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Effects of Whole-Body Vibration Exercise on Bone Mineral Content and Density in Thermally Injured Children

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Abstract

Background—Loss of bone mass, muscle mass, and strength leads to significant disability in severely burned children. We assessed the effects of exercise combined with whole-body vibration (WBV) on bone mass, lean mass (LM), and muscle strength in children recovering from burns.

Methods—Nineteen burned children (30% total body surface area [TBSA] burns) were randomly assigned to a 6-week exercise regimen either alone (EX; n = 10) or in combination with a 6-week WBV training regimen (EX+WBV; n = 9). WBV was performed concurrent to the exercise regimen for 5 days/week on a vibrating platform. Dual-energy X-ray absorptiometry quantified bone mineral content (BMC), bone mineral density (BMD) and LM; knee extension strength was assessed using isokinetic dynamometry before and after training. Alpha was set at $p < 0.05$.

Results—Both groups were similar in age, height, weight, TBSA burned, and length of hospitalization. Whole-body LM increased in the EX group ($p = 0.041$) and trended toward an increase in the EX+WBV group ($p = 0.055$). On the other hand, there were decreases in leg BMC for both groups (EX, $p = 0.011$; EX+WBV, $p = 0.047$), and in leg BMD for only the EX group (EX, $p < 0.001$; EX+WBV, $p = 0.26$). Truncal BMC decreased in only the EX group (EX, $p = 0.009$; EX+WBV, $p = 0.61$), while BMD decreased in both groups (EX, $p < 0.001$; EX+WBV group, $p < 0.001$). Leg strength increased over time in the EX group ($p < 0.001$) and the EX+WBV group ($p < 0.001$; between-group $P = 0.31$).

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Conclusions—Exercise in combination with WBV may help attenuate regional bone loss in children recovering from burns. Studies are needed to determine the optimal magnitude, frequency, and duration of the vibration protocol, with attention to minimizing any potential interference with wound healing and graft closure.

Keywords

Bone; Whole body vibration; bone density; bone content; exercise

1. Introduction

Individuals with severe burns experience a dramatic catabolic and hypermetabolic state for up to 2 years after injury[1, 2]. Children recovering from burns 30% of their total body surface area (TBSA) suffer long-term disturbances in bone metabolism, leading to deficits in bone mineral density (BMD) and bone mineral content (BMC) that can be detrimental to physical development and maturity of the skeleton[3–5]. These marked changes may result in decreased mineral anabolism and possibly decreased resorption. In some instances, these metabolic abnormalities may be present for up to 5 years, possibly resulting in failure to achieve appropriate peak bone mass[4]. Klein and colleagues have suggested that bone loss in children with burns may be partially attributed to immobilization during recovery along with metabolic abnormalities [6]. Such bone disturbances may increase fracture risk, further contributing to personal and economic burden during rehabilitation.

Exercise is an effective intervention for augmenting muscle strength and lean mass (LM) in children recovering from severe thermal injuries[7–11]. However, whether exercise increases or even prevents burn-induced loss of bone mass and density is unknown. One exercise modality that has been used in the nonburned pediatric population to increase bone mass is whole-body vibration (WBV). WBV involves standing on an oscillating platform that vibrates at a preselected frequency and amplitude of displacement; this vibratory stimulus, in turn, accelerates the entire body, imparting force onto the skeleton[12, 13]. Vibration exercise may increase BMD [14], muscle strength [15], and power in humans [16]; there is also strong evidence supporting the use of WBV to preserve bone and muscular function during activity restriction, such as bed rest in adults [17–20]. Mechanistically, WBV may increase bone mass directly through the force imparted by the metal plate onto the skeleton or through the pull of the tendon attachment site on the bone. In nonburned children, several studies show benefits of WBV on BMD. Six months of WBV (10 min daily for 5 days a week) significantly increased proximal tibia and spine BMD in a group of ambulatory boys and girls (mean age, 9.1 years) with limited mobility due to disabling conditions [21]. Likewise, significant gains in cancellous bone in the lumbar vertebrae and cortical bone in the femoral midshaft were seen in a group of young women with low BMD (age range, 15–20 years) after they completed a WBV program (10 minutes daily for 12 months) [22]. Another group of 8 females with low bone density (mean age, 9.7 years) showed a significant increase in cancellous tibia trabecular bone density and cortical bone density of the femur after 8 weeks of WBV (30 minutes a day, 3 days a week) [23].

