Journal of Exercise Physiologyonline

April 2013
Volume 16 Number 2

JEPonline

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

Long Term Running Exercise *vs.* Long Term Strength Exercise on Femoral Bone Mass Assessed in a Rat Model

Romeu Rodrigues De Souza[1], Maria Do Carmo Sitta[2], Jose Maria Santarem Sobrinho[2], Wilson Jacob Filho[2]

[1]Laboratory of Human Movement, São Judas Tadeu University, São Paulo, Brazil, [2]Department of Geriatrics and Gerontology, São Paulo University, São Paulo, Brazil

ABSTRACT

De Souza RR, Sitta MC, Santarem Sobrinho JM, Jacob Filho W. Long Term Running Exercise *vs.* Long Term Strength Exercise on Femoral Bone Mass Assessed in a Rat Model. **JEPonline** 2013;16(2):92-98. This study evaluated the efficacy of long term running exercise compared to long term strength training for enhancing bone mineral density (BMD) in male rats. Ten Wistar rats aged 3 mth were submitted to running exercise (RE group) for 1 $hr \cdot d^{-1}$, 3 days a week on a motor-driven treadmill at 16 $m \cdot min^{-1}$. Addition 10 male rats (SE group) were submitted to strength exercise that was performed 3 $d \cdot wk^{-1}$ that consisted of climbing a 1.1 m vertical (80° incline) ladder with weights tied to their tail. In both groups, the training level was maintained for 15 mth. All rats were sacrificed at 18 mth of age. Sedentary age-matched rats served as controls (CO group, n = 10). At death the right femur was obtained from each rat and the Bone Mass Density (BMD) of the femur was measured using a dual-energy X-ray absorptiometry. The BMD measurements revealed a significant training-induced increase in global BMD in both the SE and the RE groups with 18 mth of age when compared to the CO ($P<0.05$). Significant difference in BMD was found between SE and RE groups ($P<0.05$). The BMD was higher in the SE compared to the RE. In conclusion, the long-term running exercise and the long term strength exercise have a positive effect on femoral neck bone mass in aging rats. The findings demonstrate the potential therapeutic effect of the two types of exercise in protecting against osteoporotic fractures later in life.

Key Words: Physical Activity, Bone Mass, Femur, Aged Rat

INTRODUCTION

Osteoporosis is a bone disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fractures, especially occurring in the proximal femur, vertebrae, and wrist (2,14,23,25). Among the health strategies for preventing osteoporosis, the impact of both running exercise and strength exercise on bone mass in humans and animal models have been amply demonstrated (10,12,18,20,21,26). In these works, the exercises were applied for relatively short times (7,16,20,26,33,34). However, to better understand the effects of different exercise training on bone mass, it is necessary to compare different protocols that have the potential to maximize the osteogenic effects from training (13,24,30). The rat is a widely accepted model to study the effects of exercise on bone tissue.

The purpose of this study was to compare the effects of a triweekly (i.e., 3 times·wk^{-1}) resistance training with the effects of a running exercise program on a treadmill for 1 hr·d^{-1}, 3 d·wk^{-1} on bone mineral density (BMD) in the femur from Wistar rats. The right femur of exercised-trained male rats was examined for evidence of gain of bone mass at 15 mth after exercise training was initiated. Male rats were used because they do not suffer from the hormonal changes characteristic of female rats that interfere with the animal's bone structure.

METHODS

Animals

A total of 30 male Wistar rats were randomly assigned to the strength exercise group (SE group) (n = 10), the running exercise group (RE group) (n =10), or the sedentary group (control group, CO group) (n = 10). During the experiment, food and water were provided *ad libitum* to all rats. The rats were weighed initially and then at death. The rats were sacrificed with an overdose of sodium pentobarbital intraperitoneally. They were exposed to a 12:12 hr light-dark cycle, and the exercise program was performed during the dark periods. The rats were exercised at the same time each day. The handling of the rats was approved by the University Ethics Committee in adherence to the International Guiding Principles for Biomedical Research involving Animals.

