The Effect of Hip Flexion Angle on Muscle Elongation of the Hip Adductor Muscles During Stretching

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Keywords; Shear wave elastography, Stretching, Adductor muscles

Word count: 2073 (Introduction through Discussion)

Abstract

In order to perform effective static stretching of the hip adductor muscles, it is necessary to clarify the position where the muscles are most stretched. However, the effective flexion angle in stretching for each adductor muscle remains unclear. The goal of this study was to investigate the effect of hip flexion angle on muscle elongation of hip adductor muscles during stretching. Sixteen healthy men were recruited for this study. Shear elastic modulus, an index of muscle elongation, of the adductor longus (AL), and both the anterior and posterior adductor magnus (anterior AM) were measured using ultrasonic shear wave elastography at rest (supine position) and at 5 stretching positions (maximal hip abduction at 90°, 60°, 30°, 0°, and -15° hip flexion). For the AL, the shear elastic modulus at rest was significantly lower than that in all stretching positions. However, there was no significant difference among stretching positions. For the anterior AM, there was no significant difference between stretching positions and at rest. For the posterior AM, the shear elastic modulus in 90°, 60°, and 30° hip flexion were significantly higher than that at rest. The shear elastic modulus in 90° hip flexion was significantly higher than that in 60° and 30° hip flexion. Our results suggest that the AL is elongated to the same extent by maximal hip abduction regardless of hip

flexion angle, the anterior AM is not elongated regardless of the hip flexion angle; the posterior AM is elongated at all angles except at 0° and -15° hip flexion and is most extended at 90° hip flexion.

Introduction

Adductor muscle strain is a common injury in athletes. A previous study investigating lower limb muscle injuries in soccer players reported that the adductor muscle is the second most common site of injury after hamstrings and is most likely to be reinjured (Ekstrand et al., 2011). In addition, among the adductor muscles, the adductor longus (AL) is most commonly injured (Kiel and Kaiser, 2018). Because a decrease in muscle flexibility is considered one of the causes of adductor muscle strain injuries, improving the flexibility of muscles is important to prevent injuries (Ibrahim et al., 2007). Static stretching, which slowly stretches the muscle without bouncing or countermovement, is a method to increase muscle flexibility (Ichihashi et al., 2016). It is suggested that static stretching not only prevents muscle strain injuries, but also reduces the time required for returning to competition after muscle strain (Mason et al., 2012). Therefore, if the selective stretching method of each adductor muscle (such as the AL, which is the most common site of muscle strain injury) is developed further, it can be useful in the treatment of muscle strain and prevention of reinjury. In particular, men had a higher rate of hip adductor strains than women(Eckard et al., 2017). Thus, it is necessary to develop an effective stretching position suitable for men.

Passive hip abduction can be considered a method to stretch the adductor muscles.

It is reported that muscles whose forces have greater moment arms undergo greater passive strain during joint motion (Magnusson et al., 2000). In the sagittal plane, AL and the anterior adductor magnus (anterior AM) have hip flexion moment. On the other hand, the posterior adductor magnus (posterior AM) has a hip extension moment (Dostal et al., 1987). Therefore, the hip flexion angle may affect the amount of muscle elongation in the stretched muscle. However, it remains unclear how the hip joint angle affects the stretching of the adductors.

Ultrasonic shear wave elastography is used to evaluate muscle stiffness non-invasively in vivo. In this method, it is possible to quantitatively calculate the shear elastic modulus of tissue from the propagation shear wave velocity of the vibrated tissue when radiation force is applied.(Brandenburg et al., 2014). Koo et al., (2013) reported a strong linear relationship between the shear elastic modulus measured using ultrasonic shear wave elastography and muscle stiffness. Therefore, ultrasonic shear wave elastography is an eminent technique to estimate the muscle elongation in vivo (Umehara et al., 2015). The purpose of this study was to investigate the influence of hip flexion angle during hip abduction stretching of the adductor muscles using shear wave elastography. The hypotheses are that the AL and anterior AM, which generate flexion moments in the sagittal plane, are most elongated in the hip extension position, and that the posterior AM, which generates an extension moment in the sagittal plane, is most elongated in hip flexion positions.