Although there is support for the use of WBV and exercise in children without burns to improve bone mass and density, the effects of WBV and exercise on these parameters in children recovering from burns have not been reported. We studied the effect of a 6-week WBV training intervention in conjunction with exercise on bone and muscular strength in children recovering from burns. We hypothesized that both exercise alone and exercise in combination with WBV would minimize losses of whole-body, regional leg, and truncal BMC and BMD but that these positive results would be greater with exercise in combination with WBV.

2. Methods

2.1. Participants

Nineteen severely burned children (5 female and 14 male) with burns covering 30% of the TBSA completed this study. Seventeen of the injuries were characterized as flame injuries, while 2 were scalding injuries. After consent, children were randomly allocated to either an exercising control group (EX) or an intervention group that completed exercise in addition to a WBV intervention (EX+WBV). Participants were recruited immediately after discharge from the hospital and prior to beginning the 6-week exercise program, which was implemented at discharge. All participants and their legal guardians read and signed the informed consent, which was approved by the Institutional Review Board of the sponsoring university and hospital unit.

2.2. Experimental overview

A prospective, randomized controlled trial design was implemented in this study. Participants were recruited from a specialized pediatric burn hospital for children. All participants underwent occupational and physical therapy (OT/PT) specific to their impairments and medical treatment for their burn injuries. The OT/PT rehabilitation program was offered as an outpatient service. Inclusion criteria were as follows: severe burns covering 30% TBSA, ability to safely tolerate ambulatory activity and exercise, and reliable transportation to return to the exercise unit of the hospital 5 times per week. Participants were excluded if they were prescribed any medication that would affect muscle or bone metabolism.

The EX and EX+WBV groups completed an identical exercise protocol with sessions 5 days per week [11, 24]. Children in the EX+WBV group also completed a 5 day-per-week WBV intervention, which had parameters of previously published protocols [21, 22, 25]. Baseline testing for strength, LM, BMD, and BMC were completed the week before the start of the intervention; post-testing was completed the week after the 6 weeks of training concluded.

2.3. Exercise protocol

The exercise protocol is detailed elsewhere [8–11]. Briefly, the 6-week program consisted of progressive resistance exercise and aerobic conditioning that lasted from 30 minutes to 1 hour. This exercise prescription, which is based upon recommendations by the American College of Sports Medicine, enhances aerobic fitness and muscle strength in children recovering from burns [8–11]. The progressive resistance exercise protocol was carried out 3

days a week and consisted of 8 exercises: bench and shoulder press, leg press, knee curls, bicep curls, triceps presses, heel raises, and abdominal curls. Exercises performed using free weights included bicep curls and heel raises. All remaining exercises (except for abdominal curls) used variable-resistance machines. During the first week of exercise program, patients were familiarized with the weight equipment and instructed on correct weight lifting technique. The weightlifting workouts were set to approximately 50–60% of 3RM (repetition max). Subsequently, the resistance load was gradually increased to 80–85% of 3RM and continued until the end of the program. The number of repetitions at the start of the program (week one) was 10–15 for 3 sets. Thereafter, the number of repetitions was decreased to 8–12 (3 sets) and continued during weeks 2–6. The children were allowed to rest between sets for approximately one minute. The aerobic conditioning protocol included walking, running, or cycling for 20 to 30 minutes at a moderate-to-vigorous intensity for 5 days per week. Intensity was maintained at 75 to 80% of maximum heart rate, as determined using a heart rate monitor worn by the participants during training. Both the progressive resistance exercise and aerobic conditioning sessions were monitored by an investigator to ensure adherence to the protocol parameters.