Procedures

Running Exercise Protocol

At 3 months of age, rats from the RE group were subjected to an exercise program of running on a motor-driven treadmill for 1 hr·d^{-1}, 3 d·wk^{-1}. The treadmill had an initial speed of 4 m·min^{-1}, gradually increasing to 16 m·min^{-1}. Rats from this group were killed aged 18 mth, after 15 mth of exercise. The CO group was also killed aged 18 mth.

Strength Exercise Protocol

The rats in the SE group were trained to climb a 1.1 m vertical (80° incline) ladder with weights tied to their tail (8). They were trained once a day, 3 d·wk^{-1} for 15 mth. Each training session consisted of 6 climbs. The weight carried during each session was progressively increased. Over the course of 5 wk, the maximal amount of weight carried by the rats was 50% of their weight.

The rats in the CO group were placed on the stationary treadmill daily for 10 min. At death, the right hind limb was dissected from the body. After removal of all muscles and other tissues, the femur was then prepared for analyses.

Determination of BMD by Dual-Energy X-Ray Absorptiometry

Dual-energy radiograph absorptiometry measurements were made by a scanner (DXA- QDR- 2000 Plus (Hologic, Whaltman, MA, USA) equipped with *Software* for small animals (High Resolution Small Animals). Its reliability and accuracy are well studied (3,4,6,11,14,15).

Statistical Analysis

Statistical significance was evaluated by ANOVA and *post hoc* Newman-Keuls' test. Statistical significance was set at a P value of less than 0.05.

RESULTS

Effects of Exercise on Body Weight

Because chronic exercise generally induces a significant reduction in body weight, we compared the exercised groups to body weight–matched sedentary controls. However, at time of sacrifice (18 mth), the weight of the rats in the exercised groups was not significantly different from the weight of the CO group (strength exercise, 380.40 ± 48.31 g; running exercise, 372.40 ± 57.43 g; and the control, 390.70 ± 40.44 g (Figure 1).

