Whole-Body–Vibration Training and Balance in Recreational Athletes With Chronic Ankle Instability

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**Context:** Deficits in the proprioceptive system of the ankle contribute to chronic ankle instability (CAI). Recently, whole-body–vibration (WBV) training has been introduced as a preventive and rehabilitative tool.

**Objective:** To evaluate how a 6-week WBV training program on an unstable surface affected balance and body composition in recreational athletes with CAI.

**Design:** Randomized controlled clinical trial.

**Setting:** Research laboratory.

**Patients or Other Participants:** Fifty recreational athletes with self-reported CAI were randomly assigned to a vibration (VIB), nonvibration (NVIB), or control group.

**Intervention(s):** The VIB and NVIB groups performed unilateral balance training on a BOSU 3 times weekly for 6 weeks. The VIB group trained on a vibration platform, and the NVIB group trained on the floor.

**Main Outcome Measure(s):** We assessed balance using the Biodex Balance System and the Star Excursion Balance Test (SEBT). Body composition was measured by dual-energy x-ray absorptiometry.

**Results:** After 6 weeks of training, improvements on the Biodex Balance System occurred only on the Overall Stability Index (P = .01) and Anterior-Posterior Stability Index (P = .03) in the VIB group. We observed better performance in the medial (P = .008) and posterolateral (P = .04) directions and composite score of the SEBT in the VIB group (P = .01) and in the medial (P < .001), posteromedial (P = .002), and posterolateral (P = .03) directions and composite score of the SEBT in the NVIB group (P < .001). No changes in body composition were found for any of the groups.

**Conclusions:** Only the VIB group showed improvements on the Biodex Balance System, whereas the VIB and NVIB groups displayed better performance on the SEBT.

**Key Words:** Biodex Balance System, balance training, vibrating platform

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C hronic ankle instability (CAI), which has been related to impairments in balance and postural control, often appears after the first ankle sprain. Balance-training programs are frequently used to prevent ankle injuries and rehabilitate patients with them. In their systematic review and meta-analysis, Schiftan et al concluded that balance training effectively reduced the risk of ankle sprain in sport participants with a history of ankle sprains.

Whole-body–vibration (WBV) training is a form of neuromuscular training that has been increasingly used as a preventive and rehabilitative tool. The oscillating vibration platform produces fast and short-term changes in the length of the muscle-tendon complex, activating the primary endings of the muscle spindles that could elicit the tonic vibration reflex. Enhanced excitability of the a and γ motoneurons and increased synchronization of the motor units have also been suggested as possible effects of WBV training. These physiological changes could lead to more effective proprioceptive feedback, thereby improving balance ability and the active protection mechanism of the ankle joint. Apart from neurologic adaptations, WBV training has been associated with morphologic adaptations. Bosco et al reported that WBV training increased plasma concentrations of testosterone and growth hormone, which, when combined with resistance training, led to an increase in lean mass. These adaptations could help to treat the muscle weakness that has been reported in patients with unstable ankles.

Research on the effects of WBV training in patients with CAI is lacking. Cloak et al investigated the effect of 6 weeks of progressive WBV training on a stable platform and noted better balance, but not improved muscle fatigue, in patients with CAI. Training on unstable surfaces has
been suggested as a valuable aid in the sensory-motor rehabilitation of the ankle.\textsuperscript{14,15} The demands on postural control could be increased by performing WBV training on unstable surfaces. Recently, Marin and Hazell\textsuperscript{6} demonstrated that the combination of an unstable surface and WBV could increase electromyographic activity in the lower extremities and trunk muscles to maintain balance. Similarly, proprioception improved in patients with knee osteoarthritis after WBV training on a balance board.\textsuperscript{16} To our knowledge, only Cloak et al\textsuperscript{6} have investigated the effects of this combined training in patients with CAI, showing benefits to balance and stability. However, more research is needed to confirm these results. Therefore, the purpose of our study was to evaluate how a 6-week WBV training program on an unstable surface affected balance and body composition in recreational athletes with CAI. Based on the existing literature, we hypothesized that WBV on an unstable surface might lead to enhanced balance and increased lean mass.

METHODS

Participants

Fifty recreational athletes with self-reported CAI volunteered for the study. They were assigned by concealed random allocation using random numbers generated by online software (http://www.randomization.com) to 1 of 3 groups: vibration (VIB; 11 men, 6 women; age = 22.4 ± 2.6 years, height = 172.0 ± 8.3 cm, mass = 70.2 ± 8.2 kg), nonvibration (NVIB; 10 men, 6 women; age = 21.8 ± 2.1 years, height = 171.3 ± 9.0 cm, mass = 66.2 ± 10.1 kg), or control (CON; 12 men, 5 women; age = 23.6 ± 3.4 years, height = 172.7 ± 10.8 cm, mass = 70.6 ± 11.7 kg; Table 1). Sample size was calculated based on the work of Sefton et al,\textsuperscript{19} who measured posteroomedial reach in participants with CAI. The minimal number of participants required to attain a power of 0.8 and a bilateral \( \alpha \) level of .05 was calculated to be 16 per group.

