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Effect of whole-body vibration frequency on objective physical function outcomes in healthy young adults: Randomized clinical trial

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Whole-body vibration (WBV) is used to improve muscle function but is important to know if doses can affect the objective function outcomes.

Objective: To compare the effect of two frequencies of WBV on objective physical function outcomes in healthy young adults.

Methods: Forty-two volunteers were randomized into three groups: sham group (SG), and WBV groups with 30 (F30) and 45 Hz (F45). A 6-week WBV intervention protocol was applied by a vibrating platform twice a week, with the platform turn-off for SG and with two frequencies according to group, 30 or 45 Hz. The objective physical functions outcomes assessed were the proprioceptive accuracy, measured by proprioceptive tests, and quasi-static and dynamic balances, measured by Sensory Organization Test (SOT) and Y Balance Test, respectively. The outcomes were assessed before and after the WBV intervention. We used in the results comparisons, by GzLM test, the deltas percentage.

Results: After the intervention, no statistical differences were observed in percentage deltas for any outcomes (proprioceptive accuracy, quasi-static and dynamic balances).

Conclusion: Objective physical function outcomes, after the 6-week WBV protocol, did not present statistically significant results in any of the intervention groups (F30 or F45) and SG.

1. Introduction

Several functional limitations can be measure by the performance-based in physical function in tests that assessment individual's performance on a variety of daily tasks (Harkey et al., 2020). Objective physical function measures can help physiotherapists to improve both, functional diagnostics, and intervention effectiveness, being proprioception and balance examples of physical functions outcomes.

Proprioception sends constant somatosensory information to the central nervous system by internal receptors located in muscle spindles, tendons, and joint to differentiate joint position and motion (Oliver et al., 2021). Therefore, the capture of somatosensory information enables the body perception itself in space, in addition to continuous monitoring of the motor sequences, assisting in the movement's coordination and static and dynamic balance (Krö et al., 2021).

The use of whole-body vibration (WBV) has been investigated as a form to stimulate muscle plasticity, mainly to treat muscle diseases and deficits as well to improve proprioceptive feedback effectiveness and consequently, balance and motor function (Li et al., 2021a; Saquetto et al., 2015; Sierra-Guzmá et al., 2018a). It knows that WBV improves muscle function due to increased reflex activity from stimulation of the muscle spindle system and increased corticomotor excitability (Zheng et al., 2019).

Training with WBV requires to perform static or constantly controlled exercises on an oscillating platform, which can be regulated regard to amplitude and frequency parameters. (Zheng et al., 2019). In general, the oscillating platform allows one to choose oscillation amplitude between 2 and 10 mm and frequencies between 12 and 50 Hz. In addition to combining amplitude and frequency variables to determine the dose, it is possible to prescribe the training periodization manipulating the number of sets per session, weekly training frequency and total duration of the training program (Oliveira et al., 2011; Stania

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et al., 2016; Alam et al., 2018). Although a clinical trial (Oliveira et al., 2011)did not observed improvements in lower limb muscle performance in athletes as consequence of the association between training and WBV, with the dose combining 4 mm amplitude and 35 Hz frequency, there are a lack in literature if variations on dose frequency could optimize the influence in muscle function aspects.

In addition, little is known about the neuromuscular effects caused by WBV and the practical application of these reflexes in proprioception and balance training in healthy individuals, because the improvement in balance has already been observed in specific population samples, such as athletes with ankle instability (Sierra-Guzmá et al., 2018b), adults with Parkinson's disease (Li et al., 2021b) and children with CP sequelae (Saquetto et al., 2015). Based on this, the present study aims to compare the effect of two frequencies of WBV on objective physical function outcomes in healthy young adults. The hypothesis was that WBW could improve objective physical function measures compared with sham condition and that high frequency could be better than low frequency.

2. Methods

2.1. Design, study ethics, recruitment, and randomization of participants

This study was classified as a clinical trial, parallel, randomized, placebo controlled, following the recommendations of the Consolidated Reporting Trials Standards (CONSORT), published in Registro Brasileiro de Ensaios Clínicos (ReBEC) with the number RBR-4rrn7cf, and was approved by an institutional Ethics Committee on Research involving Human Beings and registered under protocol number 4.042.935. All participants, after being informed about the objectives and procedures of the research, signed the informed consent form in two copies, with one copy belonging to them and the other to the researcher.

Volunteers were recruited in a no probabilistic and consecutive way. Young adults, aged between 18 and 30 years, who did not practice systematic physical activities, of both genders were included. The disclosure of the study was done by digital media and personal approaches in the surroundings of the university where the research was developed. We excluded participants with neurological or cognitive impairments, cardiorespiratory diseases, history of any acute orthopedic