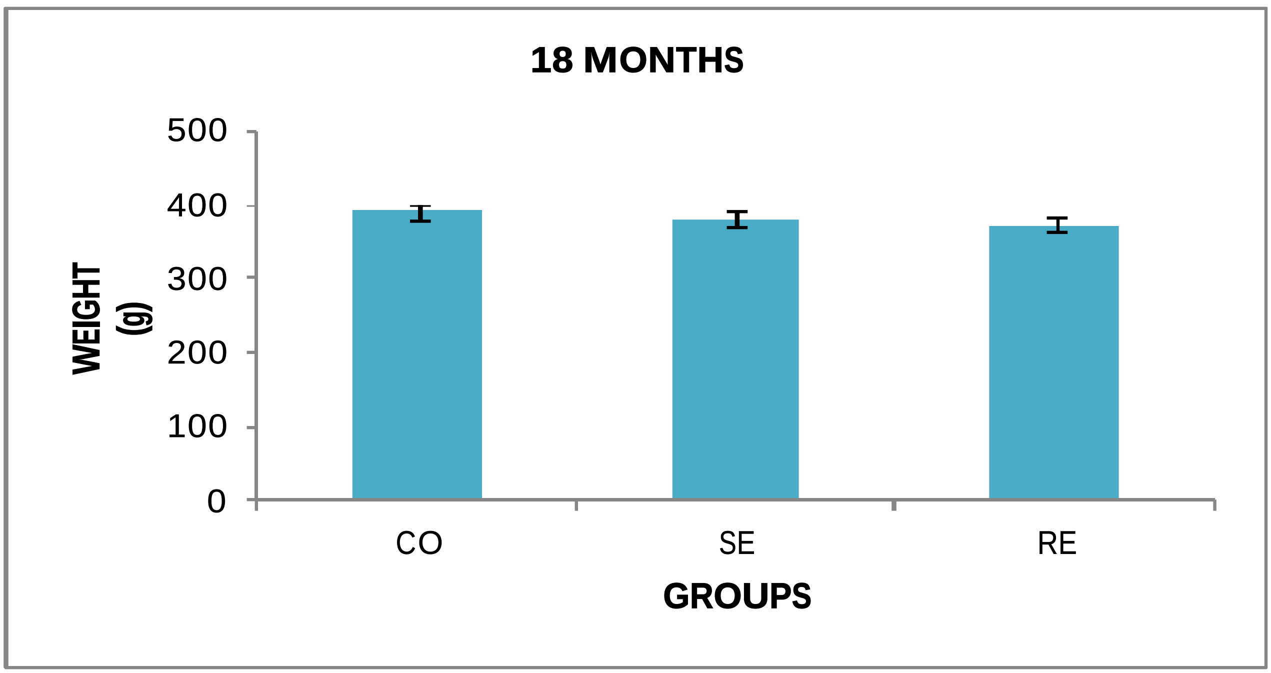

Figure 1. Effects of strength exercise (SE) and running exercise (RE) on body weight of rats after 15 mth of exercise. The data are presented as mean ± SD.

Effects of exercise on BMD

At the age of 18 mth, the femoral BMD values proved to be significantly higher ($P<0.05$) in the strength exercised group (0.2388 ± 0.0028) compared with the control group (0.2150 ± 0.0113 $g \cdot cm^{-2}$) and with the RE group (0.2267 ± 0.0114) (in both cases, $P<0.05$). The femoral BMD values (Figure 2) were also significantly higher ($P<0.05$) in the RE group (0.2267 ± 0.0114) compared with the control group (0.2150 ± 0.0113 $g \cdot cm^{-2}$) ($P<0.05$).

