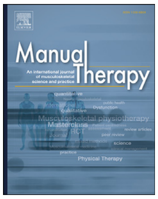
Manual Therapy 24 (2016) 1–6

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math



Original article

The difference in passive tension applied to the muscles composing the hamstrings – Comparison among muscles using ultrasound shear wave elastography

Masatoshi Nakamura [a, b, *], Satoshi Hasegawa [b], Hiroki Umegaki [b], Satoru Nishishita [b], Takuya Kobayashi [b], Kosuke Fujita [b], Hiroki Tanaka [b], Satoko Ibuki [b], Noriaki Ichihashi [b]

[a] *Institute for Human Movement and Medical Sciences, Niigata University of Health and Welfare, Niigata, Japan*
[b] *Human Health Sciences, Graduate School of Medicine, Kyoto University, Japan*

ARTICLE INFO

Article history:
Received 26 November 2015
Received in revised form
23 March 2016
Accepted 28 March 2016

Keywords:
Hamstrings
Pelvis
Shear wave elastography

ABSTRACT

Background: Hamstring muscle strain is one of the most common injuries in sports. Therefore, to investigate the factors influencing hamstring strain, the differences in passive tension applied to the hamstring muscles at the same knee and hip positions as during terminal swing phase would be useful information. In addition, passive tension applied to the hamstrings could change with anterior or posterior tilt of the pelvis.

Purpose: The aims of this study were to investigate the difference in passive tension applied to the individual muscles composing the hamstrings during passive elongation, and to investigate the effect of pelvic position on passive tension.

Methods: Fifteen healthy men volunteered for this study. The subject lay supine with the angle of the trunk axis to the femur of their dominant leg at 70° and the knee angle of the dominant leg fixed at 30° flexion. In three pelvic positions (“Non-Tilt”, “Anterior-Tilt” and “Posterior-Tilt”), the shear elastic modulus of each muscle composing the hamstrings (semitendinosus, semimembranosus, and biceps femoris) was measured using an ultrasound shear wave elastography.

Results: The shear elastic modulus of semimembranosus was significantly higher than the others. Shear elastic modulus of the hamstrings in Anterior-Tilt was significantly higher than in Posterior-Tilt.

Conclusion: Passive tension applied to semimembranosus is higher than the other muscles when the hamstring muscle is passively elongated, and passive tension applied to the hamstrings increases with anterior tilt of the pelvis.

1. Introduction

Hamstring muscle strain is one of the most common injuries in sports (Bishop and Fallon, 1999; Brooks et al., 2006; Gabbe et al., 2006; Feeley et al., 2008; Ekstrand et al., 2011) and results in considerable time lost from training and competition (Brooks et al., 2006; Ekstrand et al., 2011). Many studies have investigated the risk factors and epidemiological features of hamstring muscle strain to identify preventive measures. Some have suggested that hamstring muscle strain is particularly likely to occur during the terminal swing phase of sprinting (Heiderscheit et al., 2005; Schache et al., 2009). The biceps femoris is the most commonly injured muscle among the hamstring muscles (Verrall et al., 2003; Koulouris et al., 2007). A previous study (Thelen et al., 2005) using a computer simulation reported that the percentage change in the length of the biceps femoris muscle tendon unit from standing upright to the terminal swing phase during running was higher than that of the semitendinosus and semimembranosus muscles, and this has been considered one of the reasons for some of the epidemiological features of hamstring muscle strain.

An ultrasound technology, ultrasound shear wave elastography, has enabled us to noninvasively and reliably measure the muscle shear elastic modulus (Bercoff et al., 2004). Previous studies have reported a strong linear relationship between the shear elastic modulus measured using ultrasound shear wave elastography and

---

* Corresponding author. Institute for Human Movement and Medical Sciences, Niigata University of Health and Welfare, 1398 Shimami-cho, Kita-ku, Niigata City, Niigata, 950-3198, Japan. Tel.: +81 25 257 4451; fax: +81 25 257 4451.
E-mail address: masatoshi-nakamura@nuhw.ac.jp (M. Nakamura).

http://dx.doi.org/10.1016/j.math.2016.03.012
1356-689X/

the passive muscle tension (Maisetti et al., 2012; Chernak et al., 2013; Koo et al., 2013). Therefore, the shear elastic modulus measured using ultrasound shear wave elastography was used as an index of the indirect passive tension. Using this technique, our previous study (Umegaki et al., 2015) reported that the passive tension applied to the semimembranosus was the highest among those applied to the hamstring muscle components at 45° knee flexion and 90° hip flexion. To reveal the cause of this inconsistency, it is important to investigate the in vivo differences in the passive tension applied to the muscles composing the hamstring at the same knee and hip positions as during the terminal swing phase.

The increases in the passive tension applied to the hamstring muscles and in hamstring muscle strain occur mostly during the terminal swing phase of sprinting, in which the hamstring muscle is greatly elongated, in accordance with the hip flexion and knee extension seen in this phase (Yu et al., 2008; Chumanov et al., 2011). If the increase in passive muscle tension during this phase is an important factor in hamstring muscle strain, an anterior or a posterior tilt of the pelvis should likewise be an important factor affecting the passive tension applied to the hamstrings, considering that the hamstring muscles originate from the ischial tuberosity (Abebe et al., 2009). In addition, although the hip joint angle, which is defined as the angle of the trunk with respect to the femur, remains the same, it is possible that the anterior or posterior tilt of the pelvis is different. Therefore, we hypothesized that an anterior tilt of the pelvis can increase the passive tension applied to the hamstring muscles at the same hip joint angle. However, to the best of our knowledge, no study has investigated the effect of pelvic tilt on the passive tension applied to the hamstring muscles.