2.4. WBV exercise

In addition to completing standard exercise, the EX+WBV group underwent exercises 5 days per week using a vibration plate. The vibration plate (Power Plate Next Generation Vibration Platform; Power Plate North America, Chicago, IL USA) simultaneously oscillates in the vertical, anterior-posterior, and mediolateral planes, although the predominant plate displacement is vertical [13]. The vibration frequency, amplitude, and duration were selected based on previous studies reporting no injuries but demonstrating improvements in strength, BMC, and BMD [25]. Therefore, the frequency, amplitude, and duration utilized in this investigation were as follows: frequency: 30–40 Hz, 2–4 mm of peak-to-peak vertical plate displacement, and exercise durations ranging from 12–15 minutes.

EX+WBV participants performed 2 vibration exercises 5 times per week. The first vibration exercise, a warm-up and familiarization set, consisted of sitting in a chair with both legs on the platform and performing one repetition, which lasted 3 minutes (Fig. 1). At the completion of the 3-minute warm-up set, participants performed 3 sets of 3-minute semi-squats on the vibration platform. Vibration exercise time was increased 30 seconds each week, with 3 minutes of rest being given between repetitions. The participants were barefooted and wore similar cotton socks for each vibration session. While administering the vibration protocol, a research investigator carefully monitored the participants for pain, discomfort, numbness, redness, itching, or muscle soreness, and they discontinued the session if any of these symptoms were present.

2.5. DEXA scan

BMC (g), BMD (g/cm^2), and LM (kg) were measured using dual-energy X-ray absorptiometry (DEXA) performed using the QDR-4500^a absorptiometer (Hologic Inc, Medford, MA). The device was calibrated according to the manufacturer's specifications using a spinal phantom. Calibrations were completed against the phantom in the lateral,

anterior/posterior, and single-beam modes. With the participant in the supine position and motionless on the DEXA table, total body measurements and regional measurements of the right leg, left leg, and trunk were completed. The sum of the right and left leg mass, total body LM, BMC, and BMD were used for comparison. Calibration and measurements were completed using Hologic pediatric software (Shirley, NY). DEXA measurements are described in more detail elsewhere[11, 26].

2.6. Isokinetic testing

Muscle strength was assessed using a Biodex System-3 dynamometer (Biodex Medical System, Shirley, NY) prior to and following the 6-week intervention. Participants' thighs were securely strapped to the Biodex seat, and knees were positioned such that the axis of rotation of the dynamometer head was even with the joint line of the dominant knee used for testing. The knee joint of the dominant leg was positioned at 90° flexion and, anterior/posterior ankle pads on the dynamometer attached. The pads were attached superior of the malleoli and the posterior pad in contact with the distal soleus-gastrocnemius complex. The pads were secured so as to ensure that the children had no movement within the pads. After a warm-up session consisting of 3 (no load) repetitions, 10 maximal knee extension and flexion movements were performed. The isokinetic test was performed at an angular velocity of 150 deg·s⁻¹ which in our experience with children is the speed that is the most comfortable and yields the highest peak torque values relative to 90 deg·s⁻¹ or 180 deg·s⁻¹. The highest peak torque achieved during the 10-repetition set was reported in absolute terms and relative to leg mass [11]. The weight of the patient's lower leg was accounted for in the calculations using the Biodex software (Shirley, NY). We have utilized this technique previously^{12,50}.

2.7. Statistical analysis

Demographics were summarized by mean and standard deviation for continuous variables, while categorical variables were summarized by counts. Demographic differences between treatment groups were assessed by 2-sample t-test or chi-square test, as appropriate. Statistical analyses were completed using R statistical software (R Core Team, 2015, version 3.2.1). For each of the outcome measures, a mixed 1-way analysis of variance modeled the relation between the outcome and all levels of an interaction between treatment (EX vs. EX +WBV) and time (Pre vs Post), while blocking by subject to account for repeated measures. Differences among treatments and times were assessed by Tukey-adjusted contrasts. Alpha was set at $p < 0.05$ *a priori*, and all data are reported as mean $\pm$ standard error of the mean, unless otherwise noted.