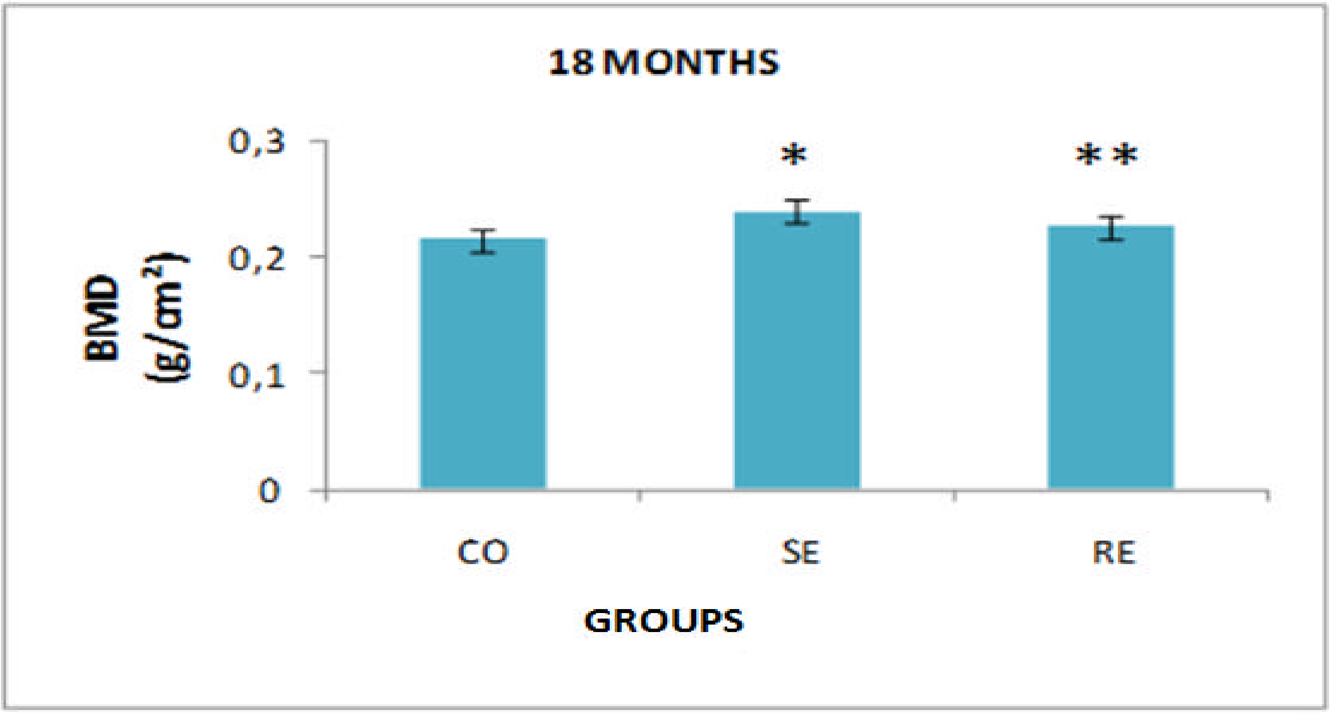

Figure 2. Effects of strength exercise (SE) and running exercise (RE) on BMD measured by dual-energy X-ray absorptiometry after 15 mth of exercise. The data are presented as mean ± SD. *Significant *vs.* CO and RE groups (P<0.05); **Significant *vs.* CO group (P<0.05).

DISCUSSION

The purpose of this study was to compare the effects of long term running training with the effects of strength training in BMD of the femur of rats. The choice of the rat was due to its extensive use as a model for studies of aging and osteoporosis (13,17,21). Although several factors may be involved in the genesis of osteoporosis, exercise is an important strategy to increase peak bone mass to prevent the expected loss by aging (10,13,24,27,29).

There are two major findings in the present study. First, both long term running training and strength training showed significant effect on BMD of the femur of rats. Second, BMD of the femur from rats submitted to long term strength exercise showed significant difference with RE group. The femur was chosen because it has been documented that the weight-bearing bones like the tibia and femur have higher sensitivity to treadmill exercise than less weight-bearing bones like the lumbar spine in rats (9). There was no significant difference between the body weights of the 3 groups of rats, therefore, it can be inferred that the rats constituted a homogeneous group (20).

The present study demonstrated a significant increase in BMD in the rats of the RE group. The efficacy of treadmill exercise to increase the bone mass of long bones has been demonstrated in male rats by several authors (9,12,16,32). Kannus et al. (12) trained the animals for a short time (8 wk) on an incline treadmill, but with a progressively increasing load. They observed a significant gain in bone mass. Likewise, Mosekild et al. (16) found a progressive increase in bone mass in groups of rats that trained on a treadmill for 4 to 10 mth in duration.

On the other hand, it has been demonstrated (1) that strenuous treadmill running (such as 105 min a day, with a speed of 30 m·min^{-1}, 10° tilt for 11 wk) is detrimental to the skeletal system. It is possible that these controversial results in the literature are due to the different times of exercise or training load that were not enough to stimulate the bone remodeling (22,31).

In the present study, when compared to the sedentary controls, the animals in the SE group exhibited a significant enhancement in BMD of the femur. These results are in accordance with Notomi et al. (21) who showed that strength exercise significantly increased the parameters of periosteal bone formation in the midfemur of rats. However, in a previous study, it was showed that animals receiving strength exercise training after 5 mth of exercise did not exhibit a significant enhancement in BMD of the femur when compared to the sedentary controls. Thus, it is reasonable to conclude that the effects of strength exercise on bone formation are time dependent.

The results cited in the present work were obtained when the BMD was measured by the dual-energy X-ray absorptiometry. Several studies (5,19,32) determined that it is a precise tool for measuring BMD of rat hindlimbs and for aged. Although the largest amount of knowledge to date on bone development and exercise has been acquired using this technique, it should be kept in mind the limitations with DXA and interpret the results accordingly (28).

CONCLUSION

The findings of this study indicate that both long term running and long term strength exercises have a positive effect on femoral neck bone mass in rats.

