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ORIGINAL ARTICLE

Effect of 4-week Whole Body Vibration on Distal Radius Density[△]

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Key words: whole body vibration; mechanical loading; distal radius; osteoporosis

Objective To assess the effects of high-frequency loading using whole body vibration on distal radius density in adults.

Methods The volunteers diagnosed with osteoporosis or osteopenia in the First Hospital of Jilin University from January 2011 to December 2014 were recruited. All the subjects performed foot-based, whole body vibrations on the vibration platform (35 Hz, 0.25 g) once a day, for 15 minutes per session over a period of 4 weeks. The bone mineral density of distal radius (rBMD) was measured using dual-energy X-ray absorptiometry at before, 2-week, and 4-week after the vibration treatment. Blood pressures were measured at the end of the vibration treatment.

Results A total of 114 volunteers were enrolled. The average rBMD before the treatment was 0.331 ± 0.014 g/cm². It was reached 0.337 ± 0.019 g/cm² at the end of the fourth week, increased by 1.79% ($P < 0.05$). Whole body vibration increased rBMD of men and women respectively (1.77% and 1.80%, $P < 0.05$). Blood pressures did not change in any of the groups.

Conclusion A 4-week whole body vibration was feasible and contributed to increase of rBMD.

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OSTEOPOROSIS is a skeletal systemic disorder characterized by low bone mass and a micro architectural deterioration of bone with increased incidence of fragility fractures. Now, there are about 84 million osteoporosis patients in China.¹

The incidence of fractures caused by osteoporosis is 9.6%, and it has a trend of increase year by year.¹ Distal radial fracture is the most frequent fragility fractures,² which can cause wrist chronic pain and stiffness, seriously affecting the hand function. When distal radius fracture occurs, it contributes to considerable disability, increases dependence for the injured patient and has become a public health issue.

Current clinical guidelines³ to treat bone loss have been focusing on anti-resorptive medication, healthful dietary intake, and traditional impact exercise, but these interven-

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tions sometimes have low patient compliance and can cause adverse side effects or may have an inherent risk of fall. Whole body vibration (WBV) therapy has been proposed as an alternative or adjunctive intervention. Evidence was provided in an animal model that low-risk, high-frequency mechanical accelerations might have a strong osteogenic effect.⁴ Several clinical studies showed that WBV training contributed to improve the bone health in human spine and hip.^{5,6} However, the effect of WBV on distal radial density has not yet been evaluated. The aim of this study was to evaluate changes in bone mineral density (BMD) at the distal radius using WBV.

PATIENTS AND METHODS

Participants

The volunteers with osteoporosis or osteopenia in the First Hospital of Jilin University from January 2011 to December 2014 were recruited. The protocol and study design were reviewed and approved by the human use committee of the First Hospital of Jilin University (NO. 2010-010). Informed consent was obtained from volunteers who agreed to participate in the study.

Inclusion criteria

The BMD of human right wrist joint was measured by dual-energy X-ray absorptiometry (DXA). The diagnosis of inadequate bone mass or osteoporosis was based on the handbook of the World Health Organization (1994 edition).³ The inclusion criteria also included normal nutritional status (as determined by questionnaire), stable weight maintenance (i.e., no elective weight loss or diet), estimated daily calcium intake of 500 mg/d, and the capability of following the protocol for daily use of the WBV device as well as understanding and providing informed consent.

Exclusion criteria

Individuals were excluded with (1) any prolonged immobilization of the axial or appendicular skeleton within the last 3 years; (2) consumption of excessive alcohol (2 drinks/day); (3) heart disease or cerebrovascular disease; blood pressure higher than 21.3/16.7 kPa under medication; systolic blood pressure less than 12.0 kPa; (4) epileptics; (5) thrombosis or a history of thrombosis within the past 6 months; (6) body implants or heart stents; (7) lumbar disc herniation or spondylolisthesis, spinal nerve canal stenosis or oppression; (8) symptoms of imbalance or vertigo; (9) any pharmacologic intervention for osteopenia in the last 6 months; and who were (10) un-recovered from surgical operations; (11) engaged in high-impact activity

at least 3 times per week.

Grouping and intervention protocol

The subjects were assigned into the male group and female group according to gender and 45-54 age group, 55-64 age group, ≥ 65 age group according to age.