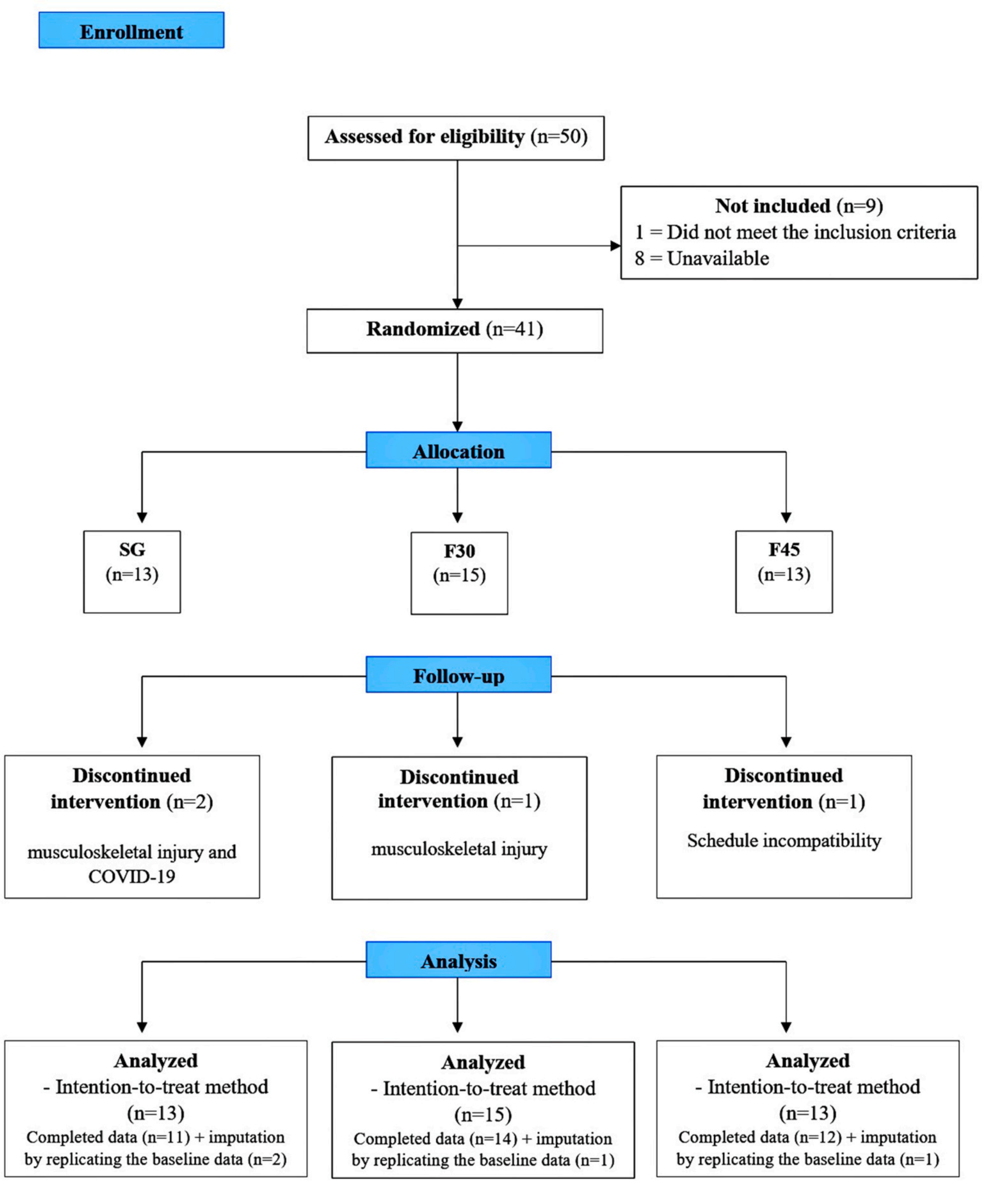

Fig. 1. Study flow chart for the distribution of volunteers into interventions.

and traumatological conditions in the lower limbs or spine in the last six months.

The volunteers were randomly divided into three interventions doses, according to WBV frequency, as follows: sham (SG), frequency 30 Hz (F30), frequency 45 Hz (F45) (explained in detail in the next item). The distribution between doses was paired with respect to gender.

The randomization process was performed by a researcher not involved in any other stage of the study and assigned only to the randomization process. The randomization list was generated electronically using GraphPad QuickCalcs Software. The recruitment process can be seen in Fig. 1.

2.2. Outcomes and evaluation procedures

The objective physical functions outcomes assessed were proprioceptive accuracy, quasi-static and dynamic balances, always by an evaluator who was blind to the group to which the volunteer belonged.

2.2.1. Proprioceptive accuracy

Proprioceptive accuracy was evaluated through joint position sense and kinesthesia, utilizing the slow passive movement perception test (Tpassive) and the joint position sense test (Tactive). The assessment procedures were adapted to determine joint angles employing kinematics (Carvalho et al., 2010). The experiments were conducted in a controlled recording environment, within a two-dimensional plane, employing an iPhone 12 Pro for data acquisition. The camera was strategically positioned at a distance ensuring comprehensive framing of the flexion-extension movement. Participants were attired in shorts exclusively to expose their lower extremities.

Initially, volunteers assumed a seated position on a stretcher to facilitate unrestricted movement of their feet. Three styrofoam markers, each measuring 3 cm in diameter, were affixed to the dominant lower limb at specific anatomical landmarks: the greater trochanter, lateral condyle, and lateral malleolus. A small pad was positioned under the popliteal fossa to facilitate movement, and a smartphone equipped with a goniometry application was securely fixed near the ankle to guide angulation variations. Subsequently, participants received instructions regarding the test protocols and execution positions, emphasizing the maintenance of a straight spine throughout the recording. To eliminate visual input, participants were blindfolded.

For passive measurements (Tpassive), predetermined angular variations of 30° and 60° were established. The first angular variation entailed the extension movement of the knee, originating from a 90° knee flexion. The second pertained to the flexion movement, commencing from a knee extension of 15°. The evaluator, guided by the goniometer, passively moved the volunteer's leg in an extension movement until reaching the predetermined angular variation for this motion. Once the target angular variation was attained, the limb was held at that angle for 10 s to familiarize the participant with the specific angle. Subsequently, the limb returned to the initial position of 90°. After a 15-s interval, the leg underwent three consecutive slow passive movements towards the same angle, each separated by 15-s intervals. The procedure was then repeated for the predetermined angular variation for knee flexion.

For the active test (Tactive), the volunteer, remaining blindfolded in the seated position, actively reproduced three pre-established angular variations: 20° knee extension, 30° knee flexion, and 60° knee extension. In the Tpassive test, the evaluator demonstrated one of the angular variations in the same manner as during familiarization. In the Tactive test, the volunteer actively replicated the angular variation while receiving verbal stimuli to concentrate on knee position, precluding the use of movement time as a strategy for repositioning. The Tactive test was conducted for the other two pre-established angles, with three executions for each angle.

