Manual Therapy 20 (2015) 610–613

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

Acute effects of static stretching on the hamstrings using shear elastic modulus determined by ultrasound shear wave elastography: Differences in flexibility between hamstring muscle components

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ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form
3 February 2015
Accepted 20 February 2015

Keywords:
Hamstrings
Stretching
Shear wave elastography

ABSTRACT

Background: Static stretching (SS) with hip flexion and knee extension is often used to stretch the hamstrings. However, it is unclear whether there are the differences in the acute effect of this SS maneuver on flexibility between each component of the hamstrings, namely the semitendinosus (ST), semimembranosus (SM), and biceps femoris (BF) muscles.
Objectives: The aims of this study were to investigate the acute effects of SS on the flexibility of the individual muscle components of the hamstrings, and to examine the difference in the acute effect of SS between these components using shear elastic modulus as the index of muscle flexibility.
Method: Twenty healthy men (age, 23.4 ± 2.3years) volunteered for this study. The shear elastic modulus of the ST, SM and BF muscles were measured using ultrasound shear wave elastography before (PRE) and immediately after (POST) 5 min of SS. Measurements of shear elastic modulus were taken with the knee at 90° (slack position) and 45° (extension position) of flexion.
Results: In all muscles, the shear elastic modulus at both knee angles decreased significantly after SS. The percentage change in the shear elastic modulus from PRE to POST in the muscles at 45° of knee flexion was greatest in the SM.
Conclusions: These results suggest that SS with hip flexion and knee extension has acute effects on increasing flexibility of the hamstring muscle components, especially the SM muscle.

1. Introduction

Stretching with the hip flexed and the knee extended is often used as a static stretching (SS) method for the hamstrings. Previous studies have reported that the range of motion of the joint increased (Magnusson et al., 1998, 2000; de Weijer et al., 2003) and stiffness of the muscle tendon unit (MTU) and passive knee flexion torque during passive knee extension decreased (Magnusson et al., 1996; Matsuo et al., 2013) immediately after SS of the hamstrings. However, MTU stiffness and passive torque are comprehensively influenced by other muscles, ligaments, and the joint capsule (Maisetti et al., 2012). The hamstrings (consisting of the semitendinosus [ST], semimembranosus [SM), and biceps femoris [BF] muscles), whose function it is to generate hip extension and knee flexion, may be simultaneously stretched during this SS maneuver. Therefore, the effect of SS on the individual muscles of the hamstrings cannot be estimated using conventional methods such as passive torque measurement. Therefore, it is unclear whether the acute effects of this SS maneuver on muscle flexibility differ between the muscles that compose the hamstrings.

Since poor hamstring flexibility increases the risk of muscle strain (Witvrouw et al., 2003; Bradley and Portas, 2007), SS is often used as an injury prevention intervention. A previous study (McHugh and Cosgrave, 2010) reported that SS before an athletic task could reduce the risk of muscle strain. On the other hand, several studies (Vanmechelen et al., 1993; Arnason et al., 2008) have reported SS had no association with the incidence of muscle strain. These inconsistent results may be because few studies have

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http://dx.doi.org/10.1016/j.math.2015.02.006
1356-689X/

investigated the effects of SS on the individual muscles of the hamstrings. Therefore, investigating the effects of SS on the individual muscles of the hamstrings, especially the BF muscle, which has a high injury rate (Verrall et al., 2003; Koulouris et al., 2007), is important for the prevention of hamstring muscle strain.

No studies have investigated the differences in the acute effects of SS on muscle flexibility between the muscles components of the hamstrings because of the difficulty in estimating individual muscle flexibility noninvasively in vivo by conventional techniques. However, in a previous study, we introduced a novel ultrasound technology to determine individual muscle flexibility (Umegaki et al., 2015), by measuring the shear elastic modulus called ultrasound shear wave elastography. Previous studies have reported that the shear elastic modulus measured by ultrasound shear wave elastography is a reliable index of individual muscle flexibility (Akagi and Takahashi, 2013; Nakamura et al., 2014; Taniguchi et al., in press).

Therefore, the aims of this study were to investigate the acute effects of SS on muscle flexibility of the ST, SM, and BF muscles, and to examine the differences in these acute effects between the muscles using shear elastic modulus measured by ultrasound shear wave elastography as the index of muscle flexibility.

2. Methods

2.1. Subjects

Twenty healthy men (age, 23.4 ± 2.3 years; height, 172.1 ± 3.3 cm; weight, 66.0 ± 6.0 kg) volunteered for this study. Subjects were non-athletes and had not been involved in any regular stretching or resistance training. Subjects with a history of neuromuscular disease or musculoskeletal injury involving their lower limbs were excluded from this study. The purpose and procedures were explained to all subjects, following which written informed consent was obtained. This study was approved by the ethics committee of Kyoto University Graduate School and the Faculty of Medicine (E−1268).

