Original article

Effects of vibration therapy on bone mineral density in postmenopausal women with osteoporosis

RUAN Xiang-yan, JIN Feng-yu, LIU Yu-lan, PENG Zhou-li and SUN Yun-gao

Keywords: *postmenopausal women; vibration; treatment; osteoporosis; bone mineral density*

Background Jaw osteonecrosis possibly associated with the administration of bisphosphonates is expected to be treated with a non-pharmacologic approach. This study aimed to determine whether noninvasive, mechanically mediated vibration would inhibit the decline in bone mineral density (BMD) that follows menopause, enhance the BMD of the lumbar and femoral neck, and reduce chronic back pain in postmenopausal women with osteoporosis.

Methods A total of 116 postmenopausal women with osteoporosis participated in this study, and they were divided into groups A (66 patients) and B (50). Group A received vibration treatment (Subjects vertically stand on the vibration platform, with a vibration frequency of 30 Hz, amplitude of 5 mm; they received the treatment five times per week, ten minutes each time and totally for six months), whereas women of group B served as controls without any treatment. L2–4 BMD, bilateral femoral neck BMD, and body mass index (BMI) were recorded before the treatment or at the third and sixth months of the treatment respectively. After the ending of the treatment, the change of BMD in each group was compared and analyzed. Chronic back pain was evaluated by visual analogue scale (VAS) at baseline and the third and sixth months of the treatment.

Results Of the 116 women, 94 including 51 women from group A ((61.23±8.20) years) and 43 women from group B ((63.73±5.45) years), completed the study. There were no significant differences in baseline characteristics including age, BMI, menopausal years, lumbar BMD, femoral neck BMD, and VAS between the two groups. The lumbar BMD of the 51 women in group A increased by 1.3% (P=0.034) after vibration treatment for 3 months and by 4.3% at the sixth month (P=0.000). The lumbar BMD in group B was decreased at the third month, but there was not statistical significance (P >0.05). At the sixth month, it was decreased by 1.9% (P <0.05). The femoral neck BMD of the 51 women in group A was slightly increased after vibration treatment for 3 months, but without statistical significance (P >0.05). At the sixth month, the BMD was increased by 3.2% (P <0.05). In group B, the BMD was not decreased significantly (P=0.185) at the third month, but decreased significantly at the sixth month (1.7%) (P <0.05) compared with the baseline. Chronic back pain (VAS) reduced more significantly in group A at the third and the sixth months (P <0.05) after vibration therapy in comparison with the baseline. The BMI was not significantly changed in the two groups during the period of follow-up.

Conclusions Vibration therapy appears to be useful in reducing chronic back pain and increasing the femoral neck and lumbar BMD in postmenopausal women with osteoporosis.

Chin Med J 2008;121(13):1155-1158

Characterized by micro-structural changes and increase of brittleness of bone, osteoporosis is a fracture-prone disease with a generalized decrease of bone mass in the entire body. In the menopausal period, not only the growth of age causes the degenerative bone loss in women, but the loss of estrogen's protective effects on skeletal structure also significantly accelerates this process. Furthermore, under normal circumstances, the peak bone mass of women is lower than that of men, leading to a higher incidence of osteoporosis in postmenopausal women. Pain, diseases, and fracture of bone, which are caused by osteoporosis, affect the quality of life for middle-aged and eldly women, and this has become an increasingly important public health issue.

Current treatment of osteoporosis is largely dependent on drugs;[1-3] however, the drugs have certain side-effects in long-term use, which is why most patients refuse this medication. Mechanical vibration is a traditional and safe physical therapy that is widely accepted in diagnosis and treatment of the disease, rehabilitation and sports medicine.[4,5] In the skeletal system, the diagnosis and treatment is mainly based on cytological and zoological research. Previous animal experiments showed that mechanical vibration with appropriate frequency can affect energy metabolism, gene activation, secretion of growth factors, and cell matrix synthesis of bone cells.[6,7] Theoretically, mechanical vibration can increase bone mass in the human skeleton as well.

Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing 100026, China (Ruan XY, Jin FY, Liu YL, Peng ZL and Sun YG)

Correspondence to: Dr. RUAN Xiang-yan, Department of Endocrinology, Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing 100026, China (Email: ruanxiangyan@163.com)

The study was supported by grants from Beijing Capital Foundation for Medical Science Development and Research, Key Project (No. 2002-2038), Beijing Natural Science Foundation Project (No. 3042009), and Beijing Municipal Science and Technology Rising Star Fund Projects (Ke Xing (2000) No. 95).

The present study aimed to observe the effects of vibration therapy on bone mass in postmenopausal women with osteoporosis.

METHODS

Study participants

A total of 116 postmenopausal women with osteoporosis who were living on the campus of the Beijing Institute of Technology during the period of 2004 to 2006 were studied. All subjects were informed the details of the study including purposes and procedures to use and signed the consent form. The research was approved by the Institutional Ethical Review Board.

Inclusion criteria

The BMD in the L2–4 and hip of the women with inadequate bone mass or osteoporosis was determined. The diagnosis of inadequate bone mass and osteoporosis was based on the 1994 criteria of the World Health Organization. Compared to normal healthy young women, spine, hip or wrist osteoporosis should be defined in women with bone mineral density < –2.5 SD (T score < 2.5) or a non-traumatic fracture in any sites, in postmenopausal women without typical menopausal symptoms, aged no more than 80 years, and in women willing to participate in this experiment as volunteers.

Exclusion criteria

Excluded were (1) women with blood pressure higher than 160/110 mmHg on medication; (2) women with systolic blood pressure less than 90 mmHg; (3) women with heart disease or cerebrovascular disease; (4) women with epileptics; (5) women with thrombosis or a history of thrombosis within the past 6 months; (6) women with body implants or heart stents; (7) women with lumbar disc herniation or spondylolisthesis, spinal nerve canal stenosis or oppression; (8) women in poor health and with symptoms of imbalance or vertigo; (9) women on treatment with drugs for osteoporosis or other agents affecting bone metabolism; (10) women un-recovered from surgical operations; (11) women un-recovered from joint injuries, fractures or muscle strain.

Grouping

The women who met the inclusion criteria and had no contraindications were divided into groups A and B. Group A was an experimental group consisting of 66 women, and group B a control group consisting of 50 women who were willing to have regular inspection but could not guarantee to present every time. In this experiment, the subjects were no longer subjected to other treatments of osteoporosis.

Study protocol

Test indicators

Chronic back pain was evaluated by visual analogue scale (VAS) at the baseline and the third or sixth month of the treatment.[8] The BMD at L2–L4 and the femoral neck of all subjects (groups A and B) was determined before the start of the treatment and at the third or sixth month of treatment respectively (Dual-energy bone densitometers, QDR-4500W, the US Hologic Corporation, USA).

Vibration treatment

Blood pressure was measured and recorded in group A 15 minutes after the subjects arrived at the laboratory. 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. With the width of their steps as same as their shoulders, the body was kept upright, and the body focus was moved to the heel, thus ensuring the vibration can be evenly conducted upward. The blood pressure was recorded again at the end of the vibration treatment and the subjects were asked for their discomfort. The treatment was given 5 times per week, 10 minutes each time, 4 weeks for a course, totalling 6 courses. The frequency of vibration was 30 Hz, and the amplitude was 5 mm.

Statistical analysis

Microsoft Office Excel was used to build up the database, and the data were analyzed with SPSS12.0. Descriptive data were calculated for the study sample and presented as means ± standard deviation (SD). The baseline data of group A (Table 1) were analyzed by Student's *t* test (with normal distribution) or Wilcoxon's rank-sum test (not in line with normal distribution). Differences in the two groups (Table 2) were determined using an analysis of variance. If variances were unequal, then the Brown-Forsythe *F* was used to test equality of means and post hoc comparisons used Dunnett's procedure. Otherwise, the equality of means was tested with the usual *F* ratio and subsequent comparisons of means used the SNK test. In all analyses, a two-tailed α level of 0.05 was used.