Following the selection criteria for patients with CAI,\textsuperscript{19} we included participants if they reported a history of at least 1 substantial ankle sprain (the most recent injury must have occurred more than 3 months before study enrollment), 2 or more episodes of the ankle “giving way” in the 6 months before the study, and a score ≤24 on the Spanish version of the Cumberland Ankle Instability Tool (CAIT).\textsuperscript{20} In participants with bilateral ankle instability, the ankle with the lower score was selected. Exclusion criteria were a history of previous surgery to the musculoskeletal structures of either lower extremity; fracture in either lower extremity requiring realignment; or acute musculoskeletal injury to the joints of the lower extremity in the 3 months before the study that affected joint integrity and function, resulting in at least 1 lost day of desired physical activity.\textsuperscript{19} Participant flow is presented in Figure 1.

All participants provided written informed consent. The study was approved by the Ethics Committee of Clinical Research at the Hospital Complex in Toledo (Spain) and was registered as trial NCT02794194 at ClinicalTrials.gov on June 8, 2016.

Procedures

A clinical trial was performed using a randomized, between-groups design. Participants were assessed at 3 times: pretraining (Pre), posttraining 1 (Post1; 48 hours after the last training session), and posttraining 2 (Post2; 6 weeks after the last training session). Measurements were performed in the following order: body-composition analysis, Biodex Balance System test (BBS; Biodex Medical Systems, Shirley, NY), and Star Excursion Balance Test (SEBT). Assessors (R.S.G., F.J.D., C.R., P.E.) and the researcher (J.A.V.) who performed the statistical analysis were blinded to group allocation.

Training Protocol

Participants followed a 6-week balance-training protocol on an unstable ankle based on previous research (Table 2).\textsuperscript{6,21} Exercises were performed barefoot on a BOSU Balance Trainer (BOSU, Ashland, OH) 3 days each week (with 48 hours between sessions; Figure 2). All exercises were carried out only on the unstable ankle and were the same for both experimental groups. Participants in the NVIB group trained with the BOSU on the floor, whereas participants in the VIB group trained on an Excel Pro vibration platform (Fitvibe, Bilzen, Belgium). Synchronous WBV was applied. The training program consisted of 3 series of four 45-second exercises with a 45-second rest between exercises. A repetition-based balance-training–progression style\textsuperscript{16} was followed. The level of difficulty of all exercises was increased after 3 weeks.\textsuperscript{22} Frequency was also increased by 5 Hz every 2 weeks. Amplitude was increased from 2 to 4 mm after the first week and then maintained for the remainder of the study. Participants in the CON group were encouraged to continue their levels of physical activity and refrain from beginning a new training program.

Biodex Balance System Test

Ankle balance was assessed using the BBS, which consists of a mobile platform that allows up to 20° of surface tilt in 360° range of motion. The platform, which is interfaced with computer software (version 1.32: Biodex Medical Systems) generates the Overall Stability Index (OSI), Anterior-Posterior Stability Index (APSI), and Medial-Lateral Stability Index (MLSI) from the degree of tilt. The APSI and MLSI represent platform displacements from the horizontal in the sagittal (Y) and frontal (X) planes, respectively, and the OSI is a composite of the APSI

| Characteristic | Vibration (n = 17) | Nonvibration (n = 16) | Control (n = 17) |
|---------------|------------------|---------------------|-----------------|
| Age, y        | 22.4 ± 2.6       | 21.8 ± 2.1          | 23.6 ± 3.4      |
| Height, cm    | 172.0 ± 8.3      | 171.3 ± 9.0         | 172.7 ± 10.8    |
| Body mass, kg | 70.2 ± 8.2       | 66.2 ± 10.1         | 70.6 ± 11.7     |
| Cumberland Ankle Instability tool, points | 18.9 ± 3.2 | 19.9 ± 4.1 | 19.8 ± 2.9 |
| No. of sprains | 4.4 ± 1.7        | 4.6 ± 2.1           | 5.4 ± 2.7       |
| Time since first sprain, y | 6.9 ± 2.4 | 7.9 ± 3.2 | 6.0 ± 2.9 |
| Time since last sprain, mo | 9.7 ± 8.7 | 14.6 ± 10.5 | 11.7 ± 10.2 |
and MLSI. The following formulas were used to generate the indices: 
\[
\text{OSI} = \left( \frac{\Sigma(0 - Y)^2 + \Sigma(0 - X)^2}{\text{samples}} \right)^{0.5},
\]
\[
\text{APSI} = \left( \frac{\Sigma(0 - Y)^2}{\text{samples}} \right)^{0.5},
\]
\[
\text{MLSI} = \left( \frac{\Sigma(0 - X)^2}{\text{samples}} \right)^{0.5}.
\]
Higher values represented poorer stability, whereas lower values represented better stability.