Materials and Methods

Participants

The sample size required for multiple comparisons after a one-way repeated analysis of variance (ANOVA) [effect size = 0.8 (large), α error = 0.05, Power = 0.80] was calculated in advance via G*power software (version 3.1, Heinrich Hein University, Germany), and the value was 15. Therefore, 16 healthy men (age, 21.5 ± 1.0 years; height, 172.0 ± 6.0 cm; weight, 72.2 ± 7.6 kg) were recruited for this study. All participants were fully informed of the procedures and purpose of the study. Written informed consent was obtained from all subjects. The ethics committee of Kyoto University Graduate School and the Faculty of Medicine (R0233-3) approved this study.

Experimental Protocol

The subjects were placed in a supine position. All measurements were taken on the right side. The rest position (Rest) was determined as 0° hip flexion, 0° hip abduction position. The stretching positions were maximum hip abduction at the following five hip flexion angles: 1)

-15° flexion (F-15); 2) 0° flexion (F0); 3) 30° flexion (F30); 4) 60° flexion (F60); 5) 90° flexion (F90); knee was maintained at 90° flexion in all the five hip flexion angles (Fig 1). The shear elastic modulus of the AL, anterior AM, and posterior AM were measured at Rest and at the five stretching positions. The hip joints were passively moved to the maximal angle at which the subjects did not feel discomfort or pain. The passive hip abduction ranges of motion (ROM) at the five stretching positions were measured using a 1°-scale goniometer. All measurements of ROM were performed twice, and the mean value was used for further analysis. In addition, to eliminate the order effect, the stretching positions (i.e. flexion or extension position of the hip) were determined in a random order, and the muscle measurements were conducted randomly. Sustained stretching for more than 2 minutes affects the elastic modulus of the muscles (Nakamura et al., 2014), so we took care to avoid continuous stretching so that the measurement itself did not affect the elastic modulus.

Measurement of Shear Elastic Modulus

The shear elastic modulus of the AL, anterior AM, and posterior AM was measured using ultrasound shear wave elastography (Aixplorer, Supersonic Imagine, France) with a linear probe (SL10-2, Supersonic Imagine, France). The measurement site was defined as the proximal 30% of the upper leg length from the femoral greater trochanter to the knee joint lateral space. The muscles were identified at this level with the use of a B-mode ultrasonic image (Fig 2). In order to distinguish between the anterior AM and posterior AM, the anterior AM was measured at the ventral end of the AM, and the posterior AM was measured at the dorsal end of the AM (Fig 3). The shear elastic modulus was measured five times for each muscle in each position, and the mean value was used for further analysis.

Statistical Analysis

Statistical analysis was performed using statistical software (SPSS statistics version 22, IBM, USA). To evaluate the intra-rater reliability of the shear elastic modulus measurements, the intraclass correlation coefficient (1,5) ($ICC_{1,5}$) with a 95% confidence interval (CI) was calculated.

To investigate the difference of the shear elastic modulus across positions, a one-way repeated measures analysis of variance (ANOVA) is used. A significant effect was observed with the Holm multiple comparison test. In addition, a one-way repeated ANOVA with a Holm multiple comparison test was also used to compare the ROM at different hip flexion angles. The statistical significance was set at an alpha level of 0.05, and all results were shown as mean ± SD.

Results

The ICC (1, 5) was 0.99 (95% CI: 0.979–0.996), 0.82 (95% CI: 0.619–0.935) and 0.85 (95% CI: 0.682–0.946) for the shear elastic modulus of AL, anterior AM, and posterior AM at Rest, respectively. For ROM, ICC (1, 2) values were 0.988 (95% CI: 0.981–0.992).

The results of shear elastic modulus of the AL, anterior AM, and posterior AM are shown in Fig 4. For AL, anterior AM, and posterior AM, one-way ANOVA indicated significant main effects in positions. In the case of the AL, the post hoc test indicated that the shear elastic modulus at each of the stretching positions was significantly higher than that at Rest. However, there was no significant difference among the stretching positions. For the anterior AM, there was no significant difference between stretching positions and at rest. For the posterior AM, the shear elastic modulus at F90°, F60°, and F30° hip flexion were significantly higher than that at rest. The shear elastic modulus at F90 was significantly higher than that at F60 and F30.

Hip abduction ROMs during stretching are shown in Fig 5. The hip abduction ROM increased along with an increase in hip flexion angle.