Address for correspondence: De Souza, RR, PhD, Department of Physical Education, São Judas Tadeu University, São Paulo, SP, Brazil, Phone +55 11 38899633; mail to: souzarrd@uol.com.br

REFERENCES

1. Bourrin S, Palle S, Pupier R, Vico L, Alexandre C. Effect of physical training on bone adaptation in three zones of the rat tibia. ***J Bone Miner Res.*** 1995;10:1745-1752.

2. Cauley JA, Fullman RL, Stone KL, Zmuda JM, Bauer DC, Barrett-Connor E, Ensrud K, Lau EM, Orwoll ES. Factors associated with the lumbar spine and proximal femur bone mineral density in older men. ***Osteoporos Int.*** 2005;16:1525-537

3. Chan GM. Performance of dual energy x-ray absorptiometry in evaluating bone, lean body mass, and fat in pediatric subjects. ***J Bone Miner Res.*** 1992;7:369-374.

4. Chen Z, Wang Z, Lohman T, Heymsfield SB, Outwater E, Nicholas JS, Bassford T, LaCroix A, Sherrill D, Punyanitya M, Wu G, Going S. Dual-energy x-ray absorptiometry is a valid tool for assessing skeletal muscle mass in older women. ***J Nutr.*** 2007;137:2775-2780.

5. Elberg J, McDuffie JR, Sebring NG, Salaita C, Keil M, Robotham D, Reynolds JC, Yanovski JA. Comparison of methods to assess change in children's body composition. ***Am J Clin Nutr.*** 2004;80:64-69.

6. Entezari V, Basto PA, Vartanians V, Zurakowski D, Snyder BD, Nazarian A. Non-invasive assessment of failure torque in rat bones with simulated lytic lesions using computed tomography based structural rigidity analysis. ***J Biomech.*** 2011;44(3):552-556.

7. Horcajada MN, Coxam V, Davicco MJ, Gaumet N, Pastoureau P, Leterrier C, Culioli J, Barlett JP. Influence of treadmill running on femoral bone in young orchidectomized rats. ***J Appl Physiol.*** 1997;83:129-133.

8. Hornberger TA Jr, Farrar RP. Physiological hypertrophy of the FHL muscle following 8 weeks of progressive resistance exercise in the rat. ***Can J Appl Physiol.*** 2004;29(1):16-31.

9. Iwamoto J, Yeh JK, Aloia JF. Differential effect of treadmill exercise on three cancellous bone sites in the young growing rat. ***Bone.*** 1999;24:163-169.

10. Iwamoto J, Shimamura C, Takeda T, Abe H, Ichimura S, Sato Y, Toyama Y. Effects of treadmill exercise on bone mass, bone metabolism, and calciotropic hormones in young growing rats. ***J Bone Miner Metab.*** 2004;22: 26-31.

11. Johnston CC, Slemenda CW, Melton LJ. Clinical use of bone densitometry. ***N Engl J Med.*** 1991;18:1105-1109.

12. Kannus P, Sievänen H, Järvinen TL, Järvinen M, Kvist M, Oja P, Vuori I, Jozsa L. Effects of free mobilization and low- to high-intensity treadmill running on the immobilization-induced bone loss in rats. ***J Bone Miner Res.*** 1994;9:1613-1619.

13. Kayser BD, Godfrey JK, Cunningham RM, Pierce RA, Jaque SV, Sumida KD. Equal BMD after daily or triweekly exercise in growing rats. ***Int J Sports Med.*** 2010;31(1):44-50.

14. Koo WW, Walter J, Bush AJ. Technical consideration of dual energy x-ray absorptiometry-based bone mineral measurement for pediatric studies. ***J Bone Miner Res.*** 1995;10:1998-2004.

15. Kröger H, Kotaniemi A, Vainio P, Alhava E. Bone densitometry of the spine and femur in children by dual energy x-ray absorptiometry. ***Bone Miner.*** 1992;17:75-78.

