# 12-weeks of Whole Body Vibration with Resistance Exercise is Osteogenic at the Spine

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## Abstract

Evidence supports weight-bearing activity as a means to increase bone mineral density (BMD) and lower risk for osteoporosis. Whole body vibration (WBV) training is a novel technique that has been minimally explored for its potential to influence bone health. Of note is the lack of independent research explaining health outcomes of WBV training. **PURPOSE**: Our aim was to evaluate whether WBV with resistance exercise could increase BMD at the spine. **METHODS**: We recruited 24 men and women between the ages of 18-23; 10 volunteers (6 male and 4 female) performed WBV exercise training, 3 times per week, for 12 weeks, while the remaining 14 subjects (4 male and 10 female) served as controls. WBV training on the Vibraflex 550 (Orthometrix, Naples, FL), began with static standing and progressed to include squat, deadlift, lunge, rowing, and push-up exercises. Frequency (15-26 Hz) of vibration, duration, repetitions, and the number of exercises varied systematically over 12 weeks. BMD at the anterior-posterior (AP) and lateral spine was measured using dual-energy x-ray absorptiometry (DXA, Hologic, Waltham, MA) before and after the 12-week program. Serum bone-specific alkaline phosphatase (BSAP) was evaluated in a subsample of participants via enzyme-linked immunosorbant assay (Quidel, Santa Clara, CA). **RESULTS**: At baseline, groups were statistically similar in age, height, weight, body mass index, calcium intake, and kilocalorie consumption. BMD at the AP spine and lateral spine was also similar between groups at baseline. A two-tailed t-test revealed significant differences ($p=0.013$) in the change in BMD at the lateral spine between the control ($-0.0149\pm0.010$ g/cm$^2$) and WBV group ($0.0221\pm0.012$ g/cm$^2$) with a trend for differences at the AP spine ($-0.0087\pm0.007$ g/cm$^2$ vs. $0.0089\pm0.007$ g/cm$^2$, $p=0.089$). A t-test comparing BSAP of the WBV ($31.39\pm10.79$ U/L) and control groups ($22.63\pm4.74$ U/L) suggest higher levels of formation markers for the trained individuals ($p=0.086$). **CONCLUSION**: In this 12-week intervention, the WBV group experienced a 2.2% increase in BMD at the lateral spine ($p=0.013$) while the control group decreased 1.7%. These preliminary results suggest that WBV with resistance exercise is a potential training method that can be used to increase BMD, and thereby lower future risk of osteoporosis..

## Background

Osteoporosis is a skeletal disease characterized by low bone mass, resulting in an increased risk for fracture. This disease is a major public health concern contributing annually to an estimated 2 million fractures costing $17 billion to the American health care system (1). Obtaining an optimal peak bone mass (PBM), which is the highest potential bone mineral density (BMD) achieved during young adult life, is vital for preventing osteoporosis. Improving dietary intake, increasing mechanical loading, and performing resistance training have shown to be effective at increasing BMD in young adults and thereby lowering risk of osteoporosis (2). Whole body vibration (WBV) is a newly recognized training method with the potential to increase bone mineral density (3). Recent experimental research has suggested WBV can improve strength of both muscle and bone (4). Therefore, the purpose of this study was to investigate whether 12 weeks of WBV training with dynamic exercise could improve BMD in healthy, college-age adults.

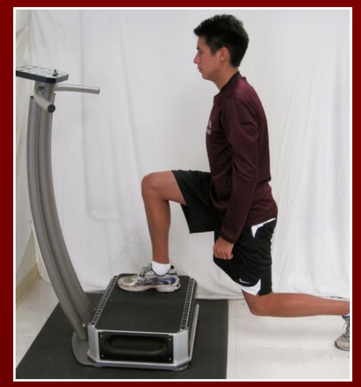
## Methods

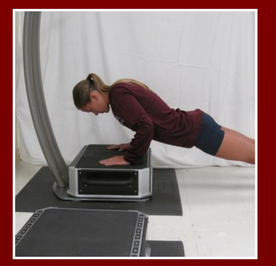
- Twenty-five active college-age men and women volunteered to complete WBV with dynamic exercise or serve as controls
- Dual energy x-ray absorptiometer (DXA) was used to measure bone mineral density (BMD) before and after 12 weeks of training
- WBV training occurred 3 days/week, for 20-30 minutes and included: squats, stiff-leg deadlifts, stationary lunges, push-up holds, bent-over rows, and jumps onto and off of the platform
- Total number of sets varied from 4-11, duration of vibration per session fluctuated from 165-540 sec, while frequency of vibration ranged from 15-26 Hz
- Bone-specific alkaline phosphatase (BAP) was measured after training using ELISA technique with a serum kit (Quidel, Microvue)
- Dietary intake was evaluated using the Block 2005 Food Frequency Questionnaire

