EFFECTS OF MODERATE EXERCISE ON BIOMECHANICAL FUNCTION OF FEMUR BONES IN WISTAR MALE RATS

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SUMMARY
The Biomechanical function of bones can be influenced by exercise. We have investigated the effects of 4 weeks of moderate exercise in Wistar male rats. The animals were randomized into two groups: exercise and control. Exercised rats ran at the treadmill speed of 20 m/min (moderate exercise intensity), for 20 minutes, 6 days/week. Laboratory and handling conditions were matched and food was controlled for both groups. Exercise training demonstrated a significantly lower body weight for the exercised rats (p<0.05). Mechanical load testing showed that exercised rats had significantly stronger femur bones than the control rats (p=0.05). Only 4 weeks of moderate exercise training was enough to cause a beneficial effect on this biomechanical property of femur bones.

Key-words: Exercise, Wistar rats, Femur Bones

1. INTRODUCTION
Exercise is known to cause changes in bone function, density and dimensions [1]. The deleterious or beneficial effects of exercise on physiological responses are also associated with a single strenuous exercise event or with training programs. Strenuous exercise is believed to lead to reduced bone density in subjects over age of 50 years [2]. On the other hand, regular moderate exercise has been shown to have a beneficial effect on bone function by improving the mechanical characteristics of bone in rats [3]. The effect of moderate exercise in humans is shown in the prevention of osteoporosis [4].

The objective of this work was to analyze the biomechanical response of femur bones to 4 weeks of regular moderate running exercise in 8 weeks old Wistar male rats.

2. METHODS
Holding a British Home Office Project Licence, twelve, 6 weeks old SPF (Specific Pathogenic Free) Wistar male rats were used. The animal room environment was controlled at a temperature of 20±2°C, a humidity of 50% and 12 hours light-dark cycle.

Exercise and control rats were housed singly in standard cages. Water was given ad libitum. In the first week, food intake was calculated as the weight of food given to the animals minus food spilt (dried) minus food left. Food was then equally restricted for all rats at mean plus 1 standard deviation value. Body weight was measured daily.

The animals were randomly divided into 2 groups of 6 rats each: One control (or sedentary) group and one exercise group. Laboratory and handling conditions were matched for both groups of rats. The exercise rats were first familiarized to the exercise treadmill in the first week of training, running for 10 minutes/day at speed of 20 m/min. Rats were subjected to run at moderate exercise intensity of 20 m/min, 20 min/day, 6 day/week over a period of four weeks. Rats were sacrificed by brain concussion approximately 24 hours after the last exercise session. Right and left femur bones were carefully dissected and cleaned. Femur lengths were determined using a sliding caliper and were weighed in pairs for each rat using an analytic balance. The left femurs were used to measure the areas of femur diaphysis cross section whereas the right femurs were used for mechanical load testing.

Right femur bones were subjected to a three-point bending test to failure on an Instron testing machine for evaluation of biomechanical function of bones. The load deformation curve was recorded. The test results provided values for maximum load (N) and maximum energy stored (N/cm2).

For cross-sectional properties, left femur bones were cut off into two parts. The proximal part was left with 55% of its full size from femur head to knee end. This was chosen due to its regular cross-sectional shape. The proximal sectional surface was photographed and magnified at 200 times. Cross-sectional areas were measured using a digital planimeter (Planix 7, Tamaya Technics Inc., Japan). The mean and 95% Confidence Interval (95% CI) were calculated for comparisons between groups. Comparisons between exercise and control groups were assessed using unpaired t-test.
3. RESULTS

The relationship between food intake and body weight of exercise and control groups of rats is illustrated in Table I.

### Table I

<table>
<thead>
<tr>
<th></th>
<th>Exercise</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Intake (g)</td>
<td>680 (16.9)</td>
<td>709 (4.3)</td>
<td>ns</td>
</tr>
<tr>
<td>Body Weight (g)</td>
<td>311 (6.9)</td>
<td>337 (4.5)</td>
<td>*</td>
</tr>
</tbody>
</table>

Values expressed as Mean (±SEM). No significant difference between groups ns (p>0.05); significant difference between groups * (p<0.05).

