

## SUMMARY

# EFFECTS OF UNLOADING AND RESISTANCE EXERCISE ON SKELETAL MUSCLE FUNCTION, SIZE AND COMPOSITION IN MAN

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**Subject** : EFFECTS OF UNLOADING AND  
RESISTANCE EXERCISE ON SKELETAL  
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### **Description :**

Exposure to microgravity, i.e., spaceflight, causes muscle unloading leading to muscle atrophy and dysfunction. Thus, there is a need for effective countermeasures to combat these effects. The present thesis aimed to study function, size and composition of anti-gravity muscles following long-duration bed rest, a valid spaceflight analogue. A further and even more important aim was to study the effects of concurrent resistance exercise using a gravityindependent device.

Prior to this, the exercise paradigm was validated during space station-like conditions. Four healthy men trained 2-3 times weekly during 110 days of confinement in a ground-based chamber, severely restricting locomotor activity. Training performance progressed over time and maximal voluntary contraction (MVC) was either increased or maintained after confinement. Since the device showed feasibility and potential as a countermeasure against muscle function deterioration, it was subsequently employed during strict unloading. Nine healthy men performed 90 days of bed rest (BR), while another group of eight men in addition carried out resistance exercise for the knee extensors and plantar flexors every third day (BRE). Different indices of muscle function were obtained together with surface electromyographic (EMG) amplitude before and after the intervention. Muscle volume was assessed by means of magnetic resonance imaging (MRI) prior to and on day 29 and 89 during bed rest. Moreover, muscle biopsies were obtained from mm. vastus lateralis (VL; all subjects) and soleus (n=3 from each group) before and on day 84 during bed rest, for subsequent analyses of single fibre myosin heavy chain (MHC) content.

In BR, muscle volume of the knee extensors decreased ( $p<0.05$ ) by 10 and 18% on day 29 and 89, respectively. The corresponding decreases for the plantar flexors were 16 and 29%, respectively. In BRE, knee extensor atrophy was prevented ( $p>0.05$ ), while the more pronounced plantar flexor atrophy was attenuated (-8 and -15%). Maximal torque, force and power, measured during different types of actions, decreased by 31-60% in BR. In BRE, MVC was maintained for the knee extensors but not for the plantar flexors. Training-specific force and power were unaltered for both muscles, while maximal torque measured in actions different

from the training task, decreased. EMG amplitude decreased during maximal and increased during submaximal actions in BR, but not in BRE. BR, but not BRE, showed increased fatigability and decreased rate of force development (RFD). In BR, there was an increase in hybrid fibres and a shift towards faster phenotypes in both VL and soleus. In BRE, this effect was attenuated in VL and offset in soleus. The phenotype shift was not manifested in altered force-velocity characteristics.

The greater atrophy of the plantar flexors compared to the knee extensors in response to unloading, may be explained by the greater content of slow fibres and the more frequent use of this particular muscle group in daily life. Further, muscle volume and single fibre data suggest that slow fibres are less responsive to the training protocol. The present findings also provide evidence that neural mechanisms, in addition to changes in muscle size, contribute to muscle function alterations induced by bed rest with or without resistance exercise, while phenotype shift may play a more modest role. Hence, it is clear that designing countermeasures for in-flight use extends beyond preserving muscle size only. Though the present work was spurred by questions addressed through the human spaceflight program, the results do have important clinical implications for e.g., aging populations or patients undergoing atrophy due to disease or injury.

Key words: atrophy, bed rest, confinement, countermeasure, electromyography, human, knee extensors, magnetic resonance imaging, microgravity, muscle function, myosin heavy chains, plantar flexors, resistance exercise, skeletal muscle, spaceflight, strength, training specificity, unloading

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