16. Mosekilde L, Danielsen CC, Søgaard CH, Thorling E. The effect of long-term exercise on vertebral and femoral bone mass, dimensions, and strength - assessed in a rat model. ***Bone.*** 1994;15:293-301.

17. Nagy TR, Prince CW, Li J. Validation of peripheral dual-energy X-ray absorptiometry for the measurement of bone mineral in intact and excised long bones of rats. ***J Bone Miner Res.*** 2001;16(9):1682-1687.

18. Nakamura T, Suzuki M. Effects of resistance exercise training on mass, strength, and turnover of bone in growing rats. ***Eur J Appl Physiol.*** 2000 82:268-274.

19. Newhall KM, Rodnick KJ, van der Meulen MC, et al. Effects of voluntary exercise on bone mineral content in rats. ***J Bone Miner Res.*** 1991;6:289-296.

20. Notomi T, Okazaki Y, Okimoto N, Saitoh S, Nakamura T, Suzuki M. A comparison of resistance and aerobic training for mass, strength and turnover of bone in growing rats. ***Eur J Appl Physiol.*** 2000;83:469-474.

21. Notomi T, Okimoto N, Okazaki_Y, Tanaka Y, Nakamura T, Suzuki M. Effects of tower climbing exercise on bone mass, strength, and turnover in growing rats. ***J Bone Miner Res.*** 2001;16:166-174.

22. Pohlman RL, Darby LA, Lechner AJ. Morphometry and calcium contents in apendicular and axial bones of exteriol ovariectomized rats. ***Am J Physiol.*** 1985;248:12-17.

23. Riggs BL, Khosla S, Melton LJ. Sex steroids and the construction and conservation of the adult skeleton. ***Endocr Rev.*** 2002;23(3):279-302.

24. Robling AG, Burr DB, Turner CH. Recovery periods restore mechanosensitivity to dynamically loaded bone. ***J Exp Biol.*** 2001;204:3389-3399.

25. Sambrook, P, Cooper C. Osteoporosis. ***The Lancet.*** 2006;367:2010-2018.

26. Sitta MC, De Souza RR, Costa JBV, Santarem Sobrinho JM, Jacob Filho W. Different BMD after Running or Strength Exercise in Growing Rats. ***JEPonline.*** 2012;15(1):40-46.

27. Søgaard CH, Danielsen CC, Thorling EB, Mosekilde L. Long-term exercise of young and adult female rats: Effect on femoral neck biomechanical competence and bone structure. ***J Bone Min Res.*** 1994;9:409-416.

28. Tishya A, Wren L, Gilsanz V. Assessing bone mass in children and adolescents. ***Current Osteoporosis Reports.*** 2006;4:153-158.

29. Turner CH. Three rules for bone adaptation to mechanical stimuli. ***Bone.*** 1998;23:399-407.

30. Turner CH, Robling AG. Designing exercise regimens to increase bone strength. ***Exerc Sport Sci Rev.*** 2003;31:45-50.

31. Tuukkanen J, Peng Z, Vaananen HK. Effect of running exercise on the bone loss induced by orchidectomy in the rat. ***Calcif Tissue Int.*** 1994;55:33-37.

32. Yeh JK, Liu CC, Aloia, JF. Effects of exercise and immobilization on bone formation and resorption in young rats. ***Am J Physiol.*** 1993;264:E182-E189.

33. Westerlind KC, Fluckey JD, Gordon SE, Kraemer WJ, Farrell PA, Turner RT. Effect of resistance exercise training on cortical and cancellous bone in mature male rats. ***J Appl Physiol.*** 1998;84(2):459-464.

34. Yeh JK, Aloia JF, Tierney JM, Sprintz S. Effect of treadmill exercise on vertebral, and tibial bone mineral content and bone mineral density in the aged rat: determined by dural energy X-ray absorptiometry. ***Calcif Tissue Int.*** 1993;52:234-238.