All the subjects performed foot-based WBVs on the vibration platform Juvent 1000 (Juvent Medical Co. 300 Atrium Drive, Somerset, USA) once a day, for 15 minutes per session over a period of 4 weeks. During the treatment, the subjects were asked to stand vertically on the vibration platform, lightly holding the handrails of the vibration machine (ZD-10 vibration therapeutic apparatus, Beijing Maidakang Medical Equipment Company, China) with both hands. The vibration created by the platform can safely be transmitted into the extremities and axial skeleton without producing any detrimental skeletal resonances. The frequency of the vibration signals was 35 Hz. The peak vertical acceleration of the vibration platform was 0.25 g.

Blood pressure

The blood pressures were recorded and the subjects were asked for their discomfort at the end of the vibration treatment. All subjects sat quietly for 5 minutes before the blood pressure was measured using a standard automatic sphygmomanometer with cuffs matched to arm size and positioned at the cardiac level.

BMD assessment

At before and 2, 4 weeks after WBV, BMD of the distal radius was assessed by DXA with the GE Lunar Prodigy device (GE Healthcare, Madison WI, USA). All scans were performed with the anterior-posterior position by one same experienced technician. The coefficient of variation (CV) for distal radial DXA measurement in this study was 0.68%.

Statistical analysis

Statistical analysis was performed using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). Continuous variables of normal distribution were expressed as mean $\pm$ standard deviation (SD). The unpaired *t* test was used to test for baseline differences between the male group and the female group. Analysis of variance (ANOVA) was used to compare BMD among baseline, 2-week and 4-week groups. $P < 0.05$ was considered statistically significant.

RESULTS

General characteristics

A total of 114 cases were enrolled into this study, including

50 males and 64 females. There were 92 cases diagnosed with osteopenia (44 males and 48 females) and 22 cases diagnosed with osteoporosis (6 males and 16 females). All the subjects successfully completed the treatment. At the end of this study, the device received reassessments and was found that the parameters were within 5% of the criteria set at the initiation (35 Hz, 0.25 g). Age, BMD and other general characteristics of the patients are shown in Table 1.

Blood pressure

Compared with baseline ($17.3 \pm 3.6/12.3 \pm 2.5$ kPa), no significant effects of the intervention were found on systolic and diastolic blood pressure at 2 weeks ($17.2 \pm 4.1/12.3 \pm 3.0$ kPa, $P=0.169$) and 4 weeks ($17.2 \pm 3.7/12.3 \pm 2.9$ kPa, $P=0.172$) after treatment.

BMD

The distal radius BMD of the patients decreased gradually with the increase of age. The average distal radius BMD before the treatment was 0.331 ± 0.014 g/cm². It was reached 0.337 ± 0.019 g/cm² at the end of 4 weeks after treatment, which increased by 1.79%, and there was statistical significance compared with that of before the treatment ($P<0.05$). The distal radius BMD of the female group was less than that of the male group before the

treatment ($P=0.011$), and the distribution trend did not change after the treatment.

In the male group, the average distal radius BMD before the treatment was 0.336 ± 0.011 g/cm², and reached 0.342 ± 0.012 g/cm² at the end of 4 weeks after treatment, increasing by 1.77%, and the difference had statistical significance ($P<0.05$). But there was no significant difference at 2 weeks after treatment ($P=0.796$). The distal radius BMDs in the 45-54 age group and the 55-64 age group significantly increased after 4-week vibration treatment ($P=0.026$ and 0.017 respectively), while there was no significant change in the ≥ 65 age group ($P=0.086$). (Table 2)

In the female group, the average distal radius BMD before the treatment was 0.328 ± 0.015 g/cm² and reached 0.334 ± 0.011 g/cm² at the end of 4 weeks after treatment, increasing by 1.80%, and the difference had statistical significance ($P<0.05$). The distal radius BMDs in the 45-54 age group and the 55-64 age group significantly increased after 4-week vibration treatment (both $P<0.05$), while there was no significant change in the ≥ 65 age group ($P=0.089$). (Table 2)

DISCUSSION

This study specifically investigated the effect of WBV on

Table 1. Comparisons of general characteristics between male and female participants at baseline[§]

Groups	<i>n</i>	Age (yrs)	Body mass (kg)	Height (cm)	BMI (kg/m ²)	BMD of the distal radius (g/cm ²)
Male	50	55.7 $\pm$ 4.5	67.1 $\pm$ 2.8	166.1 $\pm$ 5.6	24.35 $\pm$ 2.90	0.336 $\pm$ 0.011
Female	64	56.1 $\pm$ 3.8	65.4 $\pm$ 3.4	162.9 $\pm$ 5.4	24.92 $\pm$ 3.04	0.328 $\pm$ 0.015
<i>P</i> value		0.524	0.207	0.198	0.826	0.011

§: Plus-minus values are means $\pm$ SD.

