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Biomechanical performance of diaphyseal shafts and bone tissue of femurs from hypothyroid rats

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Abstract The bone changes in hypothyroidism are characterized by a low bone turnover with a reduced osteoid apposition and bone mineralization rate, and a decreased osteoclastic resorption in cortical bone. These changes could affect the mechanical performance of bone. The evaluation of such changes was the object of the present investigation. Hypothyroidism was induced in female rats aged 21 days through administration of propylthiouracil in the drinking water for 70 days (HT group). Controls were untreated rats (C group). Right femur mechanical properties were tested in 3-point bending. *Structural* (load bearing capacity and stiffness), *geometric* (cross-sectional area and moment of inertia) and *material* (modulus of elasticity) *properties* were evaluated. The left femur was ashed for calcium content determination. Plasma T_4 concentration was significantly decreased in HT rats. Body and femur weight and length in HT rats were also reduced. Femoral calcium concentration in ash was higher in HT than in C rats. However, the femoral calcium mass was significantly lower in HT than in C rats because of the reduced femoral size seen in the former. The stiffness of bone material was higher in HT than in C rats, while the bone geometric properties were significantly lower. The "load capacity" was between 30 and 50% reduced in the HT group, although, the differences disappeared when the values were normalized per 100-g body weight. The lowered biomechanical ability observed in the femoral shafts of HT rats seems to be the expression of a diminished rate of growth. Qualitative alterations in the intrinsic mechanical properties of bone tissue were observed in HT rats, probably because the mineral content and the modulus of elasticity were positively affected. The cortical bone of the HT rat thus appears as a bone with a higher than normal strength and stiffness relative to body weight, probably due to improvement of bone material quality due to an increased matrix calcification.

Keywords Bone biomechanics · Hypothyroidism · Femur diaphysis · Bone mass

Introduction

During evolution, the skeleton of vertebrates developed an important property, the resistance to deformation, and indirectly to fracture, that was adapted to the physiological mechanical demands of the environment. The criterion for adequate support function is the formation and maintenance of sufficient quantity and quality of bone to support the body throughout life and to withstand ordinary stresses to which skeletal components are subjected.

It is assumed that the mechanical properties of bones integrated as organs (*structural properties*, e.g., load bearing capacity and stiffness) are directly related to both the amount (*bone mass*) and the architectural disposition of bone material (*geometric properties*, e.g., cross-sectional area, moment of inertia and cortical thickness) and to the mechanical quality of bone material (*material properties*,

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