The test was performed at level 8 with participants barefoot in single-legged stance. They were instructed to step on the BBS platform with their eyes open, assume a comfortable position while keeping their knees slightly flexed (15°), look straight ahead at the monitor, and place their hands on their hips. Foot-position coordinates were registered to ensure that the same position was used for all tests. We instructed participants to keep a cursor, which represented the center of the platform, in the center of the bull’s eye on a visual feedback screen. Only 3 practice trials were performed to reduce any learning effects, and 3 test evaluations were then performed. Each trial lasted 20 seconds with a 10-second rest between trials. The average of the 3 test evaluations was used for data analysis. Failed trials were not recorded and were removed from the data analysis. A trial was considered a failure if the participant used the handlebars of the platform to maintain balance, put the free foot on the platform, or completely lost his or her balance.

**Star Excursion Balance Test**

The SEBT was performed as previously described. We created a grid with 8 tape measures extending from the

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Table 2: Exercise Scheme of the 6-Week Balance-Training Program With Whole-Body Vibration

| Week | 1 | 2 | 3 | 4 | 5 | 6 |
|------|---|---|---|---|---|---|
| **Frequency, Hz** | 30 | 30 | 35 | 35 | 40 | 40 |
| **Amplitude, mm** | 2 | 4 | 4 | 4 | 4 | 4 |
| **Exercise** | 1-Legged stance | 1-Legged stance with eyes shut | Cross-legged sway | Cross-legged sway with elastic resistance band attached to the ankle | Runner’s pose | Runner’s pose with single-legged heel raises | Catching and throwing a volleyball against the wall | Catching and throwing a tennis ball against the wall |
was lost, (2) any part of the foot was lifted or moved from the center at 45° from each other. Each measure was labeled according to the direction of excursion in relation to the standing limb. Oral and video instructions were given to the participants before the test. Participants stood barefoot with the stance foot centered on the grid and aligned with the anterior and posterior directions. While maintaining single-legged stance on the unstable ankle, they reached with the contralateral limb to lightly touch as far as possible in the chosen direction with the most distal part of the foot and returned to a bilateral stance. Only 5 directions of the SEBT were analyzed to avoid redundancy among the 8 directions. The anteromedial, medial, and posteromedial have been proposed to be the most sensitive directions in participants with CAI. The anterior and posterolateral directions have also been used in some studies involving participants with CAI. A composite score based on the 5 directions was calculated to quantify the overall change. A standardized protocol of 4 practice trials, followed by 3 test trials, was performed in each of the 5 directions to minimize the learning effect. Reach distances were measured by the same researcher (R.S.G.), who marked the tape measure. The average of the 3 test trials was normalized for length of the stance limb and used for analysis. While participants were lying supine, we measured their limbs from the anterior-superior iliac spine to the distal tip of the medial malleolus using a standard tape measure. A trial was discarded and repeated if (1) balance was lost, (2) any part of the foot was lifted or moved from the center grid, (3) the hands did not remain on the hips, or (4) the reach limb provided support when touching down.

Body-Composition Analysis

Height was measured using a wall-mounted stadiometer (model 220; Seca, Hamburg, Germany). Body mass (with the participant in underwear) was measured using a digital balance (model 707; Seca) with a weighing accuracy of 0.1 kg. Total and regional body compositions were measured by dual-energy x-ray absorptiometry (DXA; model Lunar iDXA; General Electric Healthcare, Fairfield, CT) using a standardized protocol specified by the manufacturer. Lean mass, fat mass, percentage of fat, bone mineral content, and bone mineral density for the total body and for the limb with CAI were obtained using enCORE software (version 13.40; General Electric Healthcare). Standard calibration procedures were performed before each testing session by the same technician (P.E.).

Statistical Analysis

The normality of each variable was initially tested using the Shapiro-Wilk test. All variables displayed normal distributions. A 2-way repeated-measures analysis of variance was performed for all outcome variables to analyze the interaction among groups (VIB, NVIB, CON) and the time of assessment (Pre, Post1, Post2). When differences were established, we applied a post hoc Bonferroni multiple-comparisons test. The effect size (ES) was calculated for all pairwise comparisons according to the formula proposed by Glass et al. When a pairwise comparison was performed between the NVIB and VIB groups, we used a pooled standard deviation for the calculations. The magnitude of the ES was interpreted using the scale of Cohen: small (<0.2), medium (0.5), and large (>0.8). All data were presented as means ± standard deviations. The α level was set at .05. Statistical analysis was performed using SPSS (version 22.0; IBM Corp, Armonk, NY).