Throughout both tests, volunteers were instructed to verbally communicate with the examiner and promptly halt the motion when their leg reached the desired target position. The angular variation was then recorded, saved, and stored on a computer. Each record was disassembled into frames, and the frames corresponding to the commencement of the test and the moment the volunteer ceased movement were processed using Kinovea software. This procedure was applied for both the familiarization phase and the effective angle reproduced. The objective was to verify the knee angle formed by lines connecting the three styrofoam markers. Statistical analysis involved the absolute difference between the angle recorded during familiarization and the effective angle reproduced for each angular variation target, defined as the 'error value.' All three measurements of the 'error value' were considered for each volunteer in each test.

2.2.2. Quasi-static balance

For the assessment of static phase balance, a Footwork Pro AM Cube baropodometer (AM3) was employed on a platform featuring 4098 (64 × 64) active capacitors arranged on a 490 mm × 490 mm active surface. This apparatus was integrated with the Footwork software, operating at a sampling frequency of 20 frames per second. Participants assumed a comfortable stance with their feet freely positioned side by side, arms parallel to the body, and eyes fixated on a stationary point situated 2 m away throughout the data collection. A 10-s accommodation period to the platform was allowed prior to recording initiation.

Each participant underwent evaluation using a modified test battery based on the Sensory Organization Test (SOT). The SOT, designed to assess visual, vestibular, and proprioceptive senses, comprises six sensory stages. Anteroposterior variations in the center of pressure (COP) were recorded by the baropodometer during each stage, reflecting somatosensory information influenced by visual and vestibular stimuli (Medeiros et al., 2003). Each stage was repeated three times, with a duration of 30 s per trial and a 30-s rest interval.

The six SOT stages were defined as follows:

(a) SOT I: Fixed platform, eyes open, and vision with a fixed reference (assessing visual, proprioceptive, and vestibular systems);
(b) SOT II: Fixed platform and eyes closed (assessing proprioceptive and vestibular systems);
(c) SOT III: Fixed platform, eyes open, and vision with an oscillating reference (assessing proprioceptive, vestibular, and visual systems);
(d) SOT IV: Oscillating platform, eyes open, and vision with a fixed reference (mainly evaluating the proprioceptive system);
(e) SOT V: Oscillating platform and eyes closed (assessing proprioceptive and vestibular systems under overload conditions);
(f) SOT VI: Oscillating platform, eyes open, and vision with an oscillating reference (evaluating proprioceptive, visual, and vestibular systems).

Visual stimuli with an oscillating reference were generated using virtual reality 3D glasses with moving black and white stripes. Platform oscillations were induced by a wooden platform mounted on springs at each corner. Anteroposterior displacements of the COP were quantified through graphic records from stabilometry using barepometric assessment (coordinates as a function of time for anteroposterior oscillations [COPap]) (Lomas Vega et al., 2005).

Before processing balance data, the center of gravity height (CGH) was estimated by measuring the distance from the floor to the spinous process of L2. Subsequently, for each evaluated SOT stage, the sine of angle α (representing COPap forward displacements) and the sine of angle β (representing COPap backward displacements) were determined (Loth et al., 2011). The schematic representation of this processing can be seen in Fig. 2.

Balance was expressed as percentage values, with 100% indicating no imbalance and 0% indicating a maximum fall or deviation from equilibrium of 12.5°. The equation for calculating balance was (Loth et al., 2011):

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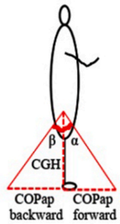

$$Sine\ \alpha = (COPap\ forward/\sqrt{(COPap\ forward)^2 + (CGH)^2}\,) + {}^{180}/_{\pi}$$

$$Sine\ \beta = (COPap\ backward/\sqrt{(COPap\ backward)^2 + (CGH)^2}\,) + {}^{180}/_{\pi}$$

Fig. 2. Description of equations to determine sines of angles α (forward direction) and β (backward direction).
Legend: anteroposterior centre pressure displacements in the forward direction (COPap forward); anteroposterior centre pressure displacements in the backward direction (COPap - backward); estimated of the center of gravity height (CGH); value = 3.14 (π).

$$Balance(\%) = 100 - (100 * [\alpha + \beta] / 12.5)$$

Since near-fall situations were not of interest in this study, it was assumed that in situations where the sum of angles α and β was greater than 11 (corresponding value of approximately 12 % in SOTs) the data were treated as missing.

For mathematical treatment, the balance data also were grouped in sensorial systems (Medeiros et al., 2003).

- Somatosensory system (SOM): (SOT II/SOT I)*100;
- Visual system (VIS): (SOT IV/SOT I.)*100;
- Vestibular system (VEST): (SOT V/SOT I)*100;
- Visual preference (PREF): ([SOT III + SOT IV]/[SOT II + SOT V]) *100.

Normality values for sensorial systems were adopted as greater than 92% for SOM, 88% for VIS, 67% for VEST, and 95% for PREF (Knijnik et al., 2019).

2.2.3. Dynamic balance

For dynamic balance assessment, the Y Balance Test (YBT) was employed to evaluate lower limb instability and unipodal dynamic balance in three directions of reach (Plisky et al., 2021). Prior to YBT, lower limb length was measured barefoot, using a tape measure from the anterosuperior iliac spine to the floor.

Three measuring tapes are affixed to the floor in a 'Y' shape, with the first tape placed anteriorly to the vertex and the other two aligned at 135° in the posteromedial and posterolateral directions. Each volunteer was first given a demonstration and instructions from the evaluator. They then positioned themselves at the intersection of the tape, with their support foot over the anterior, posterolateral, and posteromedial tapes junction, and performed unipodal support while the contralateral lower limb reached the maximum distance in each direction. One attempt was made in each direction. If the supporting foot was moved during the test, the volunteer's foot was repositioned and the test was repeated. Similarly, if the reaching foot did not reach the line, the individual repeated the movement. The distance reached by each lower limb in centimeters was recorded in each direction.

Finally, the composite average was calculated as the average of the distances achieved in each of the three directions. The results were presented as a composite score, which represents the achieved distance as a percentage of the length of the lower limb. The score was calculated using the following equation (Shaffer et al., 2013):

$$Composite\ Score = {}^{Composite\ average}/_{(3 * lower\ limb\ length)} * 100$$

2.3. Methodological procedures

The evaluations took place on three occasions in time: (i) baseline, (ii) pre-intervention; (iii) post-intervention.