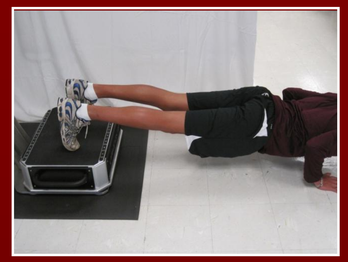
## Participants

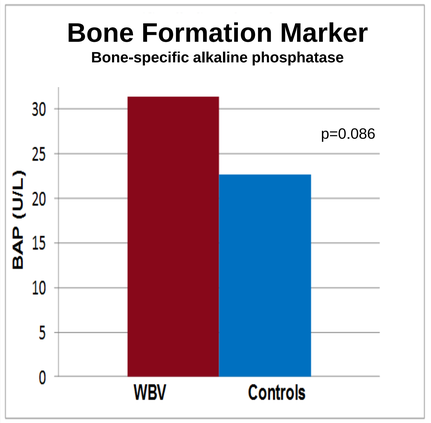
| | WBV | Controls |
|---|---|---|
| Sex | 6 males, 4 females | 1 male, 13 females |
| Age (years) | 19.3 ±1.3 | 19.8 ±1.1 |
| BMI (kg/m$^2$) | 19.9 ±1.1 | 21.3 ±2.8 |
| Percent Body Fat (%) | 17.3 ±6.5 | 26.6 ±4.2* |
| Lean Mass (kg) | 47.3 ±8.7* | 41.5 ±51.5 |
| Calcium Intake (mg/d) | 1003 ±330 | 1009 ±298 |
| Physical Activity (MET-hrs/wk) | 106.8 ±69.1 | 65.4 ±49.4 |

*p<0.05 significantly greater





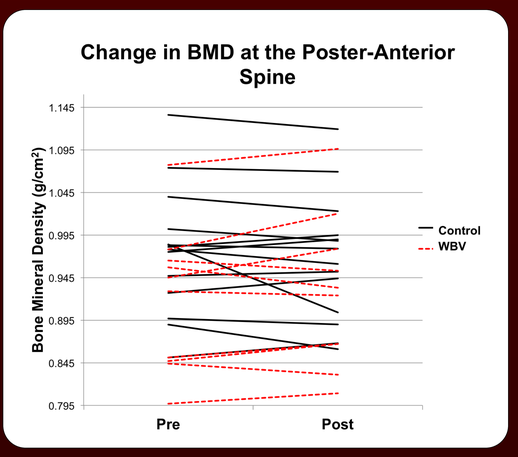


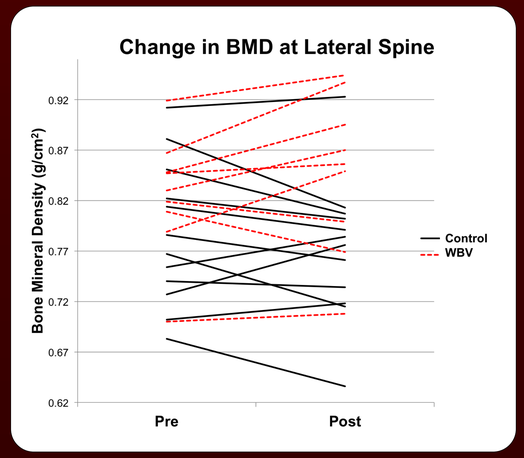



## Bone Mineral Density Results

| BMD Site | WBV Group (n=10) | | | Control Group (n=14) | | | |
|---|---|---|---|---|---|---|---|
| g/cm$^2$ | Baseline | 12-weeks | Change | Baseline | 12-weeks | Change | p-value |
| PA Spine | 0.919 ± 0.084 | 0.928 ± 0.089 | 0.009 | 0.976 ± 0.075 | 0.967 ± 0.074 | -0.009 | **0.079** |
| Lateral Spine | 0.825 ± 0.060 | 0.835 ± 0.082 | 0.022 | 0.787 ± 0.071 | 0.776 ± 0.068 | -0.015 | **0.031*** |
| Total Hip | 1.024 ± 0.114 | 1.015 ± 0.109 | -0.008 | 0.981 ± 0.064 | 0.977 ± 0.071 | -0.005 | **0.666** |
| Whole Body | 1.123 ± 0.085 | 1.124 ± 0.086 | 0.001 | 1.119 ± 0.058 | 1.123 ± 0.060 | 0.005 | **0.618** |