BMI: body mass index; BMD: bone mineral density.

Table 2. Comparison of BMD among different groups before and after treatment[§]

Groups	<i>n</i>	0 week	2 weeks	4 weeks
Male				
45-54 age	18	0.337 $\pm$ 0.019	0.339 $\pm$ 0.009	0.343 $\pm$ 0.017 ^{*#}
55-64 age	26	0.336 $\pm$ 0.022	0.337 $\pm$ 0.031	0.342 $\pm$ 0.021 ^{*#}
≥ 65 age	6	0.335 $\pm$ 0.015	0.336 $\pm$ 0.018	0.370 $\pm$ 0.022
Female				
45-54 age	25	0.330 $\pm$ 0.017	0.332 $\pm$ 0.016	0.336 $\pm$ 0.032 ^{*#}
55-64 age	20	0.327 $\pm$ 0.021	0.328 $\pm$ 0.100	0.334 $\pm$ 0.014 ^{*#}
≥ 65 age	19	0.326 $\pm$ 0.011	0.327 $\pm$ 0.007	0.328 $\pm$ 0.013

§: Plus-minus values are means $\pm$ SD.

^{*} $P<0.05$ compared with the 45-54 age group; [#] $P<0.05$ compared with the 0 week.

distal radial BMD in adults. And a large number of subjects were enrolled in this study. The results of the 4 weeks clinical data indicated that WBV with 15 minutes per day could improve bone loss. The distal radial BMD after the treatment increased by 1.79% compared with baseline ($P < 0.05$). The results from this study suggested that WBV might have an osteogenic effect, which was likely due to several factors such as the age of the participants, high compliance of the subjects and lower baseline BMD at the distal radius.

Although previous studies had been done about the effects of WBV, the mechanism of WBV increasing bone mass was not completely understood. Several researches reported that vibration loading could enhance the mechanical properties of long bones, increase the expression level of bone related protein, and promote the synthesis of bone tissue in the ovariectomized rat model of osteoporosis.⁷⁻⁹ Harris *et al*¹⁰ and Bannister *et al*¹¹ proved that mechanical vibration could affect energy metabolism of bone cell, gene activation and secretion of growth factors, and synthesis of other cell matrix. Liu *et al*¹² and McAllister *et al*¹³ also found that vibration could increase the synthesis of DNA and polysaccharide protein in the cultured cartilage cells, and accelerate the proliferation and differentiation of osteoblasts.

This study suggested that the osteogenic effect of load-bearing might decline with aging. The distal radius BMD of subjects who were younger than 65 years significantly increased after 4-week vibration treatment ($P < 0.05$), whereas no significantly difference was found in the older than 65 years group ($P > 0.05$). The short-term findings in this study were consistent with Taylor *et al*'s result.¹⁴ However, the results could not completely deny the validity of mechanical stimulation for the adults older than 65 years. It is known that osteogenesis is dependent upon complex interaction between loading frequency, magnitude and rest periods.¹⁵ The WBV protocols adopted in the study might not be optimal for inducing osteogenesis in older adults. Maybe duration of 4 weeks treatment time was too short for the elderly who had low sensitivity to WBV. The lack of significant findings might also be related to the subject characteristics.

Although without statistically significant difference, as shown in Table 2, it seemed to be an interesting phenomenon that the treatment effects of women were better than men. No similar observations were reported previously in the literature. Some clinical¹⁶ and experimental^{17,18} evidences suggested that there was an inverse relationship between the skeleton's sensitivity to WBV and the initial value of BMD. In this study, male adults might be less

sensitive to WBV than women adults because of higher baseline BMD. Besides that, it was also related to the women's better compliance. Further studies were needed to confirm these findings.

There was no significant difference in blood pressure in groups throughout this study. In particular, low back pain or injuries did not occur as well as other symptoms in all subjects. This was consistent with previous studies.^{19, 20} So WBV was a relatively safe method in the treatment of osteoporosis or osteopenia. Nevertheless, there were several limitations in this study. Firstly, research was needed to further address the long-term safety of WBV training in older subjects. Secondly, there is no control group. At last, different vibration loading parameters should be adopted such as type, magnitude, frequency, and duration, which varied the vibration stimulus and likely to result in different effects on different patients.

In conclusion, this study demonstrated that a 4-week WBV was feasible and contributed to increase distal radial bone density. Future clinical studies were needed to confirm these short-term findings for older than 45 years adults and explore the potential mechanism of vibration loading for preventing and treating osteoporosis.

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