only subacute analyses, without long-term follow-up.

Declarations

Funding

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Author contributions

Conceptualization, A.R.C. and G.R.F.B.; Methodology, C.C.S.M., G.F.M., L.M.S., A.R.C. and G.R.F.B.; Software, A.R.C. and G.R.F.B.; Validation, A.R.C. and G.R.F.B.; Formal Analysis, C.C.S.M., G.F.M., L.M.S., A.R.C. and G.R.F.B.; Investigation, C.C.S.M., G.F.M. and L.M.S.; Resources, A.R.C. and G.R.F..B.; Data Curation, A.R.C. and G.R.F.B.; Writing – Original Draft Preparation, C.C.S.M., G.F.M. and L.M.S.; Writing – Review & Editing, A.R.C. and G.R.F.B.; Visualization, C.C.S.M., G.F.M. and L.M.S.; Supervision, G.R.F.B.; Project Administration, A.R.C.; Funding Acquisition, A.R.C. and G.R.F.B.

Conflicts of interest

The authors have no conflicts of interest to declare.

Data availability

The data remains in the possession of the authors and can be presented if requested.

Ethics approval

The study was approved by the Ethics Committee on Research Involving Human Beings of the Universidade Estadual do Oeste do Paraná and registered under protocol number 5.269.114.

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