2.2. Experimental procedure

Before (PRE) and immediately after (POST) 5 min of SS of the hamstrings, the final angle, passive torque, and shear elastic modulus of the hamstrings were measured. The definition of each index is described below. The subjects were instructed to remain relaxed during each of the measurements.

2.3. Measurements of the final angle and passive torque

The subjects were placed in a supine position with their pelvis anteriorly inclined. The dominant lower leg was attached to a dynamometer (Biodex system 4.0, Biodex Medical Systems Inc., USA) so that the hip angle was set at 90° flexion. The pelvis was tilted by putting a wedge between the pelvis and the bed. The non-dominant femur was fixed to the bed with a belt so that the hip angle of the non-dominant leg would not change. The knee was passively extended by using the dynamometer while keeping the hip angle fixed at 90° flexion to the maximum angle at which there was no discomfort or pain (Morse et al., 2008; Nakamura et al., 2011). The subjects were instructed to inform verbally when they started to feel discomfort or pain, and the angle just before this occurred was defined as the final angle. The final angle was expressed as the change in the knee angle from 90° flexion. Passive torque during passive knee extension was also measured using a dynamometer. The knee was passively extended at a constant velocity of 5°/s starting from 90° flexion to the final angle. Passive torque was used as an index of flexibility of the hamstring MTU (Matsuo et al., 2013). Passive torque at 45° knee flexion, excluding the effect of the weight of the lower leg, was used for analysis.

2.4. Measurement of shear elastic modulus

Shear elastic modulus of the ST, SM, and BF muscle bellies in the dominant leg was measured. The measurement points were defined as the midpoint of the femur from the greater trochanter to the medial epicondyle for the ST and SM muscles and to the lateral epicondyle of the femur for the BF muscle. These anatomical points were confirmed by palpation and B-mode images. Measurements were taken using ultrasound shear wave elastography (Axiplorer; SuperSonic Imagine, Axi-en-Provence, France). An ultrasound transducer (50 mm long SL-15-4 liner ultrasound transducer) was positioned on the measurement points parallel to the direction of the muscle fibers, which were confirmed by tracing several fascicles without interruption across the B-mode image.

During the measurements, the subjects were placed in a supine position with their hip at 90° flexion and the pelvis inclined anteriorly. Shear elastic modulus of the ST, SM, and BF muscles was measured at 90° (slack position: Fig. 1) and 45° (extension position) knee flexion. The shear elastic modulus was measured in each setting for <10 s to avoid the effects on muscle stiffness. Each measurement was performed at random to remove the effect of measurement time. The shear elastic modulus of the ST, SM, and BF muscles was measured twice, and the mean values were used for statistical analysis. The intraclass correlation coefficient [1, 1] of the shear elastic modulus was high for the ST (PRE-knee 90° flexion: 0.897, PRE-knee 45° flexion: 0.979, POST-knee 90° flexion: 0.885, POST-knee 45° flexion: 0.892), SM (PRE-knee 90° flexion: 0.987, PRE-knee 45° flexion: 0.971, POST-knee 90° flexion: 0.975, POST-knee 45° flexion: 0.896), and BF muscles (PRE-knee 90° flexion: 0.946, PRE-knee 45° flexion: 0.954, POST-knee 90° flexion: 0.941, POST-knee 45° flexion: 0.972). None of the subjects felt discomfort or pain and the shear elastic modulus was not reached as the upper limit value during the measurement of shear elastic modulus.

2.5. SS protocol

The subjects were placed in a supine position with the pelvis inclined anteriorly. Using the dynamometer, with the hip angle fixed at 90° flexion, SS was performed up to the same knee angle as the final angle. A previous study (Matsuo et al., 2013) reported that 5 min of SS decreased stiffness of the hamstring MTU. Therefore, in this study, SS of 1 min was repeated five times (i.e., 5 min with a 30-s interval between sets).

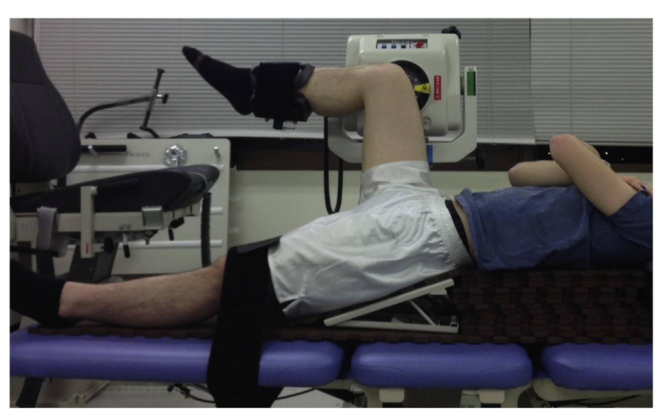

Fig. 1. Slack position: 90° knee flexion and 90° hip flexion.