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HUMAN PHYSIOLOGY STUDY

Relationship between hardness and deformation of the vastus lateralis muscle during knee flexion using ultrasound imaging

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KEYWORDS
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Vastus lateralis;
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Summary The aims of this study were to clarify the relationship between deformation of the VL during knee flexion and the stiffness of the VL. 40 lower limbs of 20 male normal volunteers were divided into control and tightness groups using the Ely test. Deformation of the VL in the transverse plane during active knee flexion from 0 to 90° was recorded using B-mode ultrasonography. Hardness of the VL was measured on the middle lateral thigh using a durometer. The reaction force at fully passive flexion was measured using a hand held dynamometer. The deformation of the VL and the hardness and passive torque showed significant differences between the 2 groups. The deformation of the VL showed a significantly higher correlation with hardness of the VL. Measurements of the deformation of the VL might be predicted by the elasticity around the VL.

Introduction

Many physical therapists, athletic trainers, and biomechanists are interested in the morphological changes that occur in skeletal muscles during physical activity. Morphological changes are difficult to quantitate, therefore, physical therapists have used manual therapy combined with imaging to monitor those changes. Ultrasonography (US) has been incorporated in the rehabilitation of muscle-skeletal disorders, such as rotator cuff tears, biceps brachialis long head tendinitis, and low back pain (Bailey et al., 2015; Hellem et al., 2015; Kiesel et al., 2007; Teyhen et al., 2007). And has been recognized as a very useful method to assess skeletal muscle under both the static and dynamic conditions (Whittaker and Emery, 2014; Koppenhaver et al., 2009).

Neuromuscular deficits have been linked with chronic musculoskeletal conditions. Rehabilitative ultrasound imaging (RUSI) has been used to assist in the rehabilitation

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of neuro-musculoskeletal disorders and to evaluate morphology and function of the skeletal muscle and soft tissue during exercise and physical tasks. RUSI is used to assist in the application of therapeutic interventions, and provides feedback to patients and physical therapists (Teyhen, 2006). However, US of skeletal muscle in many clinical settings has been under static conditions. US can capture dynamic images of soft tissue during movement and motion, but there are challenges including difficulty in fixing the transducer to body segments, interpretation of the deformation of the skeletal muscle mean, and the establishment of standard values of the deformation of the skeletal muscle under regular dynamic conditions.

The dynamics of the gastrocnemius muscle exhibit isometric contractions during motions such as walking, jumping, and running when assessed using US with a transducer fixed to the subject's leg (Fukunaga et al., 2001; Kawakami et al., 2002). Previously, we demonstrated that the dynamics of the medial head of the gastrocnemius muscle show inhibited isometric contraction during the dorsiflexion phase of the eccentric calf raise exercise using a fixed transducer on the leg (Kudo et al., 2015). In addition, skeletal muscle contraction has a role in the power generation of the motion, stabilizing the joints during joint movements, and maintaining body temperature. Through concentric contraction, the muscle is shortened in the longitudinal direction and expanded in the transverse direction. Skeletal muscles are comprised of muscle fascicles, tendons, vessels, and myofascia. The myofascia forms a network throughout the body that covers and links all organs, muscles, and nerves. It also acts as a buffer when muscle and myofibrils glide and functions as a support for traversing blood vessels, nerves, and lymphatic vessels (Schleips et al., 2012). Loose connective tissue rich in hyaluronic acid and with varying fiber directions acts as a buffer that enables the tissue to glide (Stecco et al., 2011). We hypothesized that when the elasticity of loose connective tissue of the myofascia has been changed pathologically, there is an associated decrease in the deformation of the skeletal muscle during joint motion and an increase in muscle hardness. However, no consensus standardized values of skeletal muscle deformation during joint motion have been established. Thus, skeletal deformation cannot be assessed effectively using US in the clinical setting.

The vastus lateralis muscle (VL) originates at the lateral lip of the linea aspera of the femur and inserts at the tibial tubercle. The VL acts a strong extensor of the knee, and an increase in the hardness of the VL can lead to anterior knee pain syndrome such as patelofemoral joint arthritis and jumper's knee. Therefore, evaluation of the hardness of the VL is important. However, this evaluation depends on palpation of the VL, which is not an objective method. No quantitative methods have been identified to evaluate the hardness of the VL.

The aims of this study were to clarify the relationship between deformation of the VL during knee flexion and the hardness of the VL. Moreover the cut off value, which can assess decreased deformation of the VL, was estimated.

Methods

Forty lower limbs of 20 male normal volunteers participated in this study. All of the volunteers provided informed consent. The volunteers were divided into control and tightness groups using the Ely test. Twenty limbs of 10 subjects who showed a negative score on the Ely test were assigned to the control group, and the other 20 limbs of 10 subjects who showed a positive score on the Ely test were assigned to the tightness group.

The Ely test was performed one time by a physical therapist who had 8years clinical experiences in orthopedics physical therapy. Positive Ely test was defined as the condition which could not be touched the own heel to the buttocks with keeping the bilateral anterior superior iliac spina contact to the bed in prone lying. General characteristics of all subjects are shown in Table 1. This study was approved by the ethics committee of our university.

Deformation of the VL in the transverse plane during active knee flexion from 0 to 90° was recorded using B-mode US (Mylab25; Esaote, Indianapolis, IN, USA) with a 12 MHz liner probe fixed on the lateral side of the distal one third of the thigh by an original fixation device. Movement of the postero-lateral corner of the VL in the US image from 0 to 90 degrees of knee flexion was measured using Image-J (NIH) (Fig. 1). Deformation of the VL was measured 3 times, and the mean value was accepted.

Hardness of the VL was measured using a durometer (TDM-NA1(DX) TRY-ALL INC., Japan) and a hand held dynamometer (μtus F-1, Anima co., Japan). For the durometer measurement, a single examiner performed 3 repetitions to measure the hardness on the middle lateral thigh in the supine position with the knee extended. In the torque meter measurement, the subject's knee was fully flexed and held by a single examiner using a jig with a hand held dynamometer. Subjects were positioned as prone and relaxed and their pelvis and thigh were fixed on a bed using a hard polyester band. The axis of the jig was set on the knee joint axis, and the hand held dynamometer was set on the distal end of the leg. The reaction force at fully passive flexion, assessed by a single examiner, divided by the leg length was calculated, and the mean value of the reaction force over 5 repetitions was determined as the passive torque.

The muscle tenderness at the lateral side of the middle thigh was evaluated by a single examiner using an algometer (FP meter, Matsumiya co., Japan). All parameters were measured in 3 repetitions, and the average of the 3 measurement values was accepted. All measurements were repeated 3 times to assess test-retest reliability (10

Table 1 General characteristic data.

	All	Control group	Tightness group	P-value
Age (y/o)	20.0 ± 2.3	19.1 ± 0.9	20.1 ± 2.4	0.23
Height (cm)	167.4 ± 5.8	170.4 ± 6.4	167.4 ± 6.1	0.22
Weight (kg)	59.9 ± 6.9	57.2 ± 7.3	59.9 ± 7.3	0.42
BMI	20.4 ± 2.4	19.6 ± 2.3	21.4 ± 2.3	0.1

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