The aims of this study were to investigate the differences in the passive tension applied to the individual muscles (semitendinosus, semimembranosus, and biceps femoris) composing the hamstrings during passive elongation with the knee and hip angles simulating those seen during the terminal swing phase, and to investigate the effect of pelvic tilt on the passive tension by measuring the shear elastic modulus.

2. Methods

2.1. Subjects

Fifteen healthy males (age, 22.6 ± 1.4 years; height, 172.7 ± 3.8 cm; weight, 68.1 ± 5.0 kg) volunteered for this study. Subjects with a history of neuromuscular disease or musculoskeletal injury involving their lower limbs were excluded from the study. In addition, the subjects recruited were participants in recreational sports but not in any strength or flexibility training at the time of the study. All subjects were fully informed of the procedures and purpose of the study, and then written informed consent was obtained from all of them. This study was approved by the ethics committee of the Kyoto University Graduate School and the Faculty of Medicine.

2.2. Experimental procedure

Each subject lay supine on a bed with their trunk kept horizontal. The lower leg on the dominant side was attached to a dynamometer (Biodex system 4.0, Biodex Medical Systems Inc., USA). The angle between the trunk axis and the femur (trunk–femur angle) of their dominant leg was fixed at 70°, measured using a regular goniometer, and the knee angle was fixed at 30° flexion, because these angles most closely match the angles in which the hamstrings are maximally elongated during the terminal swing phase of running (Thelen et al., 2005). The subject's knee axis was adjusted to coincide with the rotating axis of the dynamometer. The non-dominant femur was fixed to the bed using a belt to maintain a constant hip angle of the non-dominant leg. In pelvic alignment, the neutral pelvic position was defined as "Non-Tilt," and anterior and posterior tilt positions of the pelvis with respect to Non-Tilt were defined as "Anterior Tilt" and "Posterior Tilt," respectively (Fig. 1). The pelvis was tilted by placing a wedge between the pelvis and the bed. In these three positions, the shear elastic modulus, passive knee flexion torque, and joint angle were measured.

2.3. Joint angle

A schematic representation of the measurement of the joint angle is shown in Fig. 2. The subjects were fitted with 25-mm reflective markers located on the anterior superior iliac spine (a), the midpoint (b) between the anterior superior iliac spine and the posterior superior iliac spine, the greater trochanter (c), and the lateral femoral epicondyle (d) on the dominant side facing the camera (iVIS HF M43, Canon, Japan). Two reflective markers (e and f) were fitted on the bed's edge. The line that linked the two markers on the bed's edge (e and f) was defined as the trunk axis; the line that linked the markers at (a) and (b) was defined as the pelvic axis, and the line that linked the markers at (c) and (d) was defined as the femur axis. We defined the angle of the femur axis with respect to the trunk axis as the trunk–femur angle (T–F angle) and the angle of the femur axis with respect to the line perpendicular to the pelvic axis as the pelvis–femur angle (P–F angle). Pictures of the three pelvic positions were acquired using a camera positioned 3 m from the sagittal side of the subjects. Moreover, the T–F and P–F angles were quantified three times for each position using open-source digital measurement software (Image J, NIH, USA) on the pictures, and their mean values were used for further analysis. The interclass correlation coefficients [ICC (1, 3)] were high for the T–F angle (Anterior Tilt: 0.930, Non-Tilt: 0.879, Posterior Tilt: 0.965) and for the P–F angle (Anterior Tilt: 0.959, Non-Tilt: 0.961, Posterior Tilt: 0.945).

2.4. Measurement of the shear elastic modulus

The shear elastic moduli of the semitendinosus, semimembranosus, and biceps femoris muscle bellies on the dominant leg were measured at three points: the midpoints of the thigh from the greater trochanter to the medial epicondyle of the thighbone for the semitendinosus and semimembranosus, and the lateral epicondyle of the thighbone for the biceps femoris, as confirmed by palpation and B-mode imaging. These points were marked before measurement. The shear elastic moduli of the semitendinosus, semimembranosus, and biceps femoris were measured using ultrasound shear wave elastography (Axiplorer; SuperSonic Imagine,

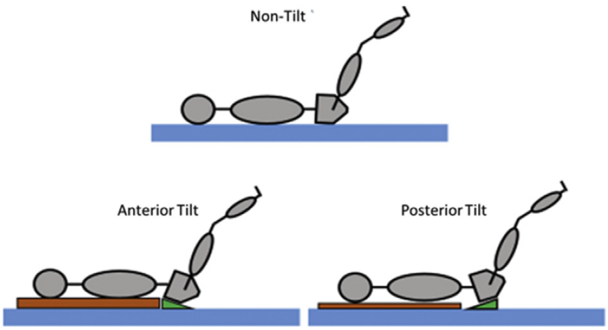


Fig. 1. Schematic representation of the experimental setup. In pelvic alignment, the neutral pelvic position was defined as "Non-Tilt," and anterior and posterior tilt positions of the pelvis with respect to Non-Tilt were defined as "Anterior Tilt" and "Posterior Tilt," respectively.