2.3.1. Baseline

After recording the sample characterization variables such as age (years), height (m), and body mass (kg), the volunteers were familiarized with the evaluative procedures described previously, aiming to minimize the learning effect. The familiarization data were not computed for the statistical analyses.

To determine the maximal squat volume used in the periodization of the intervention, by the exhaustion squat test (EST), the volunteers were asked to perform the maximum number of squats to exhaustion in a hip flexion amplitude range between 180° and 70°, delimited by fixed bars at the limits of the amplitude range. The pace of execution was determined by a metronome, and it was the same for all volunteers. The intensity of the test corresponded to the Borg scale description, as "Slightly Tiring", which is equivalent to the numerical classifications 13 and 14 within a 20-point scale (Borg, 1982). The time until the test interruption was computed, as well as the number of repetitions performed.

The volunteers who did not reach the bars that delimited the test amplitude, or who did it out of the time determined by the metronome, at three consecutive times, the test was interrupted and only the data that followed the test protocol correctly were counted.

2.3.2. Pre-intervention

The volunteers were re-evaluated, regard to the outcomes, in identical way as in baseline section, between 72 and 120 h of the latter and before the beginning of the intervention.

2.3.3. Post-intervention

The volunteers were re-evaluated, regard to the outcomes, in identical way as in previous sections, between 24 and 48 h after the end of the intervention.

2.4. Interventions

2.4.1. Whole-body vibration

The intervention was conducted in 12 sessions and lasted six weeks, with two sessions per week. The doses parameters set for the WBV, respecting the group to which the volunteer has been assigned, were amplitude of 2 mm and two different frequencies, 30 and 45 Hz (Fig. 3). Associated with the WBV (external load), all volunteers performed a squatting protocol over the oscillating platform with weekly progressive load, starting with 60% of the number of squats performed on the EST, increasing 5% every week, reaching, in the last week, the load of 90% of the EST. In sham condition, the volunteers did the same squatting protocol over the oscillating platform, but with it turned off. The internal load was obtained by collecting the level of perceived exertion (PSE) using the Borg scale of 6–20 (Borg, 1982).

2.5. Data processing

The data were treated by calculating the percentage change between the pre- and post-intervention occasions by the equation for all outcomes:

Fig. 3. Performing the squat exercise on the vibrating platform.

$$Delta\,percentage = \left(\left(\left.post\,intervention\,value\right)\middle/pre\,intervention\,value\right) - 1\right) * 100$$

2.6. Statistical analysis

SPSS 20 software was used for statistical analysis. The significance level adopted was 5% ($\alpha = 0.05$). For the intention-to-treat analyses, we decided to carry out the pre-intervention data from the participants that dropped out of the trial to their post-intervention timepoint, according to their original randomization, following an intention-to-treat protocol (McCoy, 2017).

The comparisons were made using the generalized linear model test (GzLM), which is based on maximum likelihood and uses Wald's chi-square test (Wald $\chi2$) to identify the effect of the variable in the generalized linear model. The Sidak test was used as a post hoc test.

3. Results

Based on a pilot study (Andrade Hidalgo Pibic and Rodrigo de Carvalho, 2023), which provided the effect sizes for the sensory systems evaluated by the SOT in a test and retest design, the smallest effect size found was 0.62. Considering a slightly smaller effect size than the latter study, the power of the a posteriori test for an effect size of 0.55 was calculated for the data set of the present study. The power of the a posteriori test found was 0.86.

The sample characterization data can be seen in Table 1.

No statistical differences were found for the proprioceptive accuracy tests percentage delta (Tpassive/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 1.817 and p = 0.403; Tactive/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 1.984 and p = 0.371). Descriptive statistics for proprioceptive accuracy scores at pre- and post-intervention, and percentage delta values according to intervention, can be seen in Fig. 3.

No statistical differences were observed in the percentage deltas for any of the SOT steps and for any of the sensorial systems evaluated (SOT I/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 0.569 and p = 0.752; SOT II/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 3.450 and p = 0.178; SOT III/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 4.066 and p = 0.131; SOT IV/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 0.710 and p = 0.701; SOT V/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 4.646 and p = 0.098; SOT VI/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 1.369 and p = 0.504; SOM/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 1.131 and p = 0.568; VIS/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 0.560 and p = 0.756; VEST/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 3.001 and p = 0.223; PREF/$\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 0.444 and p = 0.801). The descriptive statistics for the balance scores at pre- and post-intervention, and the percentage delta values, at each stage of the SOT and according to intervention can be seen in Fig. 4. The descriptive statistics for the sensorial systems evaluated can be seen in Fig. 5. It was observed that the averages of the sensorial systems were above the normal values.

No statistical differences were also found for the percentage delta of the dynamic balance test ($\chi2$ (Harkey et al., 2020; Oliver et al., 2021) = 0.659 and p = 0.719). The descriptive statistics for the results of the dynamic balance before and after the intervention, and the percentage delta values according to the intervention, can be seen in Fig. 6.

Table 1
Descriptive statistical analysis for sample characterization data (mean and standard deviation values).

	SG	F30	F45
Age (years)	21.5 ± 1.2	21.2 ± 2.2	20.8 ± 0.5
Body mass (kg)	71.6 ± 15.3	73.1 ± 16.0	75.8 ± 20.6
Height (m)	1.6 ± 0.0	1.7 ± 0.1	1.6 ± 0.1

Legend: sham group (SG), frequency 30 Hz (F30), frequency 45 Hz (F45).