Table 1. Baseline characteristics of the two groups (mean ± SD)

Variables	Control group (n=43)	Experimental group (n=51)
Age (year)	63.73±5.45	61.23±8.20
Menopause (year)	15.73±7.13	13.52±7.94
BMI(kg/m^2)	23.22±3.25	24.37±3.28
VAS	3.11±2.29	3.21±2.36
L-BMD (g/cm^2)	0.760±0.053	0.836±0.022
F- BMD (g/cm^2)	0.583±0.095	0.666±0.100

BMI: body mass index; VAS: pain visual analogue scale score; L-BMD: lumbar bone mineral density; F-BMD: femoral neck bone mineral density.

RESULTS

Of the 116 women, 94 completed the six-month experiment. In group A (66 women), 51 completed the experiment and 15 lost, including one lost the treatment of traumatic fracture, one failed to have vibration treatment because of sudden heart attack, two ceased the treatment for one month vacation, one withdraw from the experiment because of low blood pressure, the others left for vacation. In group B (50 women), 43 women

Table 2. Comparison of BMI, VAS and BMD at baseline and follow-up periods

Variables	Control group (n=43)			Experimental group (n=51)		
	Baseline	3 months	6 months	Baseline	3 months	6 months
BMI (kg/m^2)	23.22±3.25	23.20±3.27	23.10±3.24	24.37±3.28	24.68±3.26	24.18±3.22
VAS	3.11±2.29	3.25±2.18	3.50±2.12	3.21±2.36	1.78±2.05**	1.35±1.92**
L-BMD (g/cm^2)	0.760±0.053	0.755±0.033	0.746±0.035*	0.836±0.022	0.847±0.021*	0.872±0.024**
F-BMD (g/cm^2)	0.583±0.095	0.575±0.089	0.573±0.099*	0.666±0.100	0.669±0.103	0.687±0.106*

BMI: body mass index; VAS: pain visual analogue scale score; L-BMD: lumbar bone mineral density; F-BMD: femoral neck bone mineral density. Values are mean ± SD. $^*P$ <0.05, $^{**}P$ <0.01, compared with baseline.

completed and 7 defaulted on the experiment. The default of the 7 women was due to medication for serious back pain. Therefore their data were not analyzed.

Subject characteristics

As shown in Table 1, there were no significant differences in baseline characteristics, including age, body mass index (BMI), menopausal years, lumbar BMD, femoral neck BMD, and VAS between the two groups (P >0.05) .

Effect of vibration treatment on lumbar BMD and femoral neck BMD, and reducing chronic back pain in postmenopausal women with osteoporosis

The lumbar BMD of the 51 women in group A was increased significantly after three-month vibration treatment (Table 2). The average lumbar BMD before the treatment was 0.836±0.022. It was increased by 1.3% after three-month treatment (P=0.034), reached 0.872±0.024 at the sixth month, and finally increased by 4.3% (P=0.000). In group B, the lumbar BMD showed a decreasing trend at the third month or decreased by 0.6%, without statistical significance (P >0.05). At the sixth month, it was decreased by 1.9%, and there was statistical significance compared with the baseline (P <0.05).

In group A the femoral neck BMD of the 51 women was slightly increased after three-month vibration treatment, but there was not statistical significance (P >0.05) (Table 2). At the sixth month, it was increased significantly (P <0.05) or increased by 3.2% that was higher than the baseline. While in group B, the BMD at the third month showed a decreasing trend, but there was not statistical significance (P=0.185). At the sixth month, it was decreased significantly (P <0.05) or decreased by 1.7% compared with the baseline.

Chronic back pain (VAS) was alleviated more significantly in group A at the third month (P <0.05) and the sixth month (P <0.05) of vibration therapy than the baseline. There was no significant change in BMI between the two groups in the follow-up period.

