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Trapezius viscoelastic properties are heterogeneously affected by eccentric exercise

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A B S T R A C T

Objectives: The aim of this study was to investigate the influence of eccentric exercise (ECC) on the spatial mapping of muscle stiffness and creep of the upper trapezius, using a quantitative myotonometry device.
Design: Two groups of 16 subjects participated in the experimental sessions. In part A, the test–retest reliabilities of muscle stiffness and creep were assessed. In part B, muscle stiffness and muscle creep were mapped before, immediately after and 24 h after ECC when post-exercise soreness had developed.
Methods: The ECC protocol consisted of 50 eccentric contractions divided into 5 bouts of 10 contractions at maximum force level.
Results: The relative reliabilities of stiffness and creep measurements were found to be substantial to almost perfect. Muscle stiffness for musculotendinous sites increased at 24 h after ECC while it decreased for muscle belly immediately after and 24 h after ECC. Muscle creep for musculotendinous sites decreased, and for muscle belly sites increased, immediately after and 24 h after ECC.
Conclusions: For the first time, the present study showed sign of discrepancies in the effects of ECC on muscle stiffness and creep, underlining opposite changes in the musculotendinous and muscle belly viscoelastic properties of upper trapezius.

1. Introduction

Unaccustomed high-intensity eccentric exercise in both recreational and elite athletes can result in delayed onset muscle soreness (DOMS). DOMS is characterized by mechanical muscle hyperalgesia, occasional resting pain, and altered motor control mimicking some clinical aspects of musculoskeletal pain.[1–3] An initial bout of eccentric exercise (ECC) causes an increase in muscle soreness, blood indicators, reduction in muscle strength and range of motion, and swelling. Muscle soreness peaks between 24 and 72 h after ECC. DOMS can be assessed quantitatively using pressure pain sensitivity mapping, which reveals spatial changes in mechanical hyperalgesia over the trapezius muscle.[1] This mapping technology has shown that muscle pressure hyperalgesia is heterogeneously distributed.[1,4]

Myotonometry is a reliable technique for assessing the viscoelastic properties of muscles.[5,6] It provides information of tissue biomechanics and muscle-intrinsic elastic properties like stiffness and creep. Muscle stiffness reflects the resistance of the muscle to the force deforming the muscle, while muscle creep is the gradual elongation of a muscle over time when placed under a constant tensile stress.[6] To the best of our knowledge, no study using myotonometry has addressed the effect of ECC on muscle stiffness and creep. Similar to the pressure pain threshold, measurement of the spatial distribution of viscoelastic properties can be used to construct topographical maps of stiffness and creep. From a clinical point of view, such information can provide deeper insight into mechanisms underlying musculoskeletal disorders in the neck-shoulder region.[1–3]

The aims of this study were to use quantitative myotonometry to investigate A) the test–retest reliabilities of muscle stiffness and creep; and B) the influence of ECC on the spatial distribution of muscle stiffness and creep. In both parts, we applied topographical mapping technique to measure changes in musculotendinous (MT) and muscles belly (MB) sites.

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We hypothesized heterogeneous MT and MB changes in the viscoelastic properties of the upper trapezius after ECC.

2. Method

In part A (test–retest experiment), the group A consisted of 16 right-handed subjects (10 males and 6 females, aged 21.4 ± 1.2 years; height 177.3 ± 7.7 cm; body mass 71.2 ± 12.6 kg, BMI 22.5 ± 2.4 kg/m^2) who volunteered to participate. Group A was composed of sports science students.

In part B (eccentric exercise), the group B consisted of 16 right-handed subjects (10 males and 6 females, aged 26.6 ± 3.8 years; height 172.2 ± 7.7 cm; body mass 67.3 ± 11.2 kg, BMI 22.6 ± 2.6 kg/m^2). Informed consent was obtained from each subject. Group B consist of mixed student population.

All subjects in both groups maintained normal daily activity during the course of the study. None had participated in strength training in the past month. The exclusion criteria were: i) pain in the shoulder region prior to the experiment; ii) history of neck-shoulder disorders or injuries. Parts A and B were approved by the Ethics Committee of the University of Physical Education in Wroclaw (No 22/2016) and the North Denmark Region Committee on Health Research (N-20160023), respectively. The study was conducted in accordance with the Declaration of Helsinki.

The sample size was calculated using G*Power software (version 3.1.9.2; Kiel University, Kiel, Germany)[7] with an expected "medium" effect size ($f^2 = 0.25$) for changes in muscle stiffness over time within group, an α level of 0.05, power $(1 - \beta)$ of 0.9, and correlation among repeated measures of 0.6. The calculation showed that at least 11 participants per group were necessary, but to account for potential dropouts, 16 participants were recruited.

