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Coupaud, S. and Jamison, L. and Berry, H. and McLean, A. and Allen, D. and Hunt, K. (2006) Musculoskeletal adaptations to physical interventions in spinal cord injury. In, *Royal Academy of Engineering Futures meeting on Biomechanics, 2006*, Durham.

http://eprints.gla.ac.uk/3366/

Musculoskeletal responses to physical interventions in Spinal Cord Injury

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Aims: We describe physical intervention methods to enable people with spinal cord injury (SCI) to perform useful exercise, and illustrate musculoskeletal responses to the exercise intervention programmes in SCI subjects who have undergone treadmill training.

Background: SCI results in varying degrees of muscle paralysis and loss of sensation below the level of injury. Disuse of the paralysed limbs and reduced levels of physical activity lead to a number of long-term health issues, such as osteoporosis with increased risk of fracture in the bones of the legs, and reduced cardiopulmonary fitness with increased risk of cardiovascular diseases. Regular, intensive cyclical exercises that recruit the large leg muscles, and dynamically load the leg bones, may positively influence muscle and bone. This, in turn, may help to alleviate secondary complications of SCI.

Methods: A number of systems and protocols for exercise intervention are being developed and tested at the Centre for Rehabilitation Engineering at the University of Glasgow, and the Queen Elizabeth National Spinal Injuries Unit in Glasgow. These include electrically stimulated leg cycling for paraplegics with complete SCI, and partial-body-weight-supported treadmill training for people with incomplete SCI. We present data from the treadmill training study. Baseline peripheral Quantitative Computed Tomography (pQCT) scans were taken in the tibia, femur and radius prior to formal exercise training, and repeated after 5 months of training intervention. Epiphyseal scans (4% distal) provided trabecular bone data, and diaphyseal scans (at 25% femur, 38% tibia, and 66% tibia and radius from the distal endplate), provided cortical bone data, and muscle cross-sectional areas. Maximum isometric contractions of the quadriceps and hamstring muscles, with superimposed stimulation trains, were performed on a dynamometer at 0, 2.5, and 5 months to determine the central activation ratio and thus voluntary muscle activation.

Results: As an example, data from two subjects who completed a five-month treadmill training intervention programme (3 sessions weekly) are presented, to illustrate the physiological effects of training on muscle and bone. Subject A (male, 20 years post-injury (PI)), showed a 5% increase in trabecular bone mineral density (BMD) in the right distal tibia, and a 20% increase in the left, whilst changes in the distal femur were negligible (2% right, 1% left). Corresponding increases in muscle cross-sectional area were 13% (right) and 20% (left) in the lower leg, and 7% (right) and 6% (left) in the thigh. For Subject B (female, 2 years PI), bone parameters decreased at all sites (trabecular BMD down by 18% right and 12% left distal tibia, and by 7% right and 3% left distal femur), with negligible changes in muscle cross-sectional areas.

Conclusions: It appears that exercise involving muscles of the lower limbs can lead to changes in the muscles and bones of the paralysed limbs. However, the time since injury, and details of each individual's training programme (frequency, duration and work rates used for training) may determine whether, and to what extent, the bone parameters show improvements.

Further work: In future studies, we will apply similar bone and muscle testing protocols to determine the effectiveness of other interventions, such as robot-assisted treadmill training in SCI.