3. Results

3.1. Demographics

The EX and the EX+WBV groups were similar in age (mean $\pm$ SD; EX: 13.1 $\pm$ 4.0 years vs. EX+WBV: 11.7 $\pm$ 3.7 years), height (151.8 $\pm$ 19.5 cm vs. 145.4 $\pm$ 18.9 cm), and weight (47.7 $\pm$ 19.4 kg vs. 42.7 $\pm$ 13.8 kg) (Table 1). Furthermore, both groups had similar percent TBSA burned (mean $\pm$ SD; EX: 57 $\pm$ 12% vs. EX+WBV: 49 $\pm$ 12%), percent TBSA with

3rd-degree burns ($40 \pm 21\%$ vs. $39 \pm 23\%$), and length of hospital stay (58 ± 28 days vs. 50 ± 19 days).

3.2. Whole-body lean mass and whole-body bone composition

Over time, whole-body LM significantly increased in the EX group (1.58 ± 0.80 kg; $p = 0.04$) but did not achieve significance in the EX+WBV (1.31 ± 0.56 kg; $p = 0.09$). When corrected for height, whole-body LM significantly increased in the EX group (0.92 ± 0.47 kg/m²; $p = 0.04$) and achieved near significant increases in the EX+WBV group (0.90 ± 0.36 kg/m²; $p = 0.06$). These increases did not significantly differ between the groups. Interestingly, a significant decrease in whole BMC was observed pre- and post-treatment for the EX group (-43.6 ± 21.7 g; $p = 0.04$). However, the decrease in whole BMC for the children in the EX+WBV group did not achieve significance (-34.1 ± 17.3 g; $p = 0.11$). Changes in whole BMC did not differ between groups. Whole BMD was not altered significantly by treatment group or time (EX group -0.03 ± 0.02 g/cm²; EX+WBV group -0.01 ± 0.01 g/cm²; time effect $p = 0.29$, intervention effect $p = 0.64$) (Fig. 2).

3.3. Regional effects

Regional data obtained in the leg are presented in Table 2 and Figure 3. No significant differences were detected in leg LM over time in either group (EX: 0.81 ± 0.57 kg, $p = 0.86$; EX+WBV: 0.56 ± 0.24 kg, $p = 0.25$) or between groups. Leg BMC decreased significantly over time in both the EX (-35.5 ± 14.1 g; $p = 0.01$) and EX+WBV group (-31.2 ± 9.5 g; $p = 0.04$), with no differences being seen between the groups. Leg BMD decreased in the EX group (-0.13 ± 0.04 g/cm²; $p < 0.001$) but not in the EX+WBV group (-0.07 ± 0.05 g/cm²; $p = 0.26$). However, these changes were not significantly different between groups.

Regional changes in truncal BMC, BMD, and LBM are shown in Table 3 and Figure 4. Truncal LM did not differ from pre- to post-intervention in the EX (0.46 ± 0.29 kg; $p = 0.44$) or the EX+WBV group (0.24 ± 0.40 kg; $p = 0.88$). Truncal BMC decreased significantly over time in the EX group (-27.9 ± 11.3 g; $p = 0.01$) but not the EX+WBV group (-11.0 ± 6.4 g; $p = 0.28$). Likewise, Truncal BMD decreased significantly pre- and post-intervention in the EX group (-0.22 ± 0.05 g/cm²; $p < 0.001$), but not the EX+WBV group (-0.01 ± 0.06 g/cm²; $p = 0.91$). No difference was detected between the groups in truncal BMC or BMD.