A handheld MyotonPro device (MyotonPro, Myoton Ltd., Estonia) was applied to measure upper trapezius muscle stiffness. Muscle stiffness is the biomechanical property that characterizes the resistance to a contraction or to an external force that deforms the tissue's initial shape. Muscle stiffness (N/m) is computed as: $S = a_{max} \times m_{probe}/\Delta l$, where "a" is the acceleration of the damped oscillation; "m_{probe}" the mass of the measurement mechanism and "Δl" the probe displacement. As mentioned previously, muscle creep is the gradual elongation of a muscle over time when placed under a constant tensile stress, and is expressed as the ratio of the mechanical stress relaxation time and the time to cause maximum deformation by an external force. Mechanical stress relaxation time [ms is the time for a muscle to restore its shape from deformation after a voluntary contraction or after an external force is removed (MyotonPro, Myoton Ltd., Estonia). Latash and Zatsiorsky defined stiffness as a measure of resistance to deformation in elastic bodies. The muscle viscoelasticity is also manifested as creep, i.e., an increase in muscle length under a constant load.[8]

Myotonometric measures were performed over the upper trapezius muscle. A wax pencil was used to mark the muscle stiffness measurement points. For this study, three measurements were collected on each tested point and averaged. The subjects were seated on a comfortable chair with their forearms supported on the desk and muscles fully relaxed during myotonometric assessments.

For both parts A and B of this experiment the grid for measurement point recording was set using C7-acromion distance "d" (mean: 195 ± 15 mm). This "d" value was used to compute the inter-distance between the 15 points covering the upper trapezius muscle (Fig. 1).[9] Points 1-3-5-10-15 were considered to correspond to MT sites, and points 2-4-6-7-8-9-11-12-13-14 to MB sites.[10] Adjacent points were separated by 1/6 of d (mean: 32.5 ± 2.7 mm) except between points 1 and 2 and points 3 and 4, where the horizontal distance was 1/7 of d (mean: 27.9 ± 2.3 mm).[4] Myotonometric measurements were performed at day 0 (Part A: test; Part B: before and immediately after ECC) and day 1 (Part A: retest; Part B: 24 h after ECC) and used to generate the maps of the upper trapezius.[9,10] An inverse distance weighted interpolation approach was applied to obtain a 3D representation of the topographical maps.[9]

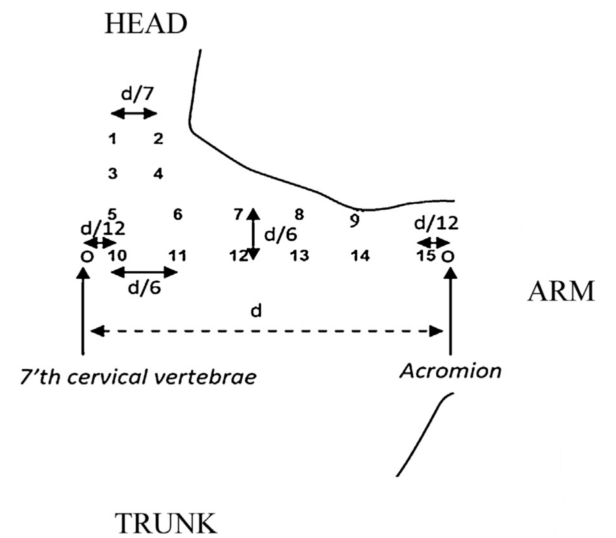

Fig. 1. Schematic representation of the grid for myotometric measurements, i.e. muscle stiffness and creep. Muscle viscoelastic properties were measured over 15 points located on the upper trapezius representing musculo-tendinous (points 1-3-5-10-15) and muscle belly (points 2-4-6-7-8-9-11-12-13-14) sites.

The ECC protocol used to induce DOMS over the upper trapezius consisted of 50 eccentric contractions divided into 5 bouts of 10 contractions at 100% of maximum voluntary contraction (MVC) level. The 5 bouts were separated by a 2-min resting period.[10] For each eccentric contraction, the subject had to counteract the dynamometer vertical force as much as possible along the previously measured shoulder range of motion. The right side was the exercise side. The ECC protocol was only performed in Part B of the study.

The dynamic shoulder dynamometer (Aalborg University, Aalborg, Denmark) consists of an actuator, load cell, control unit, cylinder, shoulder contact pad, and adjustable seat fixed on a stainless steel frame. In the eccentric mode, the dynamometer produces a constant vertical downward force that the subject must counteract. The contact point between the dynamometer and shoulder was approximately 3 cm medial to the acromion.[10] To obtain shoulder range of movement, subjects elevated and lowered their right shoulder as much as possible without lateral bend. The distance between top and bottom position was defined as the range of shoulder elevation. The subjects raised both shoulders and wore a corset during the exercise to prevent lateral bending. Three trials were performed to determine the MVC in neutral position, i.e., the maximal dominant shoulder elevation under isometric conditions for 3 s, separated by 2 min rest.

Soreness intensity (SI) was assessed before, immediately after and 24 h after ECC, using a 10-cm continuous visual analogue scale. Zero indicated "no soreness/no perceived exertion" and 10 "maximal soreness intensity/maximal perceived exertion". The SI was only assessed in Part B of the study.

Part A: the relative and absolute reliabilities of stiffness and creep measurements were computed using intra-class correlation coefficients (ICC), standard error of measurement (SEM) and minimum detectable change (MDC). The relative reliability was evaluated by calculating a 2-way fixed $ICC_{2,1}$ (for absolute agreement). ICC values were interpreted according to Landis and Koch.[11] The SEM quantifies the absolute measurement error. The SEM was