An 8-week resistance training protocol is effective in adapting quadriceps but not patellar tendon shear modulus

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ABSTRACT

Habitual loading and resistance training (RT) can lead to changes in muscle and tendon morphology as well as in its mechanical properties which can be measured by Shear Wave Elastography (SWE) technique. The objective of this study was to analyze the Vastus Lateralis (VL) and patellar tendon (PT) mechanical properties adaptations to an 8-week RT protocol using SWE. We submitted 15 untrained health young men to an 8-week RT directed for knee extensor mechanism. VL and PT shear modulus (μ) were assessed pre and post intervention with SWE. PT thickness (PTT), VL muscle thickness (VL MT) and knee extension torque (KT) were also measure pre and post intervention to ensure the RT efficiency. Significant increases were observed in VL MT and KT (pre= 2.40 ±0.40 cm and post= 2.63 ±0.35 cm, p = 0.0111, and pre= 294.66 ±73.98 Nm and post= 338.93 ±76.39 Nm, p = 0.005, respectively). The 8-week RT was also effective in promoting VL μ adaptations (pre= 4.87 ±1.38 kPa and post= 9.08.12 ±1.86 kPa, p = 0.0105), but not in significantly affecting PT μ (pre= 78.85 ±7.37 kPa and post= 66.41 ±7.25 kPa, p = 0.1287) nor PTT (baseline= 0.364 ±0.053 cm and post = 0.368 ±0.046 cm, p = 0.71). The present study showed that an 8-week resistance training protocol was effective in adapting VL μbut not PT μ.Further investigation should be conducted with special attention to longer interventions, to possible PT differential individual responsiveness and to the muscle-tendon resting state tension environment.

EXTERNAL LINK

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THIS PROTOCOL ACCOMPANIES THE FOLLOWING PUBLICATION

Analysis of the correlation between knee extension torque and patellar tendon elastic property

PDF

Mannarino2017.pdf

GUIDELINES

Resistance training protocol

Participants were designated to eight-week resistance training for the quadriceps femoris muscle consisting of free-weight Squats (SQ) and Knee Extensions (KE) in a knee extension machine (MatFitness®, São Paulo, Brazil) in this precise exercise order. RT protocol was designed based on the ACSM recommendations for healthy individuals and adapted based on previous studies with similar design [35]. The frequency of the training program was 2 sessions per week with at least 72 hours rest between sessions. A total of 16 sessions were performed in the 8-week training period with all the sessions occurring between 8 and 10 AM.

At baseline, 10RM testing was performed for both exercises. All subjects were submitted to a familiarization before testing during which the subjects performed the same exercises as used in the 10RM tests with the aim of standardizing the technique of each exercise. The 10 RM tests and retest were then performed on 2 nonconsecutive days separated by 48-72 hours. The heaviest resistance load achieved on either of the test days was considered the pre-training 10RM of a given exercise. The 10RM was determined in no more than five attempts, with a rest interval of five minutes between attempts and a 10-minute recovery period was allowed before the start of the testing of the next exercise.

The 10RM tests were used to set the initial training load. Subjects were instructed to perform both exercises to failure in all sets and the weighs were continually adjusted to keep the exercises in an 8-12 repetitions range, with a two-minute rest interval between sets. Full range of motion was used in both SQ and KE. The RT program followed a linear periodization and progressive volume with four sets per exercise in weeks 1-4 and six sets per exercise in weeks 5-8. Before each training session, the participants performed a specific warm-up, consisting of 20 repetitions at approximately 50% of the resistance used in the first exercise of the training session (SQ). Contraction time was self-determined as individuals were instructed to perform both exercises until concentric failure in the 8-12 repetition range with the highest load possible. Adherence to the program was superior to 90% in all individuals and a strength and conditioning professional and a physician supervised all the training sessions. Verbal encouragement was provided during all training sessions.

Measurement of patellar tendon shear modulus and thickness

An Aixplorer US (v.11, Supersonic Imaging, Aix-en-Provence, France) with a 60-mm linear-array transducer at 4–15 MHz frequency was used in this study. The transducer was positioned at the inferior pole of patella and aligned with the patellar tendon, with no pressure on top of a generous amount of coupling gel. B-mode was used to locate and align the PT longitudinally. When a clear image of the PT was captured, the shear wave elastography mode was then activated. The transducer was kept stationary for approximately 10 seconds during the acquisition of the SWE map. A total of four images were acquired and saved for off-line processing analysis. Scanning of PT was performed with the subject in supine lying and the knee at 30° of flexion [36]. The knee was supported on a custom-made knee stabilizer to keep the leg in neutral alignment on the coronal and transverse planes (Fig 1). Prior to testing, the subjects were allowed to have a 10-min rest to ensure the mechanical properties of PT were evaluated at resting status. The room temperature was controlled at 20° C for all image acquisitions and the same experienced operator performed all exams.

