MUSCLE TONE IMBALANCE IN HUMAN UPPER EXTREMITY

An experimental study of muscle adaptation to altered tension

Akademisk avhandling

som för avläggande av medicine doktorsexamen vid Göteborgs Universitet kommer att offentligen försvaras i Aulan, Sahlgrenska Universitetssjukhuset, Göteborg, torsdagen 18 december, 2008 kl. 9.00

av

Fredrik Einarsson

Fakultetsopponent:
Professor Per Aspenberg, Linköpings Universitet

Avhandlingen baseras på följande delarbeten:

I. Passive mechanical features of single fibres from human muscle biopsies - effects of storage
Einarsson F, Runesson E, Fridén J
Journal of Orthopaedic Surgery and Research, 2008; 3:22

II. Stress relaxation of human upper extremity muscles: implications for tensioning at tendon transfer surgery
Einarsson F, Runesson E, Fridén J,
Manuscript

III. Inferior mechanical properties of spastic muscle bundles due to hypertrophic but compromised extracellular matrix material
Lieber R, Runesson E, Einarsson F, Fridén J
Muscle and Nerve, 2003, 28; 11:464-471

IV. Subscapularis muscle mechanics in children with obstetric brachial plexus palsy
Einarsson F, Hultgren T, Ljung B-O, Runesson E, Fridén J
Journal of Hand Surgery (European Volume) 2008; 33:507-512

V. Structural characteristic of the subscapularis muscle in children with medial rotation contracture of the shoulder after obstetric brachial plexus injury
Hultgren T, Einarsson F, Runesson E, Hemlin C, Fridén J, Ljung B-O
Manuscript

VI. The supraspinatus muscle in retracted rotator cuff tears responds normally to passive mechanical testing: a pilot study
Einarsson F, Runesson E, Karlsson J, Fridén J
Manuscript

GÖTEBORGS UNIVERSITET

MUSCLE TONE IMBALANCE IN HUMAN UPPER EXTREMITY

An experimental study of muscle adaptation to altered tension

Fredrik Einarsson

Departments of Orthopaedics and Hand Surgery, Institute of Clinical Sciences
at the Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

Aim:

The aim of this thesis was to improve outcome after tendon transfer and rotator cuff surgery by investigating the impact on response to passive mechanical testing and change in structural characteristics associated with longstanding changes in the tension of skeletal muscle in the human upper extremities *in vivo*.

Patients and methods:

The investigational method was *in vitro* assessment of human upper extremity muscles. Muscle biopsies were harvested from both healthy controls and patients with conditions representing different types of change in tension in the muscle-tendon unit; upper extremity muscles from patients with spastic contractures, subscapularis muscles from patients with residual internal rotation contractures of the shoulder following obstetric brachial plexus injury and supraspinatus muscles from patients with full thickness rotator cuff tears with retraction.

Mechanical testing was performed by passively stretching single muscle fibres and muscle bundles, using the laser diffraction technique to measure changes in sarcomere length parallel to registrations of tension.

Morphology was assessed using light microscopy and standard staining techniques, including immuno-assay.

Results:

I. The mechanical testing and fibre size of muscle biopsies from human upper extremities are unaffected by freeze storage at -20°C for up to 4 weeks.

II. Stress relaxation after passive stretching follows a predictable regression pattern related, in amplitude and duration, to the measured sarcomere length after stretching. The time taken to reach a relatively stable tension plateau following the stretching of single fibres is two minutes or more in clinically relevant sarcomere lengths.

III. The mechanical quality of the extracellular matrix in muscle bundles from patients with spastic contractures is compromised, resulting in impaired mechanical performance even though the actual muscle fibres are stiffer than normal controls. This indicates that compensatory mechanisms take place in both muscle and extracellular matrix.

IV. The relative increase in the stiffness of the subscapularis muscle measured between single fibres and bundles is greater than that of normal controls, indicating a compensatory mechanism related to the extracellular matrix in children with obstetric brachial plexus palsy.

V. The subscapularis muscle from children with residual internal rotation contracture following obstetric brachial plexus injury showed essentially normal muscle histology. This indicates that the longstanding loss of amplitude of the muscle secondary to the denervation of antagonist muscles is the most probable cause of internal rotation, at least in children without severe deformation of the glenohumeral joint. A direct injury to soft tissue at delivery and subsequent fibrosis might be a contributory factor.

VI. The supraspinatus muscle from rotator cuff tears with a longstanding, significant retraction responds normally to passive mechanical testing in comparison to the healthy ipsilateral deltoid muscle, indicating that the overall stiffness in retracted rotator cuff tears is not primarily related to the mechanical or morphological deterioration of the muscle tissue. A reduction in absolute muscle volume through the loss of serially coupled sarcomeres is a possible explanation, although no evidence of the presence of this mechanism in humans has previously been demonstrated.

Conclusions:

To improve the outcome at tendon transfer surgery, assessments of the tension in the muscle-tendon unit to be transferred at surgery should preferably be made with a minimum of two minutes' delay following stretching.

Human upper extremity muscles are sensitive to changes in tension over time in different aspects.

The spastic condition with deranged neural regulation, including irregular changes in tension, appears to have a profound impact on muscle fibres, as well as on extracellular matrix mechanics.

The longstanding reduction in tension, as exemplified by the subscapularis muscle of shoulders with a persistent internal rotation following brachial plexus injury and the supraspinatus in retracted rotator cuff tears, appears to have only mild effects on muscle mechanics, but compensatory changes in the extracellular matrix can be detected, affecting the mechanical performance in the muscle-tendon unit as a whole. A possible feedback system sensitive to mechanical stimuli may involve both the direct mechanical interaction of intra- to extracellular proteins and indirect communication through the up- and down-regulation of the production of structural proteins.

Key words:

Muscle biopsy, freeze storage, upper extremity, shoulder, human, muscle, sarcomere, stress-strain relationship, stress relaxation, stiffness, elasticity, mechanical testing, morphology, spasticity, obstetric brachial plexus palsy, rotator cuff tear, tendon transfer

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