RESULTS

Biodex Balance System Test

Results for the BBS are presented in Table 3. We observed no differences among the 3 groups for any of the 3 measurements (P > .05). Within-group analysis showed decreases in the VIB group between Pre and Post1 in the OSI of −18.69% ± 21.58% (P = .01; ES = −0.96; 95% confidence interval [CI] of the mean difference [MD] of the score = −0.57, −0.06) and the APSI of −13.28% ± 25.34% (P = .02; ES = −0.68; 95% CI of MD = −0.33, −0.03) and between Pre and Post2 in the OSI of −20.14% ± 24.62% (P = .003; ES = −0.92; 95% CI of MD = −0.56, −0.09) and the APSI of −15.34% ± 27.42% (P = .03; ES = −1.33; 95% CI of MD = −0.42, −0.02). Whereas we did not demonstrate differences in the MLDI, we found large ESs between Pre and Post1 in the VIB (ES = −0.87; 95% CI of MD = −0.43, 0.06) and NVIB (ES = −0.91; 95% CI of MD = −0.50, 0.00) groups.

Star Excursion Balance Test

Results for the SEBT are presented in Table 3. We observed no differences (P > .05) among the 3 groups for
Table 3. Balance Test Results (Mean ± SD)

| Score                                      | Control                                      | Pretraining 1 | Posttraining 1 | Pretraining 2 | Posttraining 2 |
|--------------------------------------------|----------------------------------------------|---------------|----------------|---------------|---------------|
| Biodex Balance System                      | 0.36 ± 1.21a                                | 0.75 ± 0.95   | 0.35 ± 0.33b   | 0.67 ± 1.28   | 0.70 ± 0.92   |
| Anterior-Posterior Stability Index         | 0.44 ± 0.72                                 | 0.44 ± 0.72   | 0.32 ± 0.68    | 0.39 ± 0.85   | 0.35 ± 0.47   |
| Medial-Lateral Stability Index             | 0.60 ± 1.09                                 | 0.60 ± 1.09   | 0.55 ± 1.09    | 0.60 ± 1.09   | 0.55 ± 1.09   |
| Star Excursion Balance Test, cm           | 5.85 ± 82.79                                | 6.02 ± 80.30  | 6.69 ± 80.30   | 6.69 ± 80.30  | 6.69 ± 80.30  |
| Anterior                                  | 5.36 ± 81.96                                | 5.36 ± 81.96  | 5.14 ± 83.42   | 7.32 ± 85.89  | 9.71 ± 92.42  |
| Anteromedial                              | 5.39 ± 86.95                                | 5.39 ± 86.95  | 5.79 ± 86.70   | 7.48 ± 90.16  | 7.44 ± 89.67  |
| Posteromedial                             | 5.44 ± 85.15                                | 5.44 ± 85.15  | 0.32 ± 0.68    | 6.81 ± 85.65  | 5.44 ± 85.15  |
| Posterolateral                            | 5.32 ± 85.38                                | 5.32 ± 85.38  | 5.07 ± 85.38   | 7.36 ± 10.16  | 7.40 ± 86.77  |
| Composite                                  | 5.30 ± 85.15                                | 5.30 ± 85.15  | 6.07 ± 85.38   | 8.37 ± 10.07  | 8.37 ± 10.07  |

* Biodex Medical Systems, Shirley, NY.

* Indicates different from pretraining (P < .05).

* Indicates different from posttraining 1 (P < .05).

* Indicates different from posttraining 2 (P < .05).

Within-group analysis of the VIB group showed increases (P < .05) with moderate to large ESs (Figure 3) between Pre and Post1 in the medial direction of 4.93% ± 3.78% (P = .008; ES = 0.85; 95% CI of MD = 0.97, 7.69 cm), posterolateral direction of 5.21% ± 9.43% (P = .04; ES = 0.52; 95% CI of MD = 0.07, 7.78 cm), and composite score of 3.72% ± 4.09% (P = .01; ES = 0.68; 95% CI of MD = 0.60, 5.63 cm) and decreases between Post1 and Post2 in the medial direction of −2.93% ± 4.97% (P = .03; ES = −0.43; 95% CI of MD = −5.30, −0.27 cm), posterolateral direction of −3.09% ± 6.07% (P = .04; ES = −0.38; 95% CI of MD = −5.75, −0.14 cm), and composite score of −2.30% ± 2.64% (P = .007; ES = −0.47; 95% CI of MD = −3.68, −0.48 cm).