*p<0.05 significantly different




## Results

The WBV group experienced a 2.7% increase BMD of the lateral spine and 1.0% in the posterior-anterior view of the spine, while, the control group decreased 1.9% at and 0.9%, respectively.

Lean mass was significantly different between groups at baseline. However, change in lean mass over the 12 weeks was not different. An ANCOVA, revealed identical findings to the t-test and did not vary whether or not lean body mass was controlled, therefore results of the t-test are presented here.

A t-test suggests higher levels (28%) of BAP in the WBV over the control group ($p=0.086$).

## Summary

Results suggest that specific, dynamic exercise performed on a whole body vibration platform may be osteogenic at the spine. We report that a 12-week WBV training program performed 3 days per week improved spinal BMD at the lateral and posterior-anterior view. Bone responses may have been more significant at the lateral view due to its high content of trabecular bone, which is particularly responsive to changes in lifestyle patterns such as increasing weight-bearing activity.

Participants in both groups had similar height, weight, and BMI and therefore differences in body size do not likely explain the higher BAP levels. The high BAP levels should be interpreted with caution, however, considering that markers were not evaluated for changes before and after the intervention.

The osteogenic success of our program after only 12 weeks of training is likely due to several factors like the combination of vibration and dynamic exercise, the young age of our participants, high adherence of our supervised exercise program, room for improvement in BMD at the spine, and an exercise program that progressively increased intensity.

## References

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# Whole Body Vibration Training Program