Discussion

This study investigated the influence of hip flexion angle on the stretching of each muscle (AL, anterior AM, and posterior AM) during passive hip abduction. These muscles are common sites of muscle strain. To the best of our knowledge, this is the first study that investigated the effect of hip flexion angle on the muscle elongation of the individual adductor muscles.

The ICC (1, 5) values of the shear elastic modulus measurements were 0.990 (95% CI：0.979–0.996), 0.822 (95% CI：0.619–0.935), and 0.852 (95% CI：0.682–0.946) at AL, anterior AM, and posterior AM, respectively. The ICC (1, 2) values of the ROM measurements were 0.988 (95% CI：0.981–0.992). Both values are greater than 0.81 and are confirmed as "almost perfect" (Landis and Koch, 1977).

For the AL, the shear elastic modulus in all stretching positions was significantly higher than at Rest, while there was no significant difference in shear elastic moduli among the different stretching positions themselves. In other words, no difference was observed due to the hip flexion angle. This result was different from the hypothesis that the AL is most elongated in the hip extension position. We conclude that this is due to the influence of the hip abduction angle during stretching. Comparing the ROMs in each stretching position with one another, we note that the hip abduction ROM increased with an increase of the hip flexion angle. The AL has a flexion moment in most of the hip ROM (Dostal et al., 1987). However, in the present study, the abduction angle was low at the hip extension position where the muscle should be elongated, and the abduction angle was large at the flexion position, which we concluded was the reason why no significant difference was observed. In summary, regardless of the hip flexion angle, it was revealed that the AL is elongated to the same extent by maximal abduction.

For the anterior AM, there was no significant difference between stretching positions and at rest. This result was different from the hypothesis that the anterior AM is most extended in hip extension. We consider another muscle to be a factor in limiting the elongation of the anterior AM, and in constraining the ROM. A previous study reported that the AL that is elongated in all stretching positions has a greater adduction and flexion moment than the AM (Dostal et al., 1987). Therefore, the anterior AM was not elongated because the AL was elongated before the anterior AM.

For the posterior AM, the shear elastic modulus at each of the positions F90, F60, and F30 was significantly higher than that at Rest. This result is same as the hypothesis that the posterior AM is most elongated in the hip flexion position. We conclude that the reason for the posterior AM not being elongated at F0 and F-15 is the effect of the change in moment arm due to the flexion angle of the hip joint. Therefore, we conclude that the posterior AM is not elongated at F0 and F-15 because the AL is elongated before the posterior AM, as in the case of the anterior AM. Furthermore, the shear elastic modulus at F90 was significantly higher than the shear elastic modulus at F60 and F30. It is considered that because the posterior AM has a hip extension moment (Dostal et al., 1987), it is elongated more by abduction from the hip flexion position.

There are some limitations in this study. Although this study evaluated the muscle elongation during stretching using the shear elastic modulus, the actual effect of stretching intervention was not examined, and it is unclear whether continuous stretching for a long period of time will improve muscle flexibility. Future studies need to examine the effect and duration of stretching by building on the present research work. In addition, the participants in this study were limited to men. As men and women have different mechanical properties in their muscles and function of their joints (Saeki et al., 2019), we should note that the results presented in this study may not be applicable to female athletes.

In conclusion, this study examined the influence of the hip flexion angle on the stretching of the adductor muscles. It was revealed that the AL is elongated to the same extent by maximal abduction regardless of the hip flexion angle, and the anterior AM is not elongated regardless of the hip flexion angle, and the posterior AM was elongated at 90°, 60°, and 30° hip flexion, and was most extended at 90° hip flexion. To prevent injury, or to help with rehabilitation after injury, we suggest that, to stretch the AL, the hip needs to be maximally abducted regardless of the flexion angle, and to stretch the posterior AM, the hip needs to be abducted at 90° hip flexion.

Acknowledgements

We would like to thank Ms.Ibuki and Editage (www.editage.com) for English language editing.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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Figure captions

Fig 1. Stretching positions

90° hip flexion (a), 60° hip flexion (b), 30° hip flexion (c), 0° hip flexion (d) and -15° hip flexion (e).

Fig 2. Shear elastic modulus analysis image

adductor longus (a), anterior adductor magnus (b), and posterior adductor magnus (c).

Fig 3. Shear elastic modulus measurement site of AM

AM: Adductor magnus, AL: Adductor longus, SM: Semimembranosus, ST: Semitendinosus, G: Gracilis.