In the NVIB group, increases with moderate to large ESs (Figure 3) were shown between Pre and Post1 in the medial direction of 7.36% ± 10.34% (P < .001; ES = 0.78; 95% CI of MD = 2.34, 9.27 cm), posterolateral direction of 8.75% ± 13.53% (P = .002; ES = 0.83; 95% CI of MD = 2.38, 11.79 cm), posteralateral direction of 5.32% ± 7.93% (P = .03; ES = 0.43; 95% CI of MD = 0.32, 8.37 cm), and composite score of 5.51% ± 6.61% (P < .001; ES = 0.58; 95% CI of MD = 2.04, 7.22 cm). Decreases between Post1 and Post2 were noted in the anterior direction of −3.70% ± 6.70% (P = .01; ES = −0.40; 95% CI of MD = −6.25, −0.70 cm), anteromedial direction of −3.05% ± 4.59% (P = .002; ES = −0.39; 95% CI of MD = −4.76, −0.96 cm), medial direction of −4.54% ± 5.09% (P = .001; ES = −0.47; 95% CI of MD = −6.81, −1.64 cm), posteralateral direction of −4.03% ± 4.91% (P = .002; ES = −0.40; 95% CI of MD = −6.60, −1.27 cm), posterolateral direction of −3.64% ± 5.07% (P = .01; ES = −0.35; 95% CI of MD = −6.37, −0.60 cm), and composite score of −3.89% ± 3.92% (P < .001; ES = −0.41; 95% CI of MD = −5.24, −1.95 cm).

**Body-Composition Analysis**

Body-composition variables are presented in Table 4. No differences occurred among groups before or after the training (P > .05). We also observed no group-by-time interaction effect for any of the variables (P > .05).

**DISCUSSION**

The main finding of our study was that 6 weeks of WBV training on an unstable surface improved balance in participants with CAI. Both training groups performed better on the SEBT but only the VIB performed better on the BBS. Overall, our results support using balance training with or without WBV to address balance impairments in participants with CAI. We also hypothesized that lean mass could be increased with the WBV training program but observed no change in any postintervention body-composition variables.
Balance

Deficits in balance have been reported in participants with CAI. Therefore, improving their balance could decrease the risk of sustaining a new ankle sprain. Schiftan et al. showed that balance training could effectively reduce these deficits.

The BBS has been proposed as a useful method to assess balance in participants with CAI. Poor performance on the OSI at level 3 has been noted in participants with CAI as compared with healthy participants. Kim and Heo found that 4 weeks of balance training using virtual reality exercises enhanced the BBS balance indexes in participants with CAI. Similarly, after 12 weeks of proprioceptive training, healthy, young speed skaters displayed improvements.

In our study, we found that better performance on the OSI and APSI was maintained only by the VIB group at Post2. These results may indicate that adding vibration was more effective than balance training alone. Cardinale and Bosco noted that WBV training could enhance muscle-spindle sensitivity and excitability of the α and γ motoneurons. These adaptations could lead to reduced reaction time of the ankle-stabilizing muscles and the motor-unit recruitment thresholds, which may offer an advantage when adjusting position during the BBS test. To our knowledge, only Cloak et al. combined WBV and balance training in participants with CAI and reported progress in those who trained with WBV and a wobble board compared with the wobble board alone. However, given that we did not use electromyography during the balance tests, we can only assume that these differences were caused by the addition of WBV.

We also found postintervention improvements in balance. However, improvements occurred in both the VIB and NVIB groups and were reported by Cloak et al. after the combined training. Therefore, we cannot conclude that adding WBV training provided extra benefits compared with balance training alone.

The SEBT has also been described as useful for identifying deficits in participants with CAI who may benefit from rehabilitation to reestablish dynamic ability. Participants with CAI displayed poorer performance on the SEBT than copers with lateral ankle sprain. We found postintervention benefits in both training groups in the medial and posterolateral directions and the composite score. We also observed better performance in the posteromedial direction by the NVIB group. These results are similar to those found by previous researchers, who saw improvements in the medial, posteromedial, and posterolateral directions after 4 weeks of rehabilitation that addressed range of motion, strength, neuromuscular control, and functional tasks. Similarly, Sefton et al. demonstrated progress in the anteromedial, medial, and posteromedial directions after 6 weeks of balance training. In our study, we analyzed the persistence of the effects after the intervention ceased. Values tended to return to baseline levels, with decreases between Post1 and Post2 in the medial and posteromedial directions and the composite score in the VIB group and in the medial, posteromedial, and posterolateral directions and the composite score in the NVIB group. Han et al. also evaluated the persistence of the effects and reported that balance improvements were retained after training ceased. However, it is difficult to compare their results with ours because they used a force platform to assess balance and the intervention was based on elastic-tubing exercises. Furthermore, they recruited participants according to a history of ankle sprains, but they did not use a valid instrument, such as the CAIT, to determine the presence of CAI and performed the Post2 after 4 weeks instead of 6 weeks.
Table 4. Body-Composition Variables (Mean ± SD)

