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SHORT REPORT

Changes in skeletal muscle architecture following a cycloergometer test to exhaustion in athletes

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Summary We determined whether a short-term exhaustive dynamic exercise (cycling) for about 18 min induces changes in the intramuscular architecture of the quadriceps in trained athletes. Thirty-five male athletes (age 28.8 ± 9.8 years; height: 175.4. ± 5.5 cm; weight: 74 ± 11.5 kg; average years spent training: 11.1 ± 8.4 years; mean weekly duration of training: 10.4 ± 3.20 h) underwent an incremental cycloergometer test to exhaustion. Muscle thickness of the right quadriceps femoris (rectus femoris + vastus intermedius), and the angle of pennation of the right vastus lateralis on the quadriceps tendon were determined by high-resolution real time ultrasonography. Quadriceps thickness increased from 32.1 ± 3.3 mm at rest to 34.9 ± 3.0 mm after the test ($p = 0.001$). The pennation angles were significantly greater after exercise (12.8 ± 2.1° at rest; 14.4 ± 2.5° after the test ($p = 0.001$)). There are marked changes in intramuscular architecture of the quadriceps following a bout of cycloergometer exercise to exhaustion, with significant increase of quadriceps thickness and pennation angle. Ultrasonography allows to evaluate the changes of muscle architecture following exercise.

Introduction

Muscle architecture is a primary determinant of muscle function.[1,2] The pennation angle (θ) is the angle of insertion of muscle fibre into the tendon aponeurosis. Ultrasound imaging accurately depicts fibre length and orientation, both in physiological and pathological conditions.[2] Pennation angle decreases with aging,[2] and there is a definite relationship between fibre pennation and muscle size, suggesting that muscle hypertrophy involves an increase in fibre pennation angles,[3]

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even though a definite relationship between pennation and force generating capacity is not certain.[4]

We ascertained whether short-term exhaustive dynamic exercise induced changes in muscle architecture, as this variable is a major determinant of muscle function, and whether ultrasonography could be used to study acute muscular responses to exercise.

Subjects and methods

Subjects

Thirty-five male athletes (age 28.8 ± 9.8 years; height: $175.4. \pm 5.5$ cm; weight: 74 ± 11.5 kg; average years spent training: 11.1 ± 8.4 years; mean weekly duration of training: 10.4 ± 3.20 h) who underwent a pre-participation screening volunteered to participate in this study. Most of them were track and field athletes (16 subjects), five played Soccer, five were swimmers, four cycled and two undertook competitive aerobics, one Karate, one tennis and one rugby. All subjects were medically screened using a pre-exercise questionnaire prior to inclusion in this study, and written informed consent was obtained from each of them. All procedures were approved by the Local Ethics Committee.

Exclusion criteria included known cardiovascular, myopathic, inflammatory diseases and musculoskeletal trauma to the lower limb over the last 6 weeks before the test.

Methods

Each athlete underwent an incremental cycloergometer test (SECA Hamburg, Germany, Electrically braked: 60—70 RPM) to exhaustion. Each test started with a 2 min warm-up at 25 W followed by an increment of 25 W every 2 min to exhaustion. This was followed by 1 min of recovery at 25 W, and by 4 min at rest while supine. Blood lactate (Lactate Pro ARKRAY, Kyoto, Japan) was measured at rest, and immediately, 5 and 30 min after completion of the test. Assessment of total creatine kinase (CK) was performed at rest and 30 min after the test. The blood collected was transported immediately to the laboratory, centrifuged, and the assay performed using a spectrometric monotest method (EOS 880 CGA Strumenti Scientifici, Firenze, Italy) at 25 °C according to the manufacturer's instructions. We used the reference values of 10—80 U/L as normal. Muscle thickness and angles of pennation on the right leg only were determined by ultrasonography with a 10 MHz probe with the subject sitting on the examination couch with hips and knees flexed at 90°. Subjects were asked to stay relaxed. The same operator performed all measurements at the border between the lower one third and the upper two thirds of the distance between the anterior superior iliac spine and the upper pole of the patella. The measuring point was marked with a marking pen. Measurements were performed just before the exercise test, and between 12 and 15 min after the end of the cycloergometer test. We measured the thickness of the quadriceps femoris (rectus femoris + vastus intermedius) with the probe placed in the transverse plane, and the angles of pennation of the vastus lateralis with the probe placed in the sagittal plane.[5]

Intra-observer variation

To calculate the intra-observer variation, the main author measured pennation angle and quadriceps thickness bilaterally on a single subject, repeating the measurements 20 times over 2 weeks. The subject was a normal control and had no change in exercise routine over the 2 weeks period to avoid any time-related effect or bias. The coefficient of variation (CV) was calculated according to the formula

$$\mathrm{CV} = \left(\frac{\mathrm{SD}}{\mathrm{mean}}\right) \times 100$$

where SD is the square root of the variance, and the mean is the combined mean of the measurements. The CV for the pennation angle was 3.8% (left) and 4.5% (right), the CV for the quadriceps thickness was 3% (both left and right).

Statistics

Statistical analysis was performed by SPSS statistical package for Windows, release 10.0 (Chicago, IL, USA). Descriptive statistics were calculated, and values reported are mean ± standard deviation. Comparison between the values of CK obtained in the two groups before and after exercise was performed by Student's *t*-test for different samples. Relationships between the measures collected were calculated with a bivariate correlation measuring the Pearson's correlation coefficient. Differences were considered statistically significant when $p < 0.05$.