4. Discussion

The present study verified the WBV on proprioceptive accuracy and quasi-static and dynamic balances in healthy young individuals, with the hypothesis that WBV would optimize both balance and proprioception (see Fig. 7). However, there was no influence of any of the applied frequencies on any of the analyzed outcomes, and therefore the hypothesis of the study was not confirmed. Unlike what was observed in some studies using WBV that observed improvements in balance and proprioception parameters, the samples consisted of individuals with different dysfunctions, such as orthopedic, rheumatological, neurological, and respiratory (Sierra-Guzmá et al., 2018a; Song et al., 2018; Gloeckl et al., 2021; Gusi et al., 2010); this may indicate that individuals without changes that impair the musculoskeletal system, directly or indirectly, do not gain advantages from such a resource, which doesn't mean that they can't have advantages in other physical skills.

These indications are corroborated by the findings of Pollock et al. (2011) who also found no advantages of WBV (30 Hz) and balance in healthy youngsters. Torvinen et al. (2002) using a 4-month protocol of WBV, in healthy young people, with frequencies ranging from 25 to 60 Hz, observed neuromuscular adaptations with increased muscle power, but no improvements in static or dynamic balance. However, even vibration when applied localized did not show effects in healthy individuals and after ACL ligamentoplasty (Nagai et al., 2018).

In this study, we chose the orthostatic position, with volunteers performing bilateral squat exercises, due to the ease of reproduction even for untrained individuals, but capable of generating physical stress on the quadriceps, when performed correctly and in a balanced manner (Slater and Hart, 2017), an important muscle in knee stabilization and proprioception (Arumugam et al., 2021). And yet that the association with WBV is presented as a resource that generates expressive increases in strength, power, and improved muscle activation, being a safe and well-tolerated resource (Stania et al., 2016; Alam et al., 2018). Thus, the training could have been intense, and thus even worsened proprioceptive characteristics (Proske and Gandevia, 2012; Proske, 2019; Ju et al., 2010), or only acted as a training aimed at improving muscle spindle action (Krö et al., 2021; Salles et al., 2015), a fact that was not observed in the results, once again, it should be noted that for healthy individuals who are not athletes.

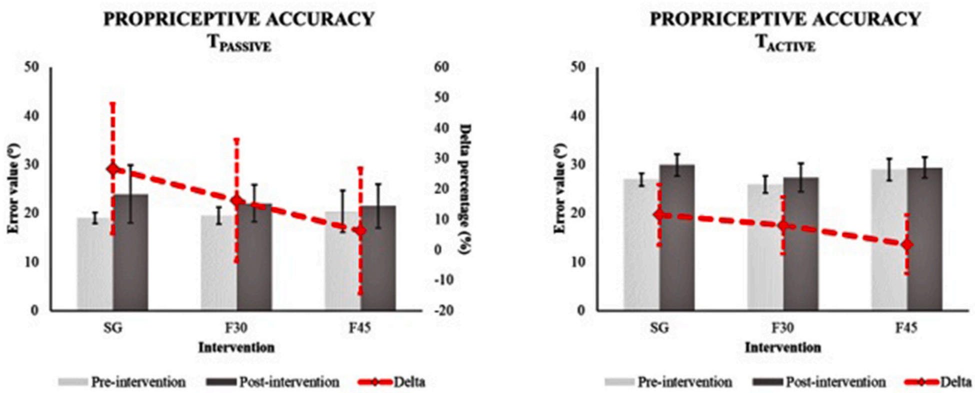

Fig. 4. Descriptive statistics, with means and 95% confidence interval, for proprioceptive accuracy data (left axis - vertical bars) and for percent delta values (right axis - thin bar) according to the intervention. Key: Passive proprioceptive accuracy test (Tpassive); Active proprioceptive accuracy test (Tactive).

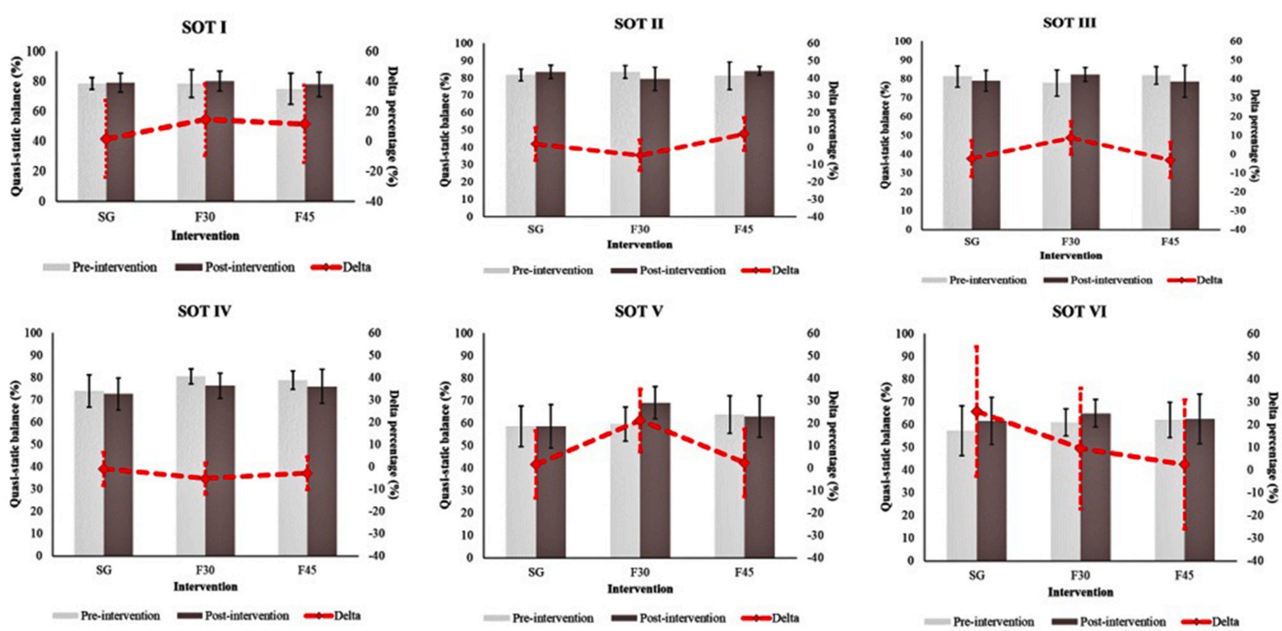

Fig. 5. Descriptive statistics, with means and 95% confidence interval, for the pre- and post-intervention quasi-static balance data (left axis - vertical bars) as well as for the percent delta values (right axis - thin bar) for each of the SOT conditions according to the intervention.