3.4. Muscle strength

Absolute knee extension peak torque increased in the EX group (23.8 ± 2.7 N·M; $p < 0.001$) and the EX+WBV (15.1 ± 2.3 N·M; $p < 0.001$), with no between-group differences. Similar to absolute strength, knee extension peak torque corrected for leg LM increased over time in both the EX group (2.05 ± 0.30 N·M/kg; $p < 0.001$) and the EX+WBV group (1.53 ± 0.35 N·M/kg; $p < 0.001$), and no significant differences were detected between the groups (Fig. 5).

4. Discussion

WBV has been investigated as a potential, non-pharmacological osteogenic exercise stimulus, and it has been shown to improve muscular strength and protect against bone and muscle loss in nonburned individuals with restricted physical activity[14, 18–21]. In the present study, we found that exercise, used either with or without WBV, was effective in increasing muscle strength. We also found that BMC and BMD in both the leg and trunk decreased significantly in the EX group, with there being only a trend towards a loss in the EX+WBV group.

Our findings lend support to our previous reports and those of others on the benefits of exercise training on muscle strength and LM in burned children [8, 9, 11] [27, 28]. The finding that exercise significantly increased whole-body, but not regional LM, is not surprising given the short duration of the study. Indeed, all of the previous studies that showed exercise to have a significant, beneficial effect on LM have had a duration of 12 weeks[8–11]. Like exercise, WBV has been shown to improve strength after burns[29–32]. Ebid and colleagues [31] compared the effects of 8 weeks of home-based physical therapy to WBV in adults. The physical therapy intervention included strength training, range of motion exercises, and daily walking sessions, while the vibration group completed a progressive WBV regimen using the same mode of vibration used in here. They found that both the physical therapy and vibration groups had significantly improved strength, but the gains were greater in the group using WBV. No results on body composition were reported. Since the intervention program implemented by Ebid et al. [31] was home-based, participants in the physical therapy group may not have achieved the same resistance exercise load and intensity as the vibration group. Our machine-based exercise regimen allowed for progressive increases in load without limitation and provided a greater overload stimulus in both groups. Thus, adding WBV to exercise did not enhance the strength improvements, suggesting that exercise alone is sufficient for neuromuscular activation to improve lower body strength in children recovering from burns. Moreover, the fact that, in the EX + WBV group, strength gains were not accompanied by a clear, significant increase in LM group suggests that early-phase strength gains are probably due to increases in motor unit recruitment, not hypertrophy. In nonburned children participating in exercise, hypertrophy is not often observed due to the fact that children have lower resting levels and exercise-induced increases in anabolic hormones than adults [33].

Studies have shown that, although exercise improves strength during rehabilitation in children recovering from burn injuries, it is not sufficient to protect against bone loss when used alone. Accordingly, despite participation in a structured exercise program that included strength training, patients still lost significant bone. Bone remodeling from exercise is site-specific to the forces imparted to the bone throughout the exercise modality. The exercise protocol used in this study primarily consists of machine-based exercises focusing on specific muscles and has been shown to be effective in improving strength in children recovering from burns[8–11]. The machine-based exercises are advantageous in this population because the patient can be carefully placed in the machine in such a way as to avoid stress on the healing tissue and avoid pain. Nevertheless, the machines used in this study may not have imparted forces directly through the spine, and thus regional bone may

not have been significantly stressed with this exercise protocol. To the extent that it is safely possible in children, adolescents, and patients recovering from burns, it may be advantageous to study other protocols implementing total body exercises such as modified squats and deadlifts, which may impart greater forces directly onto the spine.