| Variable                        | Vibration Pretraining | Vibration Posttraining 1 | Vibration Posttraining 2 | Nonvibration Pretraining | Nonvibration Posttraining 1 | Nonvibration Posttraining 2 | Control Pretraining | Control Posttraining 1 | Control Posttraining 2 |
|---------------------------------|-----------------------|--------------------------|--------------------------|--------------------------|-----------------------------|-----------------------------|----------------------|------------------------|-----------------------|
| Total body                       | Pretraining           | Posttraining 1           | Posttraining 2           | Pretraining              | Posttraining 1              | Posttraining 2              | Pretraining   | Posttraining 1         | Posttraining 2         |
| Lean mass, kg                   | 51.72 ± 9.13          | 51.98 ± 9.24             | 51.88 ± 8.90             | 50.28 ± 9.69             | 50.14 ± 9.59                | 49.99 ± 9.43                | 52.22 ± 11.26 | 52.46 ± 11.30          | 52.68 ± 11.74          |
| Fat mass, kg                    | 16.08 ± 6.70          | 16.16 ± 6.22             | 16.32 ± 5.90             | 13.57 ± 4.84             | 13.81 ± 4.83                | 13.75 ± 4.79                | 16.13 ± 5.37 | 15.69 ± 5.00           | 15.76 ± 5.09           |
| Fat mass, %                      | 22.84 ± 9.43          | 22.94 ± 9.84             | 23.09 ± 8.36             | 20.59 ± 6.85             | 20.89 ± 6.77                | 20.84 ± 6.76                | 22.98 ± 7.80 | 22.43 ± 7.47           | 22.51 ± 7.73           |
| Bone mineral content, kg        | 2.93 ± 0.41           | 3.00 ± 0.45              | 2.92 ± 0.39              | 2.85 ± 0.52              | 2.87 ± 0.52                 | 2.87 ± 0.52                 | 3.05 ± 0.64  | 3.04 ± 0.63            | 3.05 ± 0.62            |
| Bone mineral density, g/cm²     | 1.33 ± 0.10           | 1.36 ± 0.19              | 1.32 ± 0.10              | 1.30 ± 0.12              | 1.30 ± 0.11                 | 1.31 ± 0.12                 | 1.36 ± 0.13  | 1.36 ± 0.12            | 1.36 ± 0.12            |
| Limb with chronic ankle instability |                         |                          |                          |                          |                             |                             |                      |                        |                       |
| Lean mass, kg                   | 8.90 ± 1.71           | 8.96 ± 1.63              | 8.92 ± 1.52              | 8.72 ± 1.78              | 8.58 ± 1.67                 | 8.69 ± 1.65                 | 9.19 ± 2.08  | 9.21 ± 2.07            | 9.32 ± 2.12           |
| Fat mass, kg                    | 3.04 ± 1.30           | 3.05 ± 1.28              | 3.09 ± 1.18              | 2.82 ± 1.20              | 2.82 ± 1.23                 | 2.85 ± 1.26                 | 3.15 ± 1.01  | 3.11 ± 0.99            | 3.11 ± 0.97           |
| Fat mass, %                      | 24.36 ± 10.61         | 24.32 ± 10.25            | 24.64 ± 9.37             | 23.52 ± 9.08             | 23.72 ± 9.07                | 23.64 ± 9.17                | 24.72 ± 8.74 | 24.50 ± 8.58           | 24.32 ± 8.55           |
| Bone mineral content, kg        | 0.57 ± 0.09           | 0.57 ± 0.09              | 0.57 ± 0.09              | 0.56 ± 0.11              | 0.56 ± 0.11                 | 0.56 ± 0.11                 | 0.62 ± 0.14  | 0.62 ± 0.14            | 0.62 ± 0.14           |
| Bone mineral density, g/cm²     | 1.40 ± 0.14           | 1.40 ± 0.13              | 1.40 ± 0.14              | 1.38 ± 0.16              | 1.39 ± 0.16                 | 1.39 ± 0.16                 | 1.46 ± 0.17  | 1.46 ± 0.17            | 1.46 ± 0.16           |

Limitations

Whereas all participants might have homogenous characteristics, the intervention might not have challenged their sensorimotor systems equally. Furthermore, the vibration platform was targeted at single-legged balance ability. Therefore, a load was applied to the vibration platform equally, and the WBV training had no effect on the bones of young healthy adults.
hormonal change induced by the exposure to WBV would not necessarily have led to morphologic advancements without adding some type of resistance training. Another limitation was the small sample size, which might not have been adequate to detect postintervention differences among groups. It was also not possible to blind participants to group allocation, which may have influenced our results. Finally, given that the CAIT was administered only to select the participants, our results should be interpreted cautiously. We cannot affirm that our training protocol diminished the feeling of instability assessed by the CAIT.