DISCUSSION

Mechanical vibration is a new type of exercise that has been increasingly tested for the ability to prevent bone fractures and osteoporosis in frail people.[9-11] There are two currently marketed vibrating plates: (1) the whole plate oscillates up and down; and (2) reciprocating vertical displacements on the left and right side of a fulcrum, increasing the lateral accelerations. Gusi et al[12] showed that the 8-month course of vibratory exercise using a reciprocating plate is effective to improve hip BMD and balance. A few studies have shown recently the effectiveness of the up-and-down plate for increasing bone mineral density (BMD), but such studies have not been reported in China. The aim of the present study was to investigate the effects of mechanical vibration using the whole plate oscillates up and down platform at frequencies of 30 Hz on lumbar and femoral neck bone mineral density in postmenopausal women with osteoporosis.

Our data suggest that the 6-month course of mechanical vibration is effective to improve two major determinants of bone fractures: lumbar and femoral neck bone mineral density. Even the 3-month course of mechanical vibration is able to improve the lumbar BMD and reduce the chronic back pain in postmenopausal women with osteoporosis.

With appropriate frequency, mechanical vibration can affect energy metabolism of bone cell, gene activation and secretion of growth factors, and synthesis of other cell matrix.[13,14] Under appropriate conditions, vibration can increase the synthesis of DNA in cultured cartilage cells and polysaccharide protein, and the proliferation and differentiation of osteoblasts also can be greatly accelerated,[15,16] making the treatment of osteoporosis and osteoarthritis possible.[17] In 1998 Flieger et al[18] used vibration therapy in animal experiment for the first time, and they found that the mechanical vibration of low-intensity (frequency of 50 Hz, acceleration of 2 g) can be used to compensate the loss of bone salt caused by overiectomy. The BMD of mice was significantly higher than that of blank controls after daily 30-minute vibration for continuous five weeks.[19] The one year mechanical vibration treatment (with frequency of 30 Hz, acceleration of 0.3 g, 20 min/d, 5 days/week, 1 year) had the hind limb proximal femoral trabecular bone density increased by 34.2% compared with non-vibration group. Compared with the corresponding site of non-vibration group, cancellous bone volume in the experimental group increased by 32% and the number of trabeculae increased by 45%, and the gap of the bone grid decreased by 36%. These findings indicate the production of new trabeculae. Under vibration, the bone synthesis rate increased by 2.1%, and the surface salinity increased by 2.4%. Based on the previous experiments, Ward et al[20] prescribed a six-month mechanical vibration for 20 children and adolescents (4–19 years old) with walking difficulties (stand on vibration platform, 0.3 g, 90 Hz, 10 min/d, 5 days/week). The proximal tibial bone mineral density of the vibration group increased by an average of 6.3%, while in the control group it was decreased by 11.9%. Meanwhile, studies have shown that vibration has no significant effect on the diameter of the patient's muscle and bone tissues.

Vibration treatment is thought to increase hip BMD. In this study the women with osteoporosis showed marked improvement of hip BMD and significantly increased lumber BMD after six-month vibration treatment (P <0.05).

Lumbar BMD was significantly increased after vibration treatment but the change in femoral neck BMD was not marked because the subjects stand vertically on the vibration platform, and vibration was conducted upright along the longitudinal axis of the body. Since the lumbar bone is in the same direction of the transmission of the vibration, the lumbar bone was given relatively stronger vibration, with a larger impact on the synthesis and metabolism of bone cells. There is a certain angle between the direction of the femoral neck and vibration, and the femoral neck was subjected to a relatively weaker vibration, with a smaller impact on the synthesis and metabolism of bone cells.

In conclusion, vibration therapy may be effective to reduce chronic back pain and increase the femoral neck and lumbar BMD in postmenopausal women with osteoporosis.

