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Original article

The effect of hip rotation on shear elastic modulus of the medial and lateral hamstrings during stretching

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ABSTRACT

Regarding hamstring stretching methods, many studies have investigated the effect of stretching duration or frequency on muscle stiffness. However, the most effective stretching positions for hamstrings are unclear because it is impossible to quantify muscle elongation directly and noninvasively in vivo. Recently, a new ultrasound technology, ultrasonic shear wave elastography, has permitted noninvasive and reliable measurement of muscle shear elastic modulus, which has a strong linear relationship to the amount of muscle elongation. This study aimed to investigate the effect of hip internal and external rotation on shear elastic modulus of the lateral and medial hamstrings, respectively, during stretching in vivo using ultrasonic shear wave elastography. Twenty-three healthy men (age, 23.0 ± 2.1 years) were recruited for this study. To investigate the effect of hip rotation on the elongation of the medial and lateral hamstrings, shear elastic modulus of the biceps femoris (BF) and semitendinosus (ST) was measured at rest (a supine position with 90° knee flexion, 90° hip flexion, and hip neutral rotation) and in seven stretching positions (with 45° knee flexion and hip internal, external, and neutral rotation) using ultrasonic shear wave elastography. In both BF and ST, the shear elastic modulus in the rest position was significantly lower than that in all stretching positions. However, no significant differences were seen among stretching positions. Our results suggest that adding hip rotation at a stretching position for the hamstrings may not have a significant effect on muscle elongation of the medial and lateral hamstrings.

1. Introduction

Hamstring muscle strain is one of the most common sports injuries (Bishop and Fallon, 1999; Brooks et al., 2006; Gabbe et al., 2006; Ekstrand et al., 2011; Feeley et al., 2008) and causes considerable lost time from training and competition (Brooks et al., 2006; Ekstrand et al., 2011). Therefore, many studies have been performed to investigate an effective method to prevent hamstring muscle strain (Witvrouw et al., 2003; Gabbe et al., 2006; McHugh and Cosgrave, 2010). Stretching has been used as one of the main methods for preventing hamstring muscle strain, supported by the finding that less flexibility of the hamstrings increases the risk of hamstring muscle strain (Witvrouw et al., 2003). However, a recent systematic review on prevention of hamstring muscle strain found inadequate evidence for the preventive effect of stretching (Goldman and Jones, 2010). Nevertheless, limited evidence suggests that time for recovery to full function may be reduced by increased frequency of stretching (Mason et al., 2007). To clarify the value of stretching, many studies have investigated the impact of stretching on muscle flexibility with attention to stretching duration and frequency (Magnusson et al., 2000; Ylinen et al., 2009; Ben and Harvey, 2010). However, no studies have investigated effective stretching positions for improving flexibility of the hamstrings in vivo or vitro.

For hamstrings, which have knee flexion and hip extension moment arms, a stretching position with knee extended and hip flexed is generally selected. Medial hamstrings, which consist of the semitendinosus (ST) and semimembranosus, have hip internal rotation moment arms, and lateral hamstrings, which consist of the biceps femoris (BF), have hip external rotation moment arms (Dostal et al., 1986). Therefore, we hypothesized that the medial hamstrings could be stretched more by adding external rotation, and the lateral hamstrings could be stretched more by adding internal rotation.

No studies have investigated effective stretching positions in vivo because it is impossible to quantify muscle elongation directly and

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noninvasively in vivo. Recently, a new ultrasound technology, ultrasonic shear wave elastography, has permitted noninvasive and reliable measurement of muscle shear elastic modulus. Previous studies have reported a strong linear relationship between the shear elastic modulus measured by ultrasonic shear wave elastography and the amount of muscle elongation (Maisetti et al., 2012; Eby et al., 2013; Koo et al., 2014). Therefore, ultrasonic shear wave elastography is a very useful tool to estimate changes in muscle elongation in vivo. Nevertheless, no studies have investigated the most effective stretching positions using this apparatus.

This study aimed to investigate the effect of hip internal and external rotation on shear elastic modulus of the lateral and medial hamstrings, respectively, during stretching in vivo using ultrasonic shear wave elastography.

2. Methods

2.1. Subjects

Twenty-three healthy men (age, 23.0 ± 2.1 years; height, 172.0 ± 4.7 cm; weight, 66.1 ± 7.1 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 the lower limbs were excluded. All subjects were fully informed of the procedures and purpose of the study. Written informed consent was obtained from all subjects. This study was approved by the ethics committee of Kyoto University Graduate School and the Faculty of Medicine (E-1162).