Practical Applications
Balance impairments have been reported in participants with CAI. We observed that balance training on an unstable surface improved performance on the SEBT. Also, we found that the same intervention combined with WBV benefitted balance ability on the BBS. Therefore, implementing this kind of training should be considered in future interventions to reduce the risk of recurrent ankle sprains by improving the dynamic balance ability of participants with CAI.

CONCLUSIONS
The results of our study suggest that a 6-week unilateral balance-training program on an unstable surface and a vibration platform resulted in better balance on the BBS and SEBT. The same intervention without vibration also effectively enhanced balance on the SEBT. However, given that improvements in BBS performance were found only in the VIB group, we could conclude that adding vibration led to different enhancements in balance ability compared with the same intervention without vibration. We observed no differences in any body-composition variables in any group after 6 weeks of balance training. Further research is required to confirm these results and to analyze whether this training can reduce the risk of sustaining an ankle sprain in people with CAI.

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REFERENCES
1. Olmsted LC, Carcia CR, Hertel J, Shultz SJ. Efficacy of the Star Excursion Balance Tests in detecting reach deficits in subjects with chronic ankle instability. J Athl Train. 2002;37(4):501–506.
2. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Dynamic balance deficits in individuals with chronic ankle instability compared to ankle sprain copers 1 year after a first-time lateral ankle sprain injury. Knee Surg Sports Traumatol Arthrosc. 2016;24(4):1086–1095.
3. Hertel J, Braham RA, Hale SA, Olimst-Kramer LC. Simplifying the star excursions balance test: analyses of subjects with and without chronic ankle instability. J Orthop Sports Phys Ther. 2006;36(3):131–137.
4. Schifftan GS, Ross LA, Hahne AJ. The effectiveness of proprioceptive training in preventing ankle sprains in sporting populations: a systematic review and meta-analysis. J Sci Med Sport. 2015;18(3):238–244.
5. Cloak R, Nevill AM, Clarke F, Day S, Wyon MA. Vibration training improves balance in unstable ankles. Int J Sports Med. 2010;31(12):894–900.
6. Cloak R, Nevill A, Day S, Wyon M. Six-week combined vibration and wobble board training on balance and stability in footballers with functional ankle instability. Clin J Sport Med. 2013;23(5):384–391.
7. Cardinale M, Bosco C. The use of vibration as an exercise intervention. Exerc Sport Sci Rev. 2003;31(1):3–7.
8. Pollock RD, Wolege RC, Martin FC, Newham DJ. Effects of whole body vibration on motor unit recruitment and threshold. J Appl Physiol (1985). 2012;112(3):388–395.
9. Bosco C, Iacovelli M, Tsarpela O, et al. Hormonal responses to whole-body vibration in men. Eur J Appl Physiol. 2000;81(6):449–454.
10. Roelants M, Delecuste C, Goris M, Verschueren S. Efficacy of the Star Excursion Balance Tests in detecting reach deficits in subjects with and without functional ankle instability. J Orthop Sports Phys Ther. 2006;36(3):131–137.
11. Lamont HS, Cramer JT, Bemben DA, Shehab RL, Anderson MA, Bemben MG. Effects of a 6-week periodized squat training with or without whole-body vibration upon short-term adaptations in squat strength and body composition. J Strength Cond Res. 2011;25(7):1839–1848.
12. Arnold BL, Linens SW, de la Mottie SJ, Ross SE. Concentric evertor strength differences and functional ankle instability: a meta-analysis. J Athl Train. 2009;44(6):653–662.
13. Willems T, Witvrouw E, Verstuyft J, Vaes P, De Clercq D. Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. J Athl Train. 2002;37(4):487–493.
14. Cug M, Duncan A, Wikstrom E. Comparative effects of different balance-training-progression styles on postural control and ankle force production: a randomized controlled trial. J Athl Train. 2016;51(2):101–110.
15. Donovan L, Hart JM, Saliba SA, et al. Rehabilitation for chronic ankle instability with or without destabilization devices: a randomized controlled trial. J Athl Train. 2016;51(3):233–251.
16. Marin PJ, Hazell TJ. Effects of whole-body vibration with an unstable surface on muscle activation. J Musculoskelet Neuronal Interact. 2014;14(2):213–219.
17. Trans T, Aaboe J, Henriksen M, Christensen R, Bliddal H, Lund H. Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. Knee. 2009;16(4):256–261.
18. Sefton JM, Yarar C, Hicks-Little CA, Berry JW, Cordova ML. Six weeks of balance training improves sensorimotor function in individuals with chronic ankle instability. J Orthop Sports Phys Ther. 2011;41(2):81–89.
19. Gribble PA, Delahunt E, Bleakley C, et al. Selection criteria for patients with chronic ankle instability in controlled research: a position statement of the International Ankle Consortium. Br J Sports Med. 2014;48(13):1014–1018.
20. Cruz-Díaz D, Hita-Contreras F, Lomas-Vega R, Osuna-Pérez MC, Martínez-Amat A. Cross-cultural adaptation and validation of the Spanish version of the Cumberland Ankle Instability Tool (CAIT): an instrument to assess unilateral chronic ankle instability. Clin Rheumatol. 2013;32(1):91–98.
21. Van Reijen M, Vriend I, Zuidema V, van Meechelen W, Verhagen EA. Increasing compliance with neuromuscular training to prevent ankle sprain in sport: does the ‘Strengthen your ankle’ mobile App make a difference? A randomised controlled trial. Br J Sports Med. 2016;50(19):1200–1205.
22. Borromei S, Calatayud J, Martin J, Colado JC, Tella V, Behm D. Exercise intensity progression for exercises performed on unstable and stable platforms based on ankle muscle activation. Gait Posture. 2014;39(1):404–409.
23. Cug M, Wikstrom EA. Learning effects associated with the least stable level of the Biodex® Stability system during dual and single limb stance. J Sports Sci Med. 2014;13(2):387–392.
24. Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the Star Excursion Balance Test. *Arch Phys Med Rehabil*. 2008;89(2):364–370.