In the present study, for the evaluation of static and dynamic balance, an adaptation of the SOT was used under different conditions, altering vision and stability, which has already proven to be a useful instrument for balance evaluation, with a strong correlation with the displacement of the center of pressure analyzed by a force platform, being a cheap and relatively accessible instrument for offices (Loth et al., 2011). The delta percentage of SOT VI for the control group (CG) exceeded 20%. Although no justification was found for this variation occurring only in the CG, Oda and Ganança's study (Oda et al., 2015) suggests that in the absence of vision, proprioception of the ankles may decrease, making the vestibular system more demanding in the task of maintaining balance. Therefore, SOT V and SOT VI may be more unstable.

For the proprioceptive accuracy test, it is suggested that in future studies, the analysis can be performed using the Kinovea software, aiming to reduce the percentage of error in the angulation analyzed (Carvalho et al., 2010). For the analysis of balance with the Y test (Plisky et al., 2021) it was decided to perform only one attempt per angle in each lower limb, in each evaluation, in order not to fatigue or produce the accentuated effect of learning, since all the volunteers, prior to the first evaluation, had done a round of tests for familiarization.

There is still a lack of literature on the use of WBV to improve proprioceptive accuracy, quasi-static and dynamic balance in healthy young adults. Future studies can further explore this theme and the different types of WBV application, with different vibration parameters (frequency, amplitude and time) and ways of performing the exercise. For this study, an amplitude of 2 mm was used, similar to that already used in our laboratory with animal studies and which proved to be effective in improving muscle architecture (Zazula et al., 2020; Maciel et al., 2022; Peretti et al., 2020), with regard to frequency, we opted to follow the two cited by Minematsu et al. (2019) in which they observed only one of the advantages for increasing bone mass in growing animals. This is a major limitation of the study, since only one type of exercise was carried out, with few variations in the equipment parameters and only on healthy individuals, not athletes. The results obtained in this study may provide a basis for further research and physiotherapeutic treatments in young healthy individuals. Future studies on the ideal patterns of vibration to be used, regarding frequency, intensity, and pattern of protocol (intervention) in this clinical condition, can be carried out.

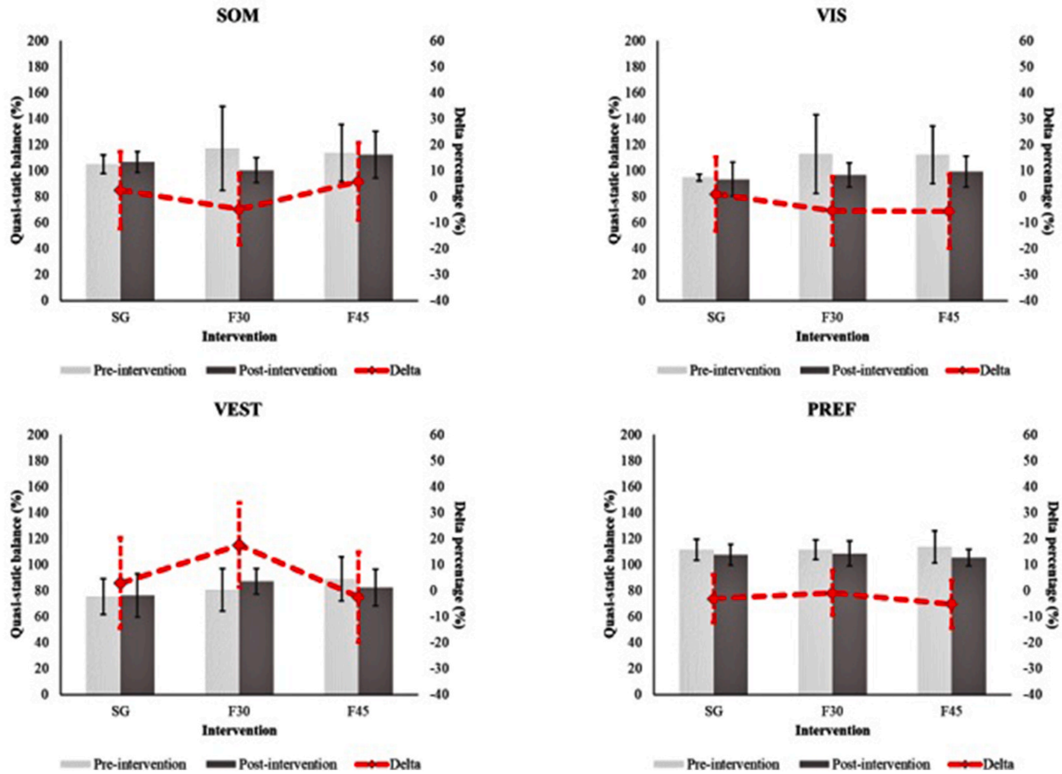

Fig. 6. Descriptive statistics, with means and 95% confidence interval, for the pre- and post-intervention quasi-static balance data (left axis - vertical bars) as well as for the percent delta values (right axis - thin bar) for each of the sensory systems according to the intervention. Key: Somatosensory system (SOM); visual system (VIS); vestibular system (VEST); visual preference (PREF).

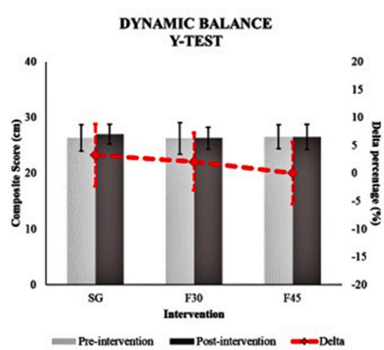

Fig. 7. Descriptive statistics, with means and 95% confidence interval, for the dynamic balance data (left axis - vertical bars) as well as for the percent delta values (right axis - thin bar) according to the intervention.

