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Author: Dr. Zully Ritter
Charité - University Medicine Berlin, Germany, zully.ritter@charite.de

Dr. Wolfgang Baumann
Zuse Institute Berlin, Germany, baumann@zib.de
Prof. Dieter Felsenberg
Charité - University Medicine Berlin, Germany, dieter.felsenberg@charite.de

IN VIVO BONE REMODELING RATES DETERMINATION AND COMPRESSIVE STIFFNESS VARIATIONS BEFORE, DURING 60 DAYS BED REST AND TWO YEARS FOLLOW UP: A MICRO-FE-ANALYSIS FROM HR-PQCT MEASUREMENTS OF THE BERLINER BED REST STUDY-2

Abstract

Summary: Bed rest studies are used for simulation and study of physiological changes as observed in unloading/non-gravity environments. Among others, bone mass reduction similar as observed due to aging osteoporosis combined with bio-fluids redistribution and muscle atrophy have been analyzed. Advanced radiological methods of high resolution such as HR-pQCT (XtremeCT) allows 3D-visualizing in vivo bone remodeling processes occurring during absence/reduction of mechanical stimuli (1g) as simulated by bed rest. Induced bone micro-structure (e.g. trabecular number, cortical thickness, porosity) and density variations can be quantified. However, these parameters are average values of each sample and important information regarding bone mass distribution and within bone strength is lost. Finite element models with hexa-elements of identical size as the HR-pQCT measurements (0.082mm x 0.082mm x 0.082 mm, ca. 7E6 elements/sample) can be used for subject specific in vivo stiffness calculation. By this technique can also be quantified if bone microstructural changes represent a risk of mechanical bone collapse (fracture). Materials and Methods: In the Berlin Bed Rest Study-2, 23 male subjects (20-50 YO) were maintained 60 days under restricted bed rest (6HDT) aiming to test a vibration exercise regime for maintenance of bone mass and muscle functionality at normal levels (base line measurements). For comparison a vibration resistive exercise and a control group were included. Base line HR-pQCT measurements, as well as during 3 days bed rest (BR3), BR30 and BR59, 15 days of recovery (R15), R30, R90, R180, R360, and R720 were performed. CT-scan voxels were converted into finite elements (hexa-82m edge length) for calculating in vivo compressive stiffness. Histograms of stresses distributions and anatomical regions susceptible for mechanical failure were identified and compared. Results: Vibration resistive exercises were able to maintain in the most of the subjects bone strength (von Mises stress distribution) as determined in the base line measurements. However no major differences were found in the group with vibration training alone. Without mechanical stimuli a reduction of up to 10% of bone strength was quantified. Anatomically von Mises stress concentrations, thus susceptible to fail mechanically, were observed at the center and the antero- posterior cortical bone. Conclusions: Finite element simulations from bed rest studies are an invaluable tool to determine subject specific in vivo stiffness and anatomical mechanically compromised regions which are not jet possible to be determined with any other method. Vibration exercise combined with a resistive compressive force was able to maintain bone structure and density.