25. Linens SW, Ross SE, Arnold BL, Gayle R, Pidcoe P. Postural-stability tests that identify individuals with chronic ankle instability. *J Athl Train*. 2014;49(1):15–23.

26. Hubbard TJ, Kramer LC, Denegar CR, Hertel J. Contributing factors to chronic ankle instability. *Foot Ankle Int*. 2007;28(3):343–354.

27. Glass GV, McGaw B, Smith ML. *Meta-Analysis in Social Research*. Beverly Hills, CA: SAGE Publications; 1981.

28. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.

29. Hale SA, Hertel J, Olmsted-Kramer LC. The effect of a 4-week comprehensive rehabilitation program on postural control and lower extremity function in individuals with chronic ankle instability. *J Orthop Sports Phys Ther*. 2007;37(6):303–311.

30. Testerman C, Vander Griend R. Evaluation of ankle instability using the Biodex Stability System. *Foot Ankle Int*. 1999;20(5):317–321.

31. Springer S, Gottlieb U, Moran U, Verhovsky G, Yanovich R. The correlation between postural control and upper limb position sense in people with chronic ankle instability. *J Foot Ankle Res*. 2015;8:23.

32. Kim KJ, Heo M. Effects of virtual reality programs on balance in functional ankle instability. *J Phys Ther Sci*. 2015;27(10):3097–3101.

33. Winter T, Beck H, Walther A, Zwipp H, Rein S. Influence of a proprioceptive training on functional ankle stability in young speed skaters: a prospective randomised study. *J Sports Sci*. 2015;33(8):831–840.

34. Han K, Ricard MD, Fellingham GW. Effects of a 4-week exercise program on balance using elastic tubing as a perturbation force for individuals with a history of ankle sprains. *J Orthop Sports Phys Ther*. 2009;39(4):246–255.

35. Osawa Y, Oguma Y, Onishi S. Effects of whole-body vibration training on bone-free lean body mass and muscle strength in young adults. *J Sports Sci Med*. 2011;10(1):97–104.

36. Artero EG, Espada-Fuentes JC, Arguelles-Cienfuegos J, Roman A, Gomez-Lopez PJ, Gutierrez A. Effects of whole-body vibration and resistance training on knee extensors muscular performance. *Eur J Appl Physiol*. 2012;112(4):1371–1378.

37. Martinez-Pardo E, Romero-Arenas S, Alcaraz PE. Effects of different amplitudes (high vs. low) of whole-body vibration training in active adults. *J Strength Cond Res*. 2013;27(7):1798–1806.

38. Gilsanz V, Wren TA, Sanchez M, Dorey F, Judex S, Rubin C. Low-level, high-frequency mechanical signals enhance musculoskeletal development of young women with low BMD. *J Bone Miner Res*. 2006;21(9):1464–1474.

39. Torvinen S, Kannus P, Sievanen H, et al. Effect of 8-month vertical whole body vibration on bone, muscle performance, and body balance: a randomized controlled study. *J Bone Miner Res*. 2003;18(5):876–884.

40. Di Giminiani R, Masedu F, Padulo J, Tihanyi J, Valenti M. The EMG activity-acceleration relationship to quantify the optimal vibration load when applying synchronous whole-body vibration. *J Electromyogr Kinesiol*. 2015;25(6):853–859.

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