5. Conclusion

Objective physical function outcomes, after the 6-week WBV protocol, did not present statistically significant results in any of the intervention groups (F30 or F45) and SG.

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none.

CRediT authorship contribution statement

Eduarda Gabrielli Recalcatti Slongo: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – review & editing. **Emanuele Vitória Ribas Bressan:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **João Paulo Rogerio dos Santos:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **Jokasta Paloma Vendrametto:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft. **Alberito Rodrigo de Carvalho:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – review & editing. **Gladson Ricardo Flor Bertolini:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Alam, M.M., Khan, A.A., Farooq, M., 2018. Effect of whole-body vibration on neuromuscular performance: a literature review. Work 59, 571–583. https://doi.org/10.3233/WOR-182699.

Andrade Hidalgo Pibic, K., Rodrigo de Carvalho, A., 2023. Reprodutibilidade entre medidas de equilíbrio quase estático por meio de uma ferramenta adaptada: estudo observacional transversal. In: Anais 9o EAICTI - Encontro Anual de Iniciação Científica. Tecnologia e Informação.

Arumugam, A., Björklund, M., Mikko, S., Häger, C.K., Häger, C.K., 2021. Effects of neuromuscular training on knee proprioception in individuals with anterior cruciate ligament injury: a systematic review and GRADE evidence synthesis. BMJ Open 11, e049226. https://doi.org/10.1136/bmjopen-2021-049226.

Borg, GA v, 1982. Psychophysical bases of perceived exertion. Med. Sci. Sports Exerc. 14, 377–381.

Carvalho, AR de, Rahn, M.E., Diedrichs, M., Lopes, A.C., Gregol, F., Grochoski, R., et al., 2010. Concordância inter-observador em testes de avaliação proprioceptiva do joelho por goniometria/Inter-rater agreement at knee proprioception tests by goniometry. Pesq 17, 7–12.

Gloeckl, R., Schneeberger, T., Leitl, D., Reinold, T., Nell, C., Jarosch, I., et al., 2021. Whole-body vibration training versus conventional balance training in patients with severe COPD—a randomized, controlled trial. Respir. Res. 22, 138. https://doi.org/10.1186/s12931-021-01688-x.

Gusi, N., Parraca, J.A., Olivares, P.R., Leal, A., Adsuar, J.C., 2010. Tilt vibratory exercise and the dynamic balance in fibromyalgia: a randomized controlled trial. Arthritis Care Res. 62, 1072–1078. https://doi.org/10.1002/acr.20180.

Harkey, M.S., Price, L.L., Reid, K.F., Lo, G.H., Liu, S.H., Lapane, K.L., et al., 2020. Patient-specific reference values for objective physical function tests: data from the Osteoarthritis Initiative. Clin. Rheumatol. 39, 1961–1970. https://doi.org/10.1007/s10067-020-04972-1.

Ju, Y.Y., Wang, C.W., Cheng, H.Y.K., 2010. Effects of active fatiguing movement versus passive repetitive movement on knee proprioception. Clin. BioMech. 25, 708–712. https://doi.org/10.1016/j.clinbiomech.2010.04.017.

Knijnik, S.R., Fifer, R., Santos, SB dos, Soldera, C.L.C., Knijnik, G.J., Bós, Â.J.G., et al., 2019. Manutenção do equilíbrio corporal: perspectivas futuras. Rev Kairos 22, 231–247. https://doi.org/10.23925/2176-901x.2019v22i1p231-247.

Kröger, S., Watkins, B., 2021. Muscle spindle function in healthy and diseased muscle. Skeletal Muscle 11, 3. https://doi.org/10.1186/s13395-020-00258-x.

Li, K.Y., Cho, Y.J., Chen, R.S., 2021a. The effect of whole-body vibration on proprioception and motor function for individuals with moderate Parkinson disease: a single-blind randomized controlled trial. Occup. Ther. Int. 2021, 441366 https://doi.org/10.1155/2021/9441366.

Li, K.Y., Cho, Y.J., Chen, R.S., 2021b. The effect of whole-body vibration on proprioception and motor function for individuals with moderate Parkinson disease: a single-blind randomized controlled trial. Occup. Ther. Int. 2021 https://doi.org/10.1155/2021/9441366.

Lomas Vega, R., López Ruiz, M.C., 2005. Estabilometría y calidad de vida en las algias vertebrales. Un estudio transversal analítico. Fisioterapia 27, 129–137. https://doi.org/10.1016/S0211-5638(05)73428-3.

Loth, E.A., Albuquerque, C.E., Ciena, A.P., Rossi, A.G., 2011. Evaluation of the postural control in young adults by use of foam-laser dynamic posturography and power plataform. Rev. Bras. Med. do Esporte 17, 171–174.

Maciel, J.I.H.N., Zazula, M.F., Rodrigues, D.F.S., De Toni Boaro, C., Boaretto, M.L., de Andrade, B.Z., et al., 2022. Whole-body vibration promotes skeletal muscle restructuring and reduced obesogenic effect of MSG in wistar rats. Appl. Biochem. Biotechnol. 194, 3594–3608. https://doi.org/10.1007/s12010-022-03923-7.

McCoy, C.E., 2017. Understanding the intention-to-treat principle in randomized controlled trials. West. J. Emerg. Med. 18, 1075–1078. https://doi.org/10.5811/westjem.2017.8.35985.

Medeiros, Í.R.T., Bittar, R.S.M., Pedalini, M.E.B., Lorenzi, M.C., Kii, M.A., Formigoni, L. G., 2003. Avaliação do tratamento dos distúrbios vestibulares na criança através da posturografia dinâmica computadorizada: resultados preliminares. J. Pediatr. 79, 337–342.