Bone dimensions and biomechanical properties of femur bones are illustrated in Table II.

### Table II

<table>
<thead>
<tr>
<th></th>
<th>Exercise</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>0.71 (0.66 - 0.75)</td>
<td>0.74 (0.72 - 0.76)</td>
<td>ns</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>2.96 (2.90 - 3.03)</td>
<td>3.01 (2.97 - 3.06)</td>
<td>ns</td>
</tr>
<tr>
<td>Cortex (mm²)</td>
<td>0.44 (0.41 - 0.48)</td>
<td>0.45 (0.42 - 0.48)</td>
<td>ns</td>
</tr>
<tr>
<td>Medullary cavity (mm²)</td>
<td>3.6 (3.3 - 3.9)</td>
<td>3.7 (3.3 - 4.0)</td>
<td>ns</td>
</tr>
<tr>
<td>Maximum Load (N)</td>
<td>90.5 (84.9 - 96.0)</td>
<td>82.7 (75.2 - 90.2)</td>
<td>*</td>
</tr>
<tr>
<td>Maximum Energy Stored (N/cm²)</td>
<td>65.8 (50.5 - 81.1)</td>
<td>63.0 (50.6 - 77.4)</td>
<td>ns</td>
</tr>
</tbody>
</table>

Values expressed as mean (95% CI). No significant difference between groups ns (p>0.05); significant difference between groups * (p<0.05).

4. DISCUSSION

Our results demonstrated that there was no significant difference in total food intake between exercise and control group of rats, though exercise rats consumed slightly less food than control ones. At the end of the training program the exercised rats had decreased their body weight significantly when compared to the control ones. This may suggest the effect of exercise on body weight loss by increasing the energy consumption.

As the rats were all at the same age, our results demonstrated that there was no significant difference in femur weight and length between exercised and controls rats. Analysis of femur cross-sectional properties demonstrated that 4 weeks of moderate exercise training did not change cross-sectional and medullary cavity areas. However, there is a report suggesting that running exercise causes bone hypertrophy in swine [5] and this may lead to change in cross-sectional properties in long bones.

Analysis of biomechanical properties demonstrated that there was no significant difference in maximum energy stored in exercised and sedentary rats though exercised rats demonstrated higher values for this test. However, maximum load test showed a marginally significant difference in strength between exercise and sedentary rats.

One of the accepted benefits of regular weight bearing exercise is the development of increased bone mineral density (BMD) [8] which may have a positive effect in the prevention of osteoporosis. Well-known contributory factors to its development are nutrition, hormonal status and lack of mechanical load bearing. While nutritional or hormonal deficiencies can be compensated by supplements of calcium, vitamin D or estrogen, the deficit of mechanical load in modern life could only be compensated by load bearing physical activity. It has been reported that mild exercise demonstrates no or only a minor positive effects on bone mineral content whereas a positive effect in increasing BMD has been demonstrated by moderate and vigorous exercise [6]. One limitation of this study is that BMD was not analyzed. However, despite of no significant changes in cross-sectional properties of femur bones, it was found in this study a positive effect of moderate exercise in bone strength.

5. CONCLUSION

Bone strength was indicated by the maximum load. Exercised rats had significantly stronger femur bones when compared to sedentary ones. Our results also showed that exercised rats had slightly higher values for maximum energy stored. However, these differences were not statistically significant. Mechanical load testing of exercised femurs demonstrated a modest benefit of regular treadmill running on bone fracture resistance. This is in agreement with other authors [7]. Only 4 weeks of moderate exercise training was needed to achieve this effect. A longer training period may be necessary to observe further changes on biomechanical properties and cross-sectional dimensions.

REFERENCES


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ABSTRACT

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