Fig 4. Shear elastic modulus of the (A) adductor longus (AL), (B) anterior adductor magnus (Anterior AM), and (C) posterior adductor magnus (Posterior AM) in each position.

Rest: 0° hip flexion and 0° hip abduction, F90: maximum hip abduction with 90° hip flexion and 90° knee flexion. F60: maximum hip abduction with 60° hip flexion and 90°

knee flexion, F30: maximum hip abduction with 30° hip flexion and 90° knee flexion, F0: maximum hip abduction with 0° hip flexion, 90° knee flexion, F–15: maximum hip abduction with –15° hip flexion, 90° knee flexion. *: Significant difference from Rest ($p < 0.05$). #: Significant difference from F60 and F30 ($p < 0.05$).

Fig 5. Hip abduction range of motion (ROM) in each position.

F90: maximum hip abduction with 90° hip flexion and 90° knee flexion. F60: maximum hip abduction with 60° hip flexion and 90° knee flexion, F30: maximum hip abduction with 30° hip flexion and 90° knee flexion, F0: maximum hip abduction with 0° hip flexion, 90° knee flexion, F–15: maximum hip abduction with –15° hip flexion, 90° knee flexion. †: Significant differences between all positions.

Fig 1

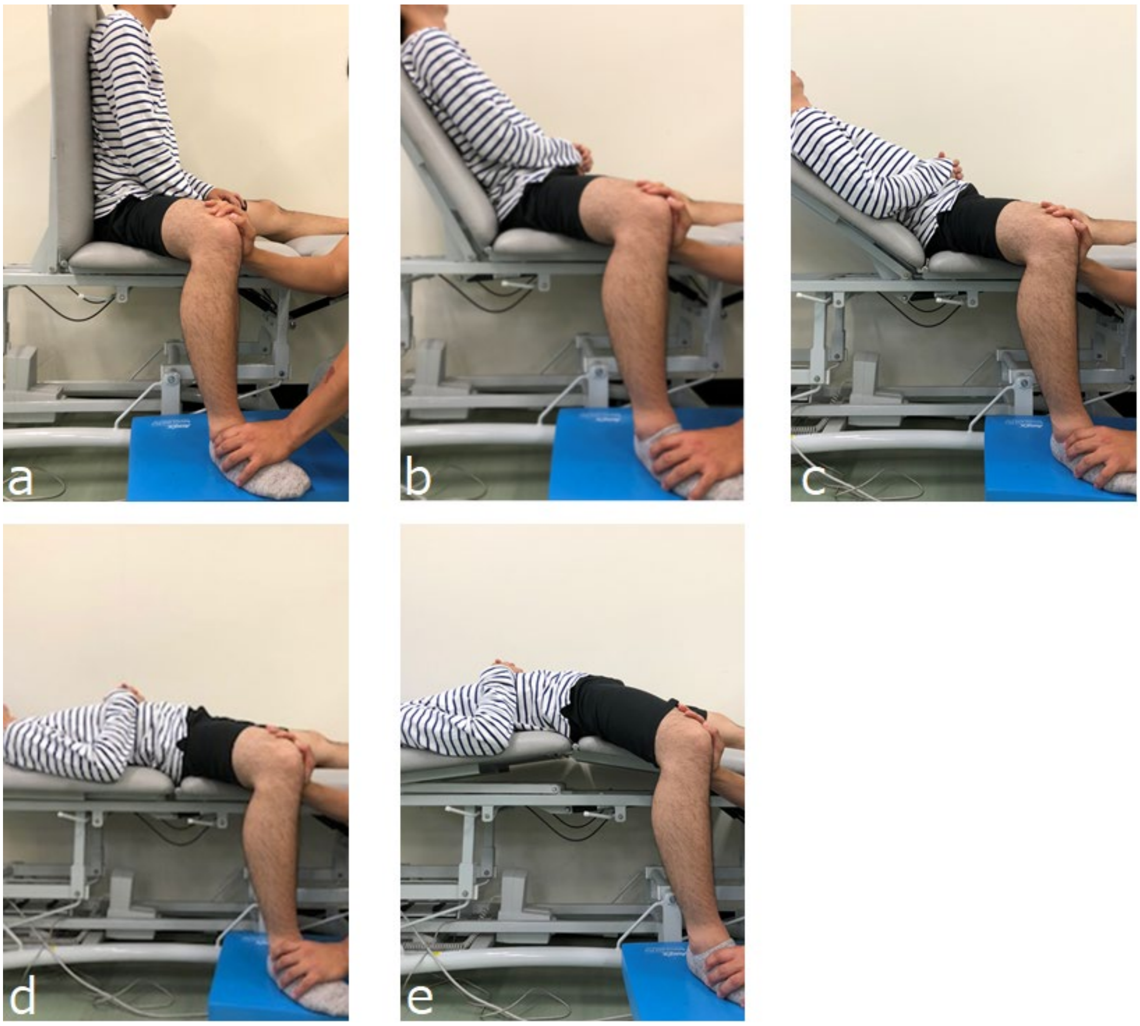


Fig 2

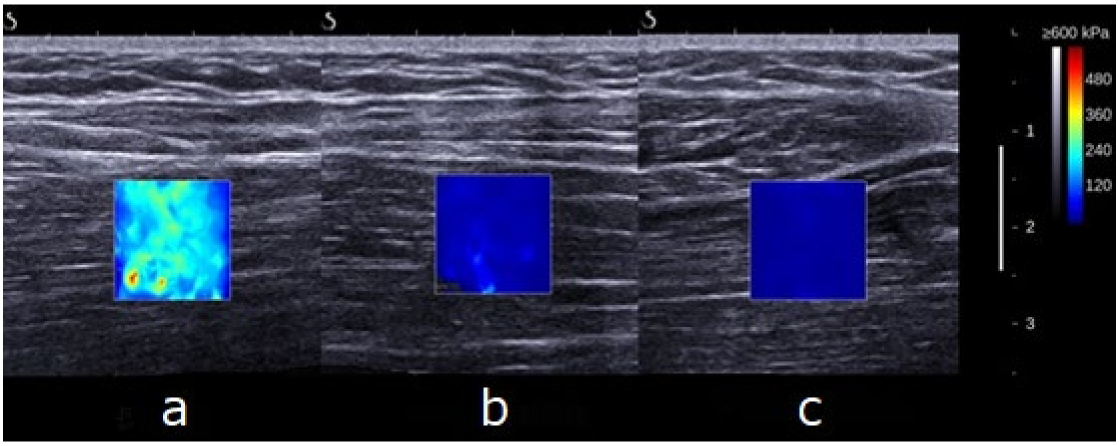


Fig 3

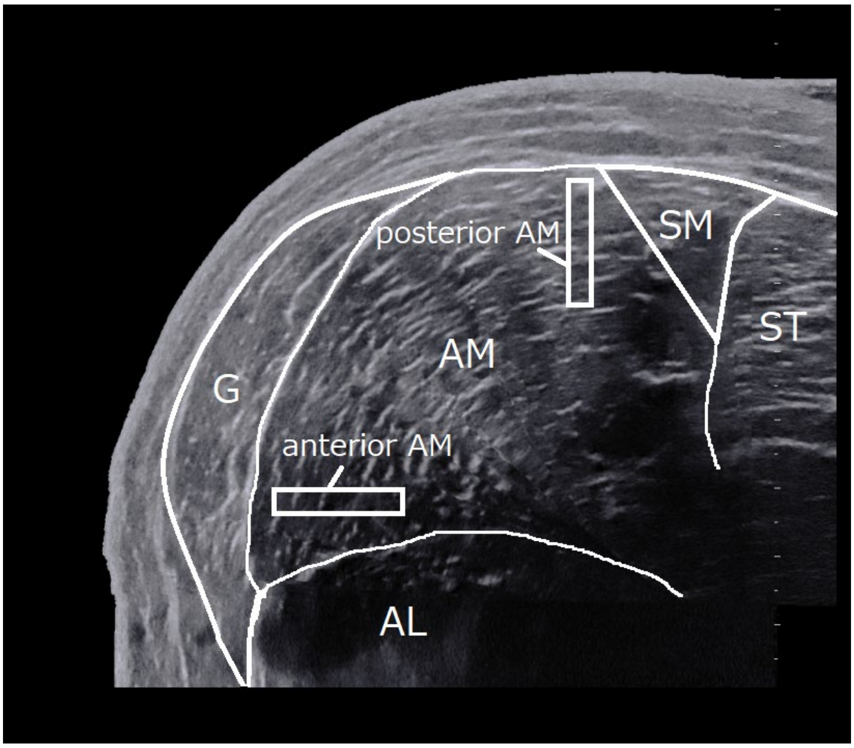
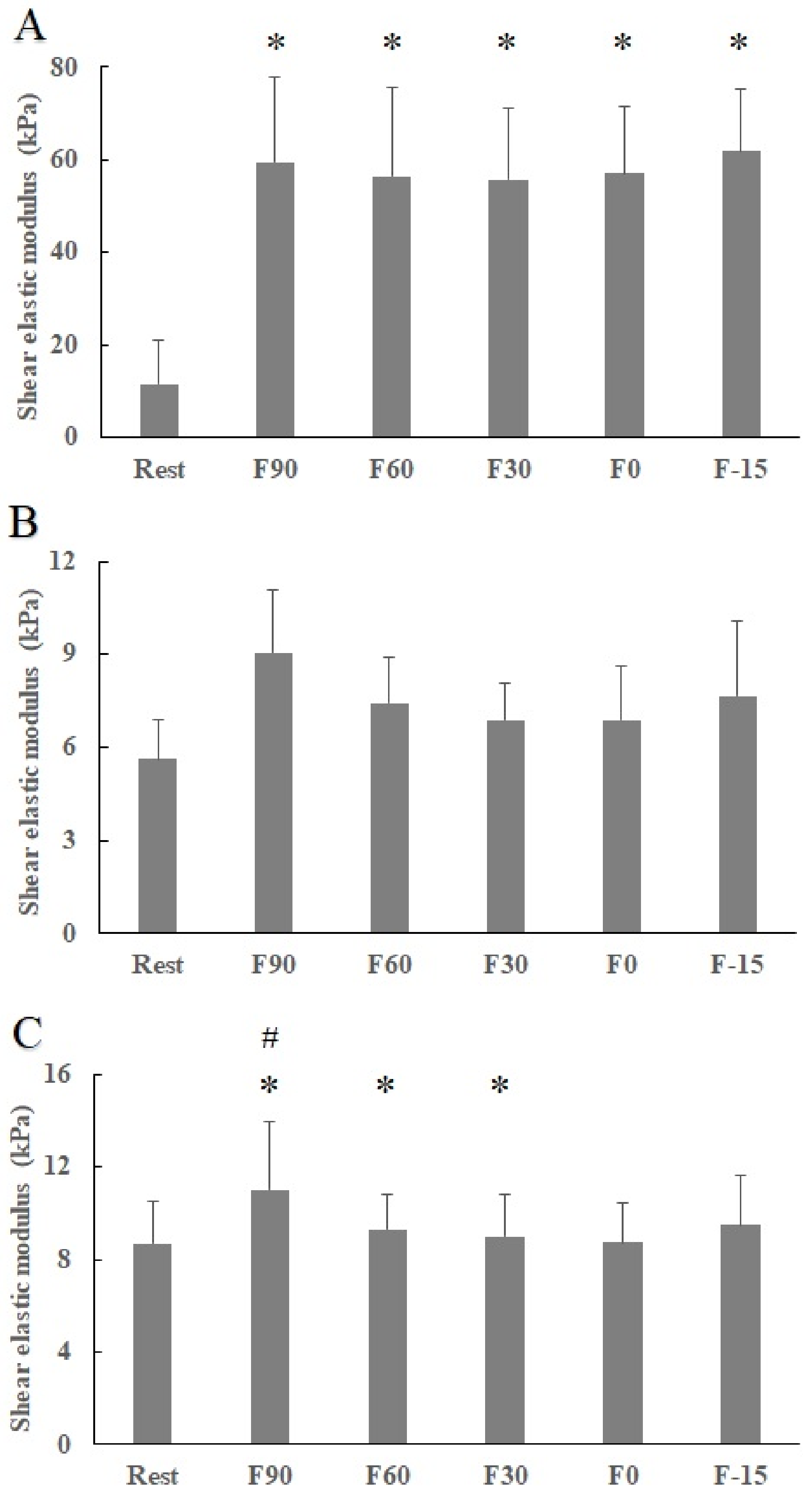


Fig 4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Shear elastic modulus (kPa)
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Shear elastic modulus (kPa)
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Fig 5