K9: Muscle/Bone Adaptation in Weightlessness

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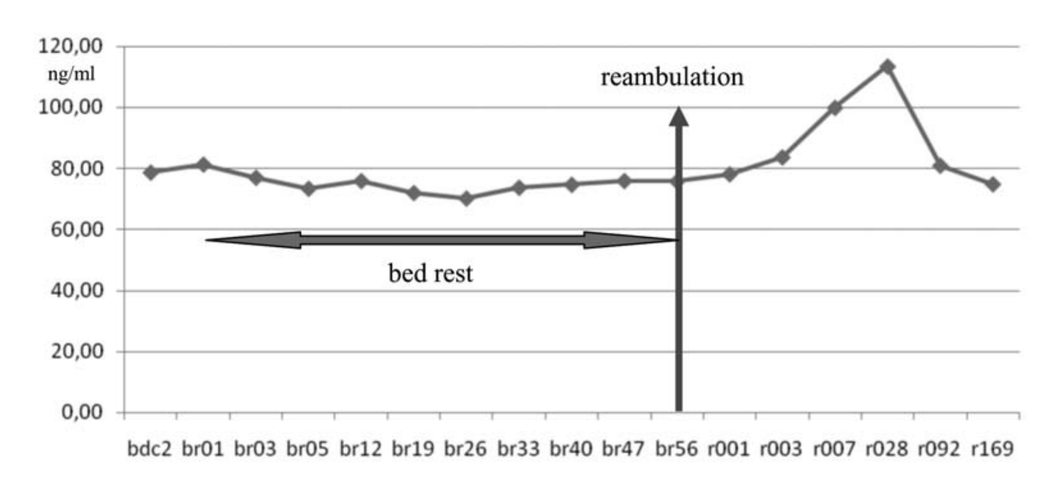
Immobilisation, unused muscles, weightlessness, and paralysis are the most important factors emerging muscle atrophy and loss of muscle function. Consequences of these conditions are loss of bone and high risk of falls and fractures. Especially the modern space programs like long-term flights to mars or a stay of more than six months on space stations are associated with this human risks.

Astronauts and cosmonauts who participated in long-duration flights aboard MIR and ISS have shown consistent loss of regional bone mineral, with 92% experiencing a minimum 5% loss in at least one skeletal site and over 40% experienced a 10% or greater loss in at least one skeletal site. These declines occurred in spite of the crewmembers' participation in exercise regimens aboard the MIR and ISS space station. All data to date support the idea that the lack of mechanical forces on the skeleton in microgravity leads to increased bone remodeling. In weightlessness remodeling is uncoupled - resorption is increased while formation is little changed.