Our data suggest that, when combined with exercise, WBV may have a small, albeit protective effect against regional bone loss. Previous research supports the anabolic effects of WBV on bone in a variety of populations including postmenopausal women, the elderly, and patients with restricted mobility[14, 18, 19]. The regional protection in bone observed here was not surprising given the previously reported kinetics of WBV. Abercromby and colleagues[13, 34] studied the transmission of WBV through the skeleton using 2 vibration platforms: a predominantly vertical vibration device identical to the one used in this study and a rotational vibration device. Using an accelerometer attached to a bite bar, they showed that a significant amount of vibration was transmitted from the plate to the head; greater transmission was evident through the skeleton using the predominantly vertical vibration device than the rotational device. Over time, the transmission of mechanical force from WBV could prove to be beneficial. On the other hand, is possible that exercise with and without WBV may not be sufficient to overcome the physiological state triggered by burn injuries. Although we did not measure osteocyte activity, Klein and coworkers have postulated that, in burned children, osteocytes are abnormally low to absent, and hence increases in bone mass due to any exercise intervention may be difficult to obtain [35, 36]. Future studies are needed definitively determine the effectiveness of WBV on bone loss as well as to define cellular responses to exercise interventions with the goal of understanding the mechanisms underlying bone loss.

Although there is minimal information available relating to safe and effective guidelines for the application of WBV in burned children[31], previous research supports the short-term safety in adults[37]. We do not know if vibration improved wound and graft healing, although we speculate that there could be a positive effect due to increased blood flow to the skin with vibration[38, 39]. However, we anecdotally observed that vibration also caused physical movement of the grafted skin. Although the “health” of the grafted skin was not assessed, we recommend caution when using WBV, as excessive movement may compromise the integrity of the graft. More research is needed to study lower magnitude vibration or potentially different frequencies, which may result in less stress on the skin graft or tissue. It is possible that a lower magnitude, higher frequency stimulus may also be beneficial for bone[40, 41].

Finally, we must acknowledge the short duration of the study as a potential limitation. Despite the relatively short time frame for exercise training, we still saw significant and meaningful increases in isokinetic strength and decreases in BMC and BMD. These findings support the robust effectiveness of exercise in improving strength during burn recovery and underscore the severity of burn-induced catabolism, with bone loss persisting despite vigorous exercise. Further research is greatly needed to investigate exercise training of longer durations or other countermeasures for bone loss, including emerging pharmacological treatments.

5. Conclusion

In children recovering from burns, use of exercise in conjunction with WBV is well-tolerated, improves strength, and may have had a small protective effect on bone loss in the leg and trunk.

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Abbreviations

BMC	bone mineral content
BMD	bone mineral density
DEXA	dual energy x-ray absorptiometry
EX	exercise only group
EX+WBV	exercise + whole-body vibration group
LM	lean mass
TBSA	total body surface area
OT/PT	occupational therapy/physical therapy
WBV	whole-body vibration

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Highlights

- Exercise alone improves muscle mass and muscle strength.
- Exercise alone does not prevent bone loss in burned children.
- Combining whole-body vibration with exercise does not further improve strength.
- Combining whole-body vibration with exercise does not further improve muscle mass.
- Combining whole-body vibration with exercise may help prevent regional bone loss.

Fig. 1. Participants performing exercise on the whole-body vibration platform. (A) Participant during a warm-up period. (B) Participant during an exercise stimulus.

Fig. 2.

Effect of EX and EX+WBV on whole-body lean mass and bone composition pre and post training. (A) Whole-body lean mass (LM). (B) Whole-body bone mineral content (BMC). (C) Whole-body bone mineral density (BMD). Whole-body lean mass improved significantly ($p = 0.04$) after training in the EX group, but not in the EX+WBV group ($p = 0.06$). Whole-body bone mineral content decreased significantly ($p = 0.04$) after training in the EX group, but not in the EX+WBV group ($p = 0.11$). Whole-body bone mineral density was not significantly decreased in either group after training. Data are presented as mean $\pm$ standard error. * $p < 0.05$. NS, non-significant.

Fig. 3.

Effect of EX and EX+WBV on leg lean mass and bone composition obtained pre and post training. (A) Leg lean mass (LM). (B) Leg bone mineral content (BMC). (C) Leg bone mineral density (BMD). Leg LM did not change significantly ($p = 0.86$) after training in the EX group, or in the EX+WBV group ($p = 0.25$). Leg BMC decreased significantly after training in both the EX group ($p = 0.01$) and the EX+WBV group ($p = 0.04$). Leg BMD decreased significantly in the EX group ($p = 0.001$), but not the EX + WBV group ($p = 0.26$). Data are presented as mean $\pm$ standard error. * $p < 0.05$. NS, non-significant.