REFERENCES

1. Välimäki MJ, Farrerons-Minguella J, Halse J, Kröger H, Maroni M, Mulder H, et al. Effects of risedronate 5 mg/d on bone mineral density and bone turnover markers in late-postmenopausal women with osteopenia: a multinational, 24-month, randomized, double-blind, placebo-controlled, parallel-group, phase III trial. Clin Ther 2007; 29: 193719-193749.
2. Rizzoli R. Osteoporosis: non-hormonal treatment. Climacteric 2007; 10 Suppl 2: 74-78.
3. Scharla S, Oertel H, Helsberg K, Kessler F, Langer F, Nickelsen T. Skeletal pain in postmenopausal women with osteoporosis: prevalence and course during raloxifene treatment in a prospective observational study of 6 months duration. Curr Med Res Opin 2006; 22: 2393-2402.
4. Issurin VB, Tenenbaum G. Acute and residual effect of vibratory stimulation on explosive strength in elite and amateur athletes. J Sports Sci 1999; 17: 177-182.
5. Torvinen S, Kannus P, Sievänen H, Järvinen TA, Pasanen M, Kontulainen S. Effect of four-month vertical whole body vibration on performance and balance. Med Sci Sports Exerc 2002; 34: 1523-1528.
6. Issurin VB, Liebermann DG, Tenenbaum G. Effect of vibratory stimulation training on maximal force and flexibility. J Sport Sci 1994; 12: 561-566.
7. Klyscz T, Ritter-Schempp C, Jünger M, Rassner G. Biomechanical stimulation therapy as physical treatment to farthrogenic venous insufficiency. Hautarzt 1997; 48: 318-322.
8. Kasperk C, Hillmeier J, Nöldge G, Grafe IA, Dafonseca K, Raupp D, et al. Treatment of painful vertebral fractures by kyphoplasty in patients with primary osteoporosis: a prospective nonrandomized controlled study. J Bone Miner Res 2005; 20: 604-612.
9. Melchiorri G, Andreoli A, Padua E, Sorge R, De Lorenzo A. Use of vibration exercise in spinal cord injury patients who regularly practise sport. Funct Neurol 2007; 22: 151-154.
10. Iwamoto J, Takeda T, Sato Y, Uzawa M. Effect of whole-body vibration exercise on lumbar bone mineral density, bone turnover, and chronic back pain in post-menopausal osteoporotic women treated with alendronate. Aging Clin Exp Res 2005; 17: 157-163.
11. Cardinale M, Pope MH. The effects of whole body vibration on humans: dangerous or advantageous? Acta Physiol Hung 2003; 90: 195-206.
12. Gusi N, Raimundo A, Leal A. Low-frequency vibratory exercise reduces the risk of bone fracture more than walking: a randomized controlled trial. BMC Musculoskelet Disord 2006; 7: 92.
13. Nakamura H, Moroji T, Nagase H, Okazawa T , Okada A. Changes of cerebral vasoactive intestinal polypeptide and somatostatin-like immunoreactivity induced by noise and whole-body vibration in the rat. Eur J Applpysiol 1994; 68: 62-67.
14. Bannister SR, Lohmann CH, Liu Y, Sylvia VL, Cochran DL, Dean DD. Shear force modulates osteoblast response to surface roughness. J Biomed Mater Res 2002; 60: 167-174.
15. Liu J, Sekiya I, Asai K, Tada T, Kato T, Matsui N. Biosynthetic response of cultured articular chondrocytes to mechanical vibration. Res Exp Med (Berl) 2001; 200: 183-193.
16. McAllister TN, Frangos JA. Steady and transient fluid shear stress stimulates NO release in osteoblasts through distinct biochemical pathways. J Bone Miner Res 1999; 14: 930-936.
17. Logvinov SV, Levitskiĭ EF, Poliakova SA, Strelis LP, Laptev BI. The morphofunctional vadidation of the use of vibration-traction for the correction of contractures of the joints. Vopr Kurortol Fizioter Lech Fiz Kult 1998; 6: 43-45.
18. Flieger J, Karachalios T, Khaldi L. Mechanical stimulation in the form of vibration prevents post menopausal bone loss in ovariectimized rats. Calcif Tissue Int 1998; 63: 510-514.
19. Rubin C, Turner AS, Bain S, Mallinckrodt C, McLeod K. Low mechanical signals strengthen long bones. Nature 2001; 412: 603-604.
20. Ward K, Alsop C, Caulton J, Rubin C, Adams J, Mughal Z. Low magnitude mechanical loading is osteogenic in children with disabling conditions. J Bone Miner Res 2004; 19: 360-369.

(Received November 13, 2007)
Edited by QIAN Shou-chu and WANG Mou-yue