BioNanoScience (2018) 8:864–867
https://doi.org/10.1007/s12668-018-0551-2

The Influence of Hindlimb Unloading on the Bone Tissue's Structure

Tatyana Baltina[1] · Oskar Sachenkov[1] · Oleg Gerasimov[1] · Maxim Baltin[1] · Artur Fedyanin[1] · Igor Lavrov[1,2]

Published online: 28 July 2018

Abstract
The results of numerous studies indicate interactions between antiortostatic support and bone's tissue. It is known that mechanical, genetic, endocrine, and age-related factors can influence the bones at the same time. Nevertheless, the physiological and pathological mechanisms of interconnection between unloading hindlimb and bones are largely unclear. The purpose of this study is to evaluate the correlation between unloading hindlimb and changes in bone's tissue. After unloading of the hindlimb during 14 days, femoral bones were collected in order to evaluate the weight, density, and geometrical bone parameters. Additionally, a test with a three-point bending and computed tomography scanning was carried out. Using computed tomography data, fabric tensor was built. From the assumption that the bone tissue is orthotropic (exists a maximum of three mutually orthogonal axes with different material properties), we performed this analysis. Orthotropic properties of the bone tissue were analyzed in assumption that the principal direction of the fabric tensor is coaxial with the axes of orthotropy of the material. It was found that the axes of orthotropy of the bone tissue in the cross section are mostly directed in tangent direction, and after hindlimb unloading, axes of orthotropy rotate 90° (became directed in radial direction). Anisotropy ratio in the cross section changes significantly. Meanwhile, Young's modulus and ultimate strength decrease. It shows that unloading of the hindlimb aggravates quality of the bone tissue.

Keywords Antiortostatic support · Fabric tensor · Bone density · Rats

1 Introduction

Bone tissue is continuously under the influence of external force factors and accordingly undergoes structural and mechanical changes. Decrease in motor activity may activate the mechanisms, which are leading to the bone tissue embitterment. The most informative and developed tool at this time for bone structure analysis is a computed tomography (CT).

Several studies have been performed in the conditions of unloading of the hindlimb or on models designed to minimize the influence of gravity, supporting the hypothesis about the influence of gravitational load on a bone tissue. It was found that in the conditions of hindlimb unloading, postural muscles have the greatest loss in weight [1–3]. Previously, we conducted studies that showed that a decrease in motor activity affects the macro mechanical properties of bone tissue [1]. Interestingly, that increase in bone weight does not necessary lead to improvement in mechanical properties [4, 5]. These results support the importance of future evaluation of the functional bone changes in order to estimate the influence of the gravitational load and physical activity. Interactions between physical activity and bone tissue in normal condition and in pathological state, nevertheless, require understanding the physiological and pathological mechanisms connecting the physical activity and bone structural changes which are still unclear [6, 7].

The goal of this study was to estimate the changes in bone structure at case of unloading hindlimb on rats and also changes in bone orthotropic properties, in terms of fabric tensor.

2 Material and Methods

All tests were conducted on nonlinear laboratory male rats (230–260 g). As a model of gravitational unloading, we used antiortostatic support model by unloading the hindlimb according to Morey-Holton [8]. All animals were divided into two groups: (1) control—intact animals ($n = 10$) and (2) GU14—14-day unloading hindlimb ($n = 10$). All experiments

✉ Tatyana Baltina
tvbaltina@gmail.com

[1] Kazan Federal University, 18 Kremlevskaya Str, Kazan, Russia 420008

[2] Mayo Clinic, 200 First St. SW, Rochester, MN 55905, USA