Fig. 4.

Effect of EX and EX+WBV on trunk lean mass and bone composition obtained pre and post training. (A) Trunk lean mass (LM). (B) Trunk bone mineral content (BMC). (C) trunk bone mineral density (BMD). LM did not change significantly ($p = 0.44$) after training in the EX group, or in the EX+WBV group ($p = 0.88$). BMC decreased significantly ($p = 0.01$) after training in the EX group but not the EX+WBV group ($p = 0.28$). BMD decreased significantly in the EX group ($p = 0.001$), but not the EX + WBV group ($p = 0.91$). Data are presented as mean $\pm$ standard error. * $p < 0.05$. NS, non-significant.

Fig. 5.

Effect of EX and EX+WBV on relative knee extension peak torque pre- and post-intervention. Leg strength improved significantly ($p = 0.001$) after training in the EX group and the EX+WBV group ($p = 0.001$). Pre-intervention strength levels were not statistically different ($p = 0.06$) between both groups. Both groups significantly improved strength at the end of their specific intervention; however, the degree of improvement was not significantly different between the groups ($p = 0.31$). Data are presented as mean $\pm$ standard error. * $p = 0.001$

Table 1

Patients characteristics

Characteristic	Exercise (n = 10)	Exercise + WBV (n = 9)	P Value
Sex	8 male/2 female	5 male/4 female	0.64
TBSA burned (%)	57 ± 12	49 ± 12	0.19
TBSA burned 3 rd degree (%)	40 ± 21	39 ± 23	0.79
Age (years)	13.1 ± 4.0	11.7 ± 3.7	0.33
Height (cm)	151.8 ± 19.5	145.4 ± 18.9	0.39
Weight (kg)	47.7 ± 19.4	42.7 ± 13.8	0.45
LOS (days)	58 ± 24	50 ± 19	0.42

Values are expressed as the mean ± SD. TBSA, total body surface area; LOS, length of hospital stay; WBV, whole-body vibration.

Table 2

Effect of exercise with and without WBV on leg lean mass, bone mineral content and bone mineral density

Intervention	Pre/Post Training	Lean Mass (kg)	Bone Mineral Content (g)	Bone Mineral Density (g/cm ²)
Exercise (n = 10)	Pre	9.9 ± 1.1	577.0 ± 85.7	1.87 ± 0.15
	Post	10.7 ± 1.3	541.5 ± 85.9 [*]	1.74 ± 0.13 [*]
Exercise + WBV (n = 9)	Pre	8.6 ± 1.0	530.7 ± 84.6	1.91 ± 0.15
	Post	9.1 ± 1.1	499.5 ± 77.8 [*]	1.84 ± 0.14

Values are expressed as the mean ± SEM. WBV, whole-body vibration.

^{*} p < 0.05 for within-group changes (pre to post delta).

Table 3

Effect of exercise with and without WBV on truncal lean mass, bone mineral content, and bone mineral density

Intervention	Pre/Post Training	Lean Mass (kg)	Bone Mineral Content (g)	Bone Mineral Density (g/cm ²)
Exercise (n = 10)	Pre	17.1 ± 1.9	372.0 ± 54.4	3.43 ± 0.23
	Post	17.5 ± 2.1	344.1 ± 50.6 *	3.22 ± 0.21 *
Exercise + WBV (n = 9)	Pre	14.1 ± 1.6	329.3 ± 44.5	3.59 ± 0.20
	Post	14.4 ± 1.6	318.3 ± 46.2	3.58 ± 0.22

Values are expressed as the mean ± SEM. WBV, whole-body vibration.

* $p < 0.05$ for within-group changes (pre to post delta).