Minematsu, A., Nishii, Y., Imagita, H., Sakata, S., 2019. Possible effects of whole body vibration on bone properties in growing rats. Osteoporos Sarcopenia 5, 78–83. https://doi.org/10.1016/j.afos.2019.07.001.

Nagai, T., Bates, N.A., Hewett, T.E., Schilaty, N.D., 2018. Effects of localized vibration on knee joint position sense in individuals with anterior cruciate ligament reconstruction. Clin. BioMech. 55, 40–44. https://doi.org/10.1016/j.clinbiomech.2018.04.011.

Oda, D.T.M., Ganança, C.F., 2015. Computerized dynamic posturography in the assessment of body balance in individuals with vestibular dysfunction. Audiology - Communication Research 20, 89–95. https://doi.org/10.1590/s2317-64312015000200001469.

Oliveira, WL de, Silva, R.D., Custódio, I.J.O., Barcelos, SAMG de, 2011. Análise da influência da plataforma vibratória no desempenho do salto vertical em atletas de futebol: ensaio clínico randomizado. Fisioter Mov 24, 265–274.

Oliver, K.M., Florez-Paz, D.M., Badea, T.C., Mentis, G.Z., Menon, V., de Nooij, J.C., 2021. Molecular correlates of muscle spindle and Golgi tendon organ afferents. Nat. Commun. 12, 1451. https://doi.org/10.1038/s41467-021-21880-3.

Peretti, A.L., Kakihata, C.M.M., Tavares, AL. de F., de Oliveira, C.M.T., Guimarães, A.T. B., Costa, R.M., et al., 2020. Short-term effects of whole-body vibration on the soleus of ooforectomized rats: histomorphometric analysis and oxidative stress in an animal model. Acta Histochem. 122, 151598 https://doi.org/10.1016/j.acthis.2020.151598.

Plisky, P., Schwartkopf-Phifer, K., Huebner, B., Garner, M.B., Bullock, G., 2021. Systematic review and meta-analysis of the y-balance test lower quarter: reliability, discriminant validity, and predictive validity. Int J Sports Phys Ther 16, 1190–1209. https://doi.org/10.26603/001c.27634.

Pollock, R.D., Provan, S., Martin, F.C., Newham, D.J., 2011. The effects of whole body vibration on balance, joint position sense and cutaneous sensation. Eur. J. Appl. Physiol. 111, 3069–3077. https://doi.org/10.1007/s00421-011-1943-y.

Proske, U., 2019. Exercise, fatigue and proprioception: a retrospective. Exp. Brain Res. 237, 2447–2459. https://doi.org/10.1007/s00221-019-05634-8.

Proske, U., Gandevia, S.C., 2012. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. Physiol. Rev. 92, 1651–1697. https://doi.org/10.1152/physrev.00048.2011.-This.

Salles, J.I., Velasques, B., Cossich, V., Nicoliche, E., Ribeiro, P., Amaral, M.V., et al., 2015. Strength training and shoulder proprioception. J. Athl. Train. 50, 277–280. https://doi.org/10.4085/1062-6050-49.3.84.

Saquetto, M., Carvalho, V., Silva, C., Conceição, C., Gomes-Neto, M., 2015. The effects of whole body vibration on mobility and balance in children with cerebral palsy: a systematic review with meta-analysis. J. Musculoskelet. Neuronal Interact. 15, 137–144.

Shaffer, S.W., Teyhen, D.S., Lorenson, C.L., Warren, R.L., Koreerat, C.M., Straseske, C.A., et al., 2013. Y-balance test: a reliability study involving multiple raters. Mil. Med. 178, 1264–1270. https://doi.org/10.7205/MILMED-D-13-00222.

Sierra-Guzmán, R., Jiménez-Diaz, F., Ramírez, C., Esteban, P., Abián-Vicén, J., 2018a. Whole-body-vibration training and balance in recreational athletes with chronic ankle instability. J. Athl. Train. 53, 355–363. https://doi.org/10.4085/1062-6050-547-16.

Sierra-Guzmán, R., Jiménez-Diaz, F., Ramírez, C., Esteban, P., Abián-Vicén, J., 2018b. Whole-body-vibration training and balance in recreational athletes with chronic ankle instability. J. Athl. Train. 53, 355–363. https://doi.org/10.4085/1062-6050-547-16.

Slater, L v, Hart, J.M., 2017. Muscle activation patterns during different squat techniques. J. Strength Condit Res. 31, 667–676.

Song, S., Lee, K., Jung, S., Park, S., Cho, H., Lee, G., 2018. Effect of horizontal whole-body vibration training on trunk and lower-extremity muscle tone and activation, balance, and gait in a child with cerebral palsy. Am J Case Rep 19, 1292–1300. https://doi.org/10.12659/AJCR.910468.

Stania, M., Juras, G., Słomka, K., Chmielewska, D., Król, P., 2016. The application of whole-body vibration in physiotherapy - a narrative review. Acta Physiol. Hung. 103, 133–145. https://doi.org/10.1556/036.103.2016.2.1.

Torvinen, S., Kannus, P., Sievänen, H., Järvinen, T.A.H., Pasanen, M., Kontulainen, S., et al., 2002. Effect of four-month vertical whole body vibration on performance and balance. Medicine & Scienci in Sports & Exercise 34, 1523–1528. https://doi.org/10.1249/01.MSS.0000027713.51345.AE.

Zazula, M.F., Wutzke, M.L.S., da Costa, J.R.G., Guimarães, A.T.B., Costa, R.M., Bertolini, G.R.F., et al., 2020. Morphological effects of whole-body vibration on remobilization of the tibialis anterior muscle of Wistar rats. Anat. Rec. https://doi.org/10.1002/ar.24390.

Zheng, Y.L., Wang, X.F., Chen, B.L., Gu, W., Wang, X., Xu, B., et al., 2019. Effect of 12-week whole-body vibration exercise on lumbopelvic proprioception and pain control in young adults with nonspecific low back pain. Med. Sci. Mon. Int. Med. J. Exp. Clin. Res. 25, 443–452. https://doi.org/10.12659/MSM.912047.