THE EFFECTS OF ENDURANCE EXERCISE ON THE SIZE AND STRENGTH OF ADULT AND AGED RAT FEMORA AND TIBIAE

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INTRODUCTION

As a potential treatment for osteoporosis, exercise has been shown to exert some positive effects on bone strength, but the exact nature and duration of the most effective regimen is still unknown. Many studies have examined effects of endurance or resistance exercise on bone strength in developing skeletons or in a single age group [1-7], but few have compared younger animals to aged animals [8]. The present study is unique in the fact that it compares both young adult and aged rats under the same exercise regimen to help clarify the effects of endurance exercise on the adult and aged male skeleton.

MATERIALS AND METHODS

Exercise Protocol

Adult (6 mo, n=28) and aged (24 mo, n=28) male Fisher 344 rats were used in this study. The animals were randomly divided into four groups (n=14/group) as follows: Adult Sedentary (YS), Adult Trained (YT), Aged Sedentary (OS), and Aged Trained (OT). The trained animals were conditioned to run on a treadmill with a 10% grade at 28 m/min (young) or 16 m/min (old) for 1 hr/day for 5 days/week for 12 weeks. The sedentary animals were handled and placed on a stationary treadmill twice a week to control for effects of handling stress. After 12 weeks, the animals were sacrificed and the right femur and tibia were excised and measured.

Mechanical Testing

Three different mechanical tests were performed using an MTS Mini-Bionix 385: 3-point bending of both femur and tibia, and a shear test on the femoral head. A 20 mm span equipped with carbon steel rods at the contact points and a crosshead speed of 2 mm/s was used for both the femur and tibia 3-pt bending tests. After failure, the bones were returned to saline solution. For the shear test, the proximal half of the femur was embedded in custom-made brass pots filled with a low melting point alloy. A 3 mm diameter plunger was lowered onto the superior aspect of the femoral head at a rate of 2 mm/s until failure. All force and displacement data for each test was recorded at a rate of 20 Hz.

RESULTS

Bone Physical Characteristics

Treadmill exercise produced longer and wider hind limb bones in the aged trained rats, but had little or even negative effects on the adult trained animals (Figures 1 and 2). Tukey's pairwise comparison t-tests showed that exercise had significant effects on femoral length and tibial sagittal width ($p < 0.05$) in the aged trained group as compared to the aged sedentary animals, and no significant differences for exercise between the adult sedentary and adult trained groups.

Bone Mechanical Characteristics

Animal age had a significant effect in the mechanical characteristics of the femur and tibia. Ultimate load, yield load, and stiffness were all significantly increased with age for each test ($p < 0.05$ for all), but exercise did not significantly change the strength parameters between exercised and sedentary animals in each age group.

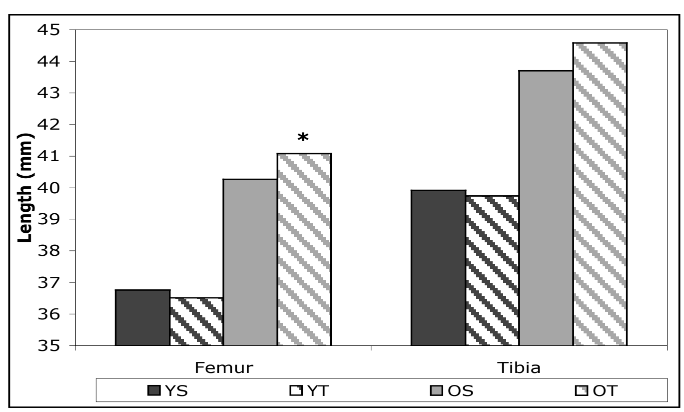

Figure 1: Comparison of Bone Length (* = significant for exercise, p < 0.05)

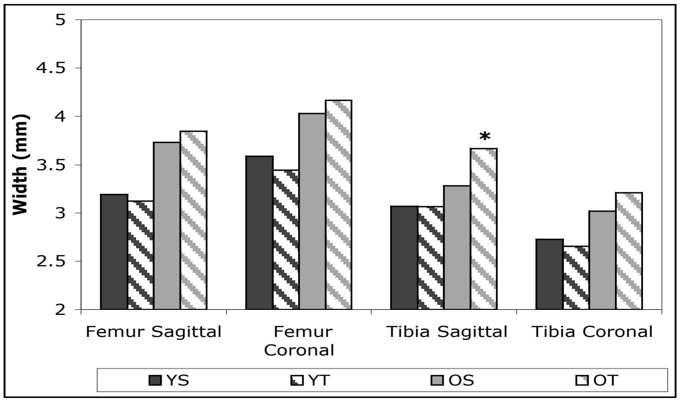

Figure 2: Comparison of Bone Width
(* = significant for exercise, $p < 0.05$)

DISCUSSION

Exercise increased bone size in the aged trained animals as compared to the aged sedentary animals, without having an effect on the adult animals. This finding wasn't anticipated and is very intriguing. Many articles dealing with biomechanical measurements related to bone don't report bone morphometric characteristics [1, 3, 5, 7, 9] and of the few studies that do [2, 4, 8], only Iwamoto et al. found increased femur length in only the exercised animals after 12 weeks of treadmill running. However, it was attributed to "transient stimulation on longitudinal growth of bone during the early growing period, (166)" because the rats used were only 4 weeks old at the beginning of the study. The rat isn't skeletally mature until approximately 18 weeks of age, but growth plates remain unfused. Studies of resistance training in young and old rat age groups showed no significant differences in bone size after 9 or 10 weeks of training [2, 8]. Although these previous studies did not find significant changes in bone length, or attributed it to "transient stimulation," the current study found that endurance exercise significantly increased bone length in only the aged rats. We believe that the growth may be due to stimulation of growth hormones from exercise, but this has not yet been explicitly studied.

Since the Fisher 344 rats grow nearly continuously throughout their lives, the aged animals had significantly larger and stronger bones than the smaller adult animals. However, exercise did not have any significant effects on bone strength. Even with the increased bone size in the aged trained group, no strength parameters showed any differences due to exercise alone, which is in agreement with many previous studies of both endurance running and strength training that haven't shown any exercise effects [2, 3, 5-9]. One laboratory has shown positive results from resistance training [1, 6] but none from endurance running. Although 12 weeks of endurance exercise did not increase the loading capability of the bones studied, this is in accordance with previous studies that have not shown any positive strength results from endurance training.

CONCLUSIONS

The final results confirmed a positive increase in bone size and mechanical performance with advanced age. Contrary to what was hypothesized, endurance training did not increase the loading capability of weight-bearing bones, but this is not an uncommon finding in endurance training studies. However, an intriguing and unexpected result was finding that 12 weeks of endurance exercise resulted in longer bones in aged animals, while not having an effect on adult animals.

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