The Q-box selected was the larger possible rectangle in order to consider more PT elasticity information. The μ values were obtained by a custom MatLab®routine and ROI limits were defined as the area between 5 and 25 mm from the inferior pole of the patella excluding the paratendon (Fig 2) [37]. The custom routine calculated the μ by dividing the mean E generated from the system by 3 [38].

Off-line analysis using ImageJ® 1.43u (National Institutes of Health, Bethesda, MD, USA) was performed with using two B-mode recorded images and the mean values were considered for analysis. PTT was measured at 20 mm from the inferior pole of the patella. The measure was limited by the PT deep and superficial paratendon and oriented transversely to the tendon fibers (Fig 3).

Measurement of vastus lateralis shear modulus

The same equipment was used for VL μ measurement. A longitudinal line was drawn between the most superficial and palpable portion of the great trochanter and the lateral epicondyle. Scans were taken at 50% of the length of the line [39]. The line length and distance from the great trochanter where the imaging was performed was registered for every volunteer to ensure that the post intervention analysis was made in the same exact location in the. B-mode was used to locate and align the probe with the VL. The images were recorded with subjects lying supine with their knee fully extended and their muscles fully relaxed [39]. When a clear image of the VL was captured, the SWE mode was then activated. The ROI was selected avoiding any detectable vascular structure and the deep fascia and based on the quality map (Fig 4).

Measurement of vastus lateralis muscle thickness

The images acquisition was performed by an experienced researcher, using a US (GE LogiqE, Healthcare, EUA), frequency of 8 MHz, for longitudinal scans of the VL muscle. The US probe was centered and the images were recorded with subjects on the same position and location used for VL SWE. The VL images were obtained on longitudinal plane laterally and the MT was determined as the mean of three distances (proximal, middle and distal) between superficial and deep aponeurosis for each image [40](Fig 5). The images were processed with publicly available software (ImageJ 1.43u; National Institutes of Health, Bethesda, MD, USA). For each image, two consecutive measurements were performed and the mean values were considered for analysis.

Measurement of knee extension torque

The maximal isometric extension KT was measured with an isokinetic dynamometer (BIODEXâ, Biodex Medical Systems, Shirley, NY, USA) at 80° of knee flexion [39]. Subjects were positioned seated with inextensible straps fastened around the waist, trunk and distal part of the thigh. The backrest inclination and seat translation as well as the dynamometer height were adjusted for each subject, to ensure proper alignment of the rotation axis of the dynamometer with the lateral condyle of the femur. The right knee was fixed to the dynamometer lever arm 5 cm above the lateral malleolus. Settings were recorded for re-test reproducibility. After a specific warm-up consisting of two submaximal isometric knee extensions, the subjects performed two 5-s maximal voluntary isometric contractions (MVIC) with one-minute rest between trials. Subjects were verbally encouraged to reach maximal effort while a visual feedback of the torque level was provided. The highest peak torque among trials (corrected for gravity) was recorded for analysis.

Statistical analysis

Descriptive data such as mean ± standard deviation (SD) were calculated. The software GraphPad Prism 7® was used for statistical analysis. After the normality distributions were verified using the Shapiro-Wilk tests, paired t-tests were used to compare the PT μ, PT thickness, the VL μ, the VL MT and the KT at baseline and after the resistance training protocol. A value of $p < 0.05$ was adopted as statistically significant.

BEFORE START

Ethics statement

The University Hospital Ethics Committee approved this study (registration number 2.811.595). The experimental procedures were conducted in accordance with the Declaration of Helsinki. All participants received instructions about the study procedures and provided informed written consent before testing.

Experimental procedure

The study was conducted at the Biomedical Engineering Department in our University between july 2017 and august 2018. The body weight and height of all subjects were measured and body mass index (BMI) was calculated. Age and dominant leg were informed. All subjects' PT and VL were submitted to SSI evaluation pre and post intervention. As a form to assure that the RT protocol was effective, Vastus Lateralis muscle thickness (VL MT) and knee extensor torque (KT) were measured at baseline and after the eight weeks of RT. PT thickness (PTT) was measured pre and post intervention to detect possible tendon structural adaptations. All post intervention measures were performed at one week after the last training session.

Subjects

In this longitudinal study, 15 untrained male volunteers (28.6 ± 3.26 years old, 177.3 ± 6.88 cm height, 91.8 ± 17.25 kg of body mass and 28.84 ± 4.44 kg/m^2 of body mass index) had the right knee examined. Age was set between 25 and 40 years old to eliminate any variation of PT properties due to age or gender. None of the subjects had participated in any systematic training or physical activity for at least 6 months. Any clinical history or report of knee pain/injuries, systemic disease or previous knee surgery was considered as exclusion criteria. All subjects were right handed.

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