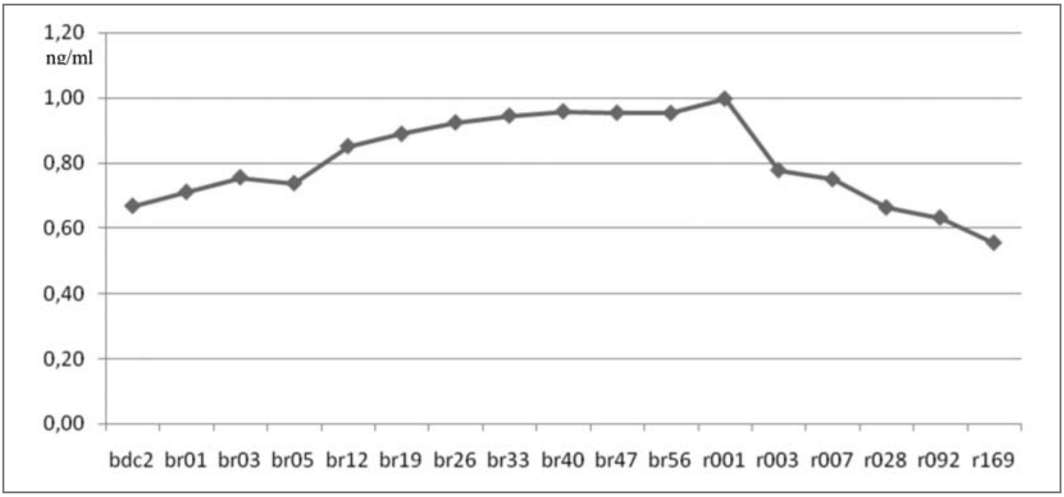


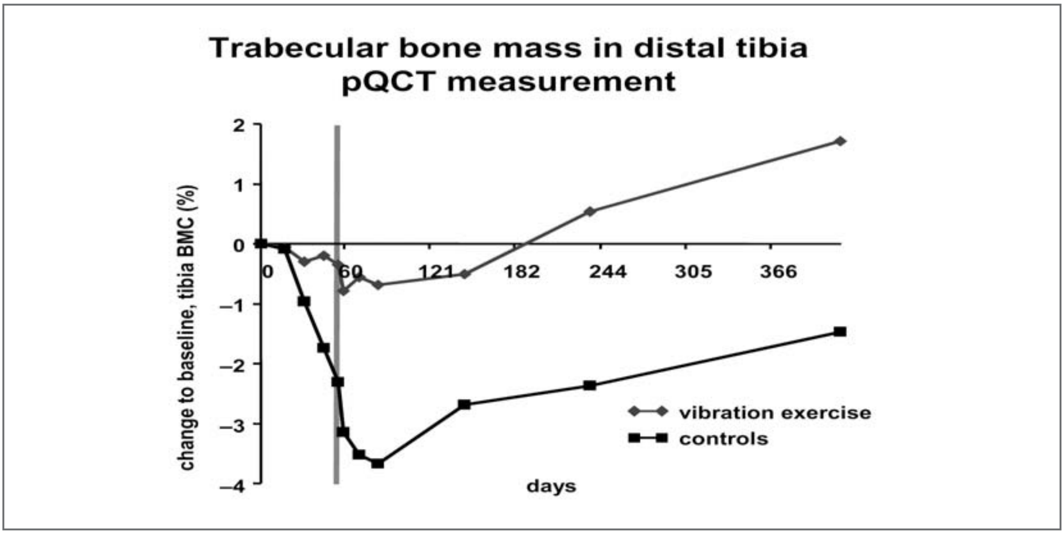
Equal results have been generated in the first Berlin BedRest Study (BBR1, 2003-2004). Figure 1 shows the bone formation marker P1NP in the control group.

bdc = baseline data collection; br= bedrest, r=reambulation, numbers in days

Figure 1: Follow-up measurements of serum bone formation marker P1NP (ng/ml) of the control group in BBR1. Nearly no change during bed rest phase (br01-br56). After reambulation significant increase of 44,2% within the first 4 weeks and normalization within the following 5 months. N=10 volunteers in the control group.

Resorption marker (CTX) increased continuously during bed rest phase in the control group, which is illustrated in figure 2. After reambulation the resorption activity was reduced, instantaneously.





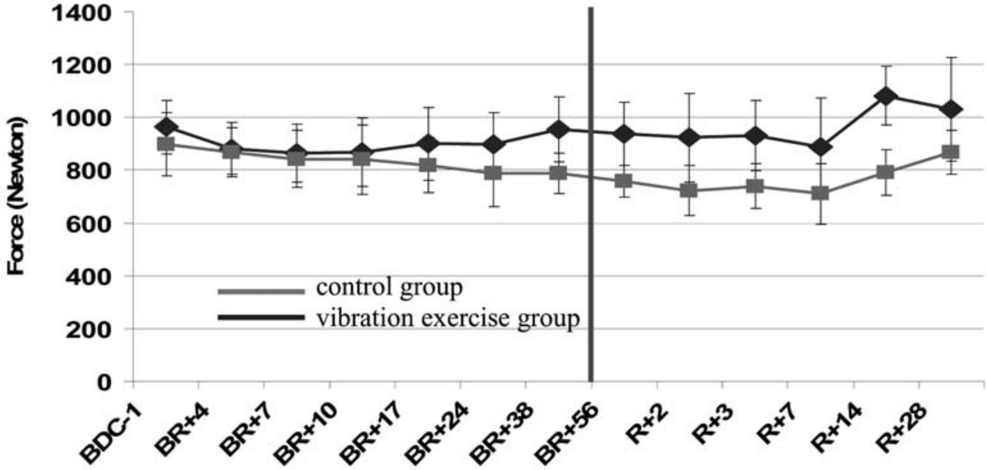


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Figure 2: Bone resorption marker CTX in bed rest volunteers of the control group. Follow-up measurements during bed rest phase and recovery after reambulation. Volunteers in the control group N = 10.

Uncoupling of bone resorption and bone formation leads to increased urinary and fecal calcium excretion and negative calcium balance. Negative calcium balance is manifested in bone loss. In the BBR1 significant loss of bone was identified in the distal tibia, only (Figure 3). Spine and hip BMD (DXA) was not significantly changed.

Figure 3: Bone mass measurement in vibration exercise and control group. Bone mass was measured with pQCT in the distal tibia.

The bone loss is induced by the loss of muscle force, function and power. In figure 4 the loss of muscle force during bed rest is documented.

Figure 4: Change of muscle force during bed rest study (BBR1). There was a significant loss of muscle force in the control group (pink line) by about 20-30% in the leg muscles.

<u>In conclusion:</u> muscle force, power and function is reduced in weightlessness firstly, emerging decreased strain, increased bone remodeling and bone resorption. After reambulation muscle recovers entirely and bone to a great extend (after 12 months lack of 1,5%).