2.2. Experimental protocol

The subjects were placed in a supine position, and their pelvises were secured by a belt. The rest position (Rest) was defined as the position with 90° knee flexion, 90° hip flexion, and hip-neutral rotation. Stretching was performed in the following seven positions: 1) R0 (45° knee flexion and 90° hip flexion at hip-neutral rotation); 2) IR10 (adding 10° hip internal rotation to R0); 3) IR20 (adding 20° hip internal rotation to R0); 4) IR30 (adding 30° hip internal rotation to R0); 5) ER10 (adding 10° hip external rotation to R0); 6) ER20 (adding 20° hip external rotation to R0); 7) ER30 (adding 30° hip external rotation to R0). These positions were determined by measuring the joint angles using a goniometer and were manually maintained. Rest and R0 are shown in Fig. 1. Our study (Nakamura et al., 2013) reported that >2 min of stretching decreased muscle stiffness. Therefore, in this study, each position was maintained for <10 s to avoid the effects of changes in muscle stiffness. The order in which positions were measured was randomized to remove the effect of measurement time.

2.3. Measurement of shear elastic modulus

Shear elastic modulus of the BF and ST muscle bellies of the dominant leg was measured at the midpoint of the thigh from the greater trochanter to the lateral and medial epicondyles of the thighbone. These points were confirmed by palpation and marked prior to measurement. Shear elastic modulus of the BF and ST was measured using ultrasonic shear wave elastography (Axiplorer; SuperSonic Imagine, Axi-en-Provence, France). This apparatus uses acoustic radiation force created by ultrasound beams to perturb muscle tissues by inducing shear waves that propagate within the muscle. As the shear waves propagate, they are captured by the ultrasound transducer at an ultrafast frame rate. Shear wave propagation speed is estimated at each pixel using a cross-correlation algorithm. Shear elastic modulus (G) can be calculated using the shear wave speed (v) by the following equation:

$$G = \rho v^2$$

where ρ is the muscle mass density, which is assumed to be 1000 kg/m^3. An ultrasound transducer (50 mm long SL-15-4 linear ultrasound transducer) was positioned on the marking points along the sagittal plane of the muscle fibers for BF and ST, which were confirmed by tracing several fascicles without interruption across the B-mode image. Shear wave elastography generated color-coded images with a scale from blue (low) to red (high) (in the web version) depending on the shear wave propagation speed (Fig. 2). The region of interest (ROI) was set near the center part of the muscle belly in the image. The mean shear wave propagation speed (m/s) of an 11-mm-diameter circle set near the center of the ROI was automatically calculated. The measurements of shear elastic modulus for ST and BF were performed once in each position. Measurement of shear elastic modulus was performed by an experienced measurer. The reliability of the shear elastic modulus measured by this apparatus has been confirmed in previous studies (Maisetti et al., 2012; Koo et al., 2014).

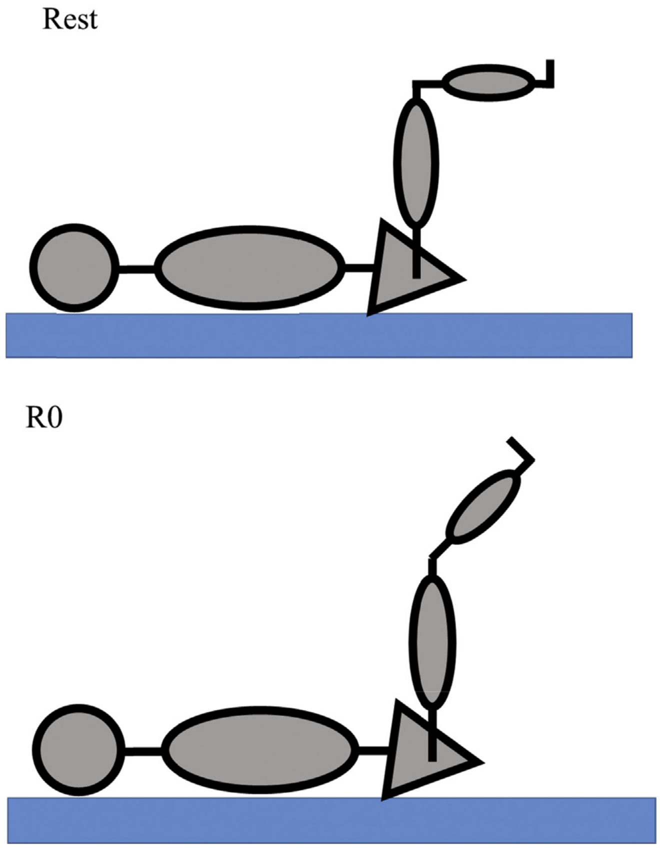

Fig. 1. Rest: the position with 90° knee flexion, 90° hip flexion, and hip-neutral rotation. R0: the position with 45° knee flexion and 90° hip flexion at hip-neutral rotation.

2.4. Measurement reliability

Measurements of shear elastic modulus were repeated twice, in different sessions, to assess reliability (8 healthy men; age 22.8 ± 1.8 years; height 172.8 ± 3.6 cm; body mass 67.0 ± 7.5 kg).

2.5. Priori sample size calculation

We calculated the sample size needed for one-way repeated measures analysis of variance (ANOVA) (alpha error = 0.05,