| | Standing | | | Squat | | | Deadlift | | | Lunge | | | Push Up Hold | | | Bent Over Row | | | Jumps | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sec | Sets | Hz | Sec | Sets | Hz | Sec | Sets | Hz | Sec | Sets | Hz | Sec | Sets | Hz | Sec | Sets | Hz | Sec | Sets | Hz |
| Week 1 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 30 | 3 | 15 | 30 | 2 | 15 | 30 | 2 | 15 | | | | | | | | | | | | |
| Day 2 | 30 | 3 | 20 | 30 | 2 | 15 | | | | | | | 15 | 1 | 15 | | | | | | |
| Day 3 | 30 | 3 | 25 | 30 | 2 | 20 | 30 | 2 | 15 | 30 | 2 | 15 | 15 | 2 | 15 | | | | | | |
| Week 2 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 30 | 3 | 25 | 30 | 3 | 20 | 30 | 2 | 20 | 30 | 3 | 15 | 15 | 2 | 15 | | | | | | |
| Day 2 | 45 | 3 | 25 | 30 | 3 | 20 | 30 | 2 | 20 | | | | 15 | 2 | 15 | | | | | | |
| Day 3 | 45 | 3 | 25 | 30 | 2 | 25 | 30 | 2 | 20 | 30 | 2 | 20 | 15 | 2 | 20 | | | | | | |
| Week 3 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 45 | 3 | 25 | 60 | 3 | 25 | 30 | 3 | 25 | | | | 15 | 3 | 25 | | | | | | |
| Day 2 | 60 | 3 | 25 | | | | 30 | 3 | 25 | 60 | 3 | 25 | 15 | 3 | 25 | | | | | | |
| Day 3 | 60 | 3 | 25 | 60 | 4 | 25 | 45 | 2 | 25 | 60 | 4 | 25 | | | | | | | | | |
| Week 4 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 3 | 25 | 60 | 3 | 25 | 30 | 3 | 25 | | | | | | | 30 | 1 | 25 | | | |
| Day 2 | 60 | 3 | 25 | | | | 60 | 3 | 25 | 60 | 2 | 25 | 30 | 2 | 25 | 30 | 2 | 25 | | | |
| Day 3 | 60 | 3 | 25 | 60 | 2 | 25 | 60 | 2 | 25 | 60 | 2 | 25 | 30 | 2 | 25 | | | | | | |
| Week 5 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 3 | 25 | 60 | 4 | 25 | 60 | 3 | 25 | | | | 30 | 3 | 25 | | | | | | |
| Day 2 | 60 | 3 | 25 | | | | 60 | 3 | 25 | 60 | 3 | 25 | | | | 30 | 3 | 25 | | | |
| Day 3 | 60 | 3 | 25 | 60 | 3 | 25 | 60 | 3 | 25 | 60 | 2 | 25 | | | | | | | | | |
| Week 6* | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 2 | 26 | 60 | 4 | 25 | 60 | 4 | 25 | | | | 30 | 4 | 25 | | | | | | |
| Day 2 | 60 | 2 | 26 | | | | 60 | 4 | 25 | 60 | 3 | 25 | | | | 60 | 3 | 25 | | | |
| Day 3 | 60 | 2 | 26 | 60 | 3 | 25 | 60 | 2 | 25 | 60 | 1 | 25 | 30 | 2 | 25 | 60 | 1 | 25 | | | |
| Week 7 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 25 | 60 | 5 | 25 | | | | 30 | 4 | 25 | | | | | | |
| Day 2 | 60 | 1 | 26 | | | | 60 | 5 | 25 | 60 | 3 | 25 | | | | 60 | 4 | 25 | | | |
| Day 3 | 60 | 1 | 26 | 60 | 3 | 26 | 60 | 2 | 25 | 60 | 1 | 25 | 30 | 2 | 25 | 60 | 4 | 25 | | | |
| Week 8 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 26 | 60 | 5 | 25 | | | | 30 | 4 | 25 | | | | | | |
| Day 2 | 60 | 1 | 26 | | | | 60 | 5 | 25 | 60 | 3 | 25 | | | | 60 | 3 | 25 | | | |
| Day 3 | 60 | 1 | 26 | 60 | 3 | 26 | 60 | 2 | 25 | 60 | 1 | 25 | 30 | 2 | 25 | | | | | | |
| Week 9 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 26 | 60 | 5 | 25 | | | | 30 | 4 | 25 | | | | | | |
| Day 2 | 60 | 1 | 26 | | | | 60 | 2 | 26 | 60 | 3 | 25 | | | | 60 | 3 | 25 | 10 | 2 | 15 |
| Day 3 | 60 | 1 | 26 | 60 | 3 | 26 | 60 | 2 | 26 | 60 | 1 | 25 | 30 | 4 | 25 | 60 | 2 | 25 | 10 | 3 | 15 |
| Week 10 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 26 | 60 | 5 | 26 | | | | 30 | 4 | 25 | | | | 10 | 2 | 20 |
| Day 2 | 60 | 1 | 26 | | | | 60 | 2 | 26 | 60 | 2 | 26 | | | | 60 | 3 | 26 | 10 | 2 | 25 |
| Day 3 | 60 | 1 | 26 | 60 | 3 | 26 | 60 | 2 | 26 | 60 | 1 | 26 | 30 | 4 | 25 | 60 | 2 | 26 | 10 | 2 | 25 |
| Week 11† | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 26 | 60 | 5 | 26 | | | | 30 | 4 | 26 | | | | 10 | 2 | 25 |
| Day 2 | 60 | 1 | 26 | | | | 60 | 2 | 26 | 60 | 2 | 26 | | | | 60 | 3 | 26 | 10 | 2 | 25 |
| Day 3 | 60 | 1 | 26 | 60 | 3 | 26 | 60 | 2 | 26 | 60 | 1 | 26 | 30 | 4 | 26 | 60 | 2 | 26 | 10 | 2 | 26 |
| Week 12 | | | | | | | | | | | | | | | | | | | | | |
| Day 1 | 60 | 1 | 26 | 60 | 5 | 26 | 60 | 5 | 26 | | | | 30 | 4 | 26 | | | | 10 | 3 | 26 |
| Day 2 | 60 | 1 | 26 | | | | 60 | 2 | 26 | 60 | 2 | 26 | | | | 60 | 3 | 26 | 10 | 3 | 26 |
| Day 3 | 60 | 1 | 26 | 60 | 2 | 26 | 60 | 2 | 26 | 60 | 1 | 26 | 30 | 4 | 26 | 60 | 2 | 26 | 10 | 3 | 26 |

*introduced calf and toe raises into the exercises

†introduced the use of bands around the knees