THE RELATIONSHIP BETWEEN OPTIMAL KNEE FLEXION ANGLE AND HAMST RING FLEXIBILITY: INDICATION FOR HAMSTRING STRAIN INJURY

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The purpose of this study was to determine the relationships among hamstring flexibility, optimal knee flexion angle for maximal knee flexion moment, maximal knee flexion moment. Ten male and 10 female reactional athletes were tested for hamstring flexibility and isokinetic strength. The maximal knee flexion moment and the knee flexion angle corresponding to the maximal knee flexion moment were determined for each participant. Optimal knee flexion angle was a function of hamstring flexibility score and gender, but not of the hamstring strength. Optimal knee flexion angle and hamstring strength were not correlated. These results indicate that hamstring muscle optimal length is correlated to its flexibility, but not to its strength. Increased hamstring flexibility is correlated with increased muscle optimal length. Hamstring flexibility may be a risk factor for hamstring strain injury.

KEY WORDS: Hamstring strain injury, flexibility, muscle optimal length.

INTRODUCTION: Hamstring strain injury is one of the most common injuries in track and field, soccer, Australian football, rugby, American football involving high-speed running, jumping and kicking, accounting for up to 29% of all injuries in these sports. Athletes who sustained hamstring strain injury typically need 2 to 8 weeks to recover from the injury and get back to the pre-injury level of activity, which result in significant time and financial loses. Athletes who sustained hamstring muscle strain injuries have a high re-injury rate of 12-31% (Croisier, 2004; Woods et al, 2004). Although tremendous efforts have been made to prevent hamstring strain injury and improve the rehabilitation of the injury in the last three decades, the injury rate and re-injury rate, however, remain unchanged (Opar et al, 2014), which indicate an urgent need of studies on hamstring strain injury prevention and rehabilitation.

To effectively prevent hamstring strain injury and improve the rehabilitation of the injury, understanding the mechanisms and risk factors of the injury is critical. Hamstring flexibility and strength are two proposed risk factors of hamstring injury previous clinical studies were focused on (Liu et al, 2012). However, the results of the studies on the relationships of these two factors with the risk for hamstring strain injury are inconsistent due to a lack of theoretical support (Liu et al, 2012).

Several studies suggest that the direct cause of muscle strain injury is muscle strain instead of muscle force force (Brooks & Faulkner, 2001; Garrett et al., 1987; Lieber & Friden, 1993). Muscle strain is defined as the ratio of muscle length deformation to muscle resting length that is defined as the maximum muscle length at which the parallel elements are not generating force. The results of a recent study indicate that hamstring muscle optimal lengths measured as the knee optimal angle might be correlated to hamstring flexibility (Alonso et al, 2009), which may provide a theoretical support to hamstring flexibility as the risk factor for hamstring strain injury.

To set a theoretical basis for further studies on the risk factors for hamstring strain injury, the purpose of this study was to examine the relationships among knee optimal angle, flexibility, and strength. We hypothesized that knee optimal angle for maximal hamstring moment would be positively correlated to hamstring flexibility and strength. We also hypothesized that the hamstring strength and flexibility would be significant correlated.

METHODS: Ten male and 10 female healthy college students volunteered to participate in this study. All participants had no history of hamstring muscle strain injury when participating in this study. The use of human subjects in this study was approved by Internal Review Board at Beijing Sport University.

Each participant had a 5 – 10 min warm-up including jogging and stretch, and then had a straight leg raise (SLR) test to evaluate hamstring muscle flexibility for both legs (Gajdosik et al., 1985) and a hamstring muscle isokinetic strength test to determine hamstring muscle optimal length for both legs. An experienced sports medicine clinician served as the tester in the SLR test for all participants. In each SLR test, the participant laid on the floor in a supine position. The tester raised the participant's leg with one hand, and monitored the pelvis rotation with the other hand placed on the anterior superior iliac spine of the contralateral side. The participant's leg was raised to a hip flexion angle with a straight knee when the tester clearly felt the resistance to further hip flexion or a pelvis posterior rotation. The hip flexion angle at this position was referred to as maximal hip flexion angle. The participant had three SLR test trials for each leg. The body position with maximum hip flexion angles in the flexibility test were recorded using a 25 Hz high definition camera. The camera was placed 5 cm height above the floor with its optical axis perpendicular to the sagittal plane of participant. The video records were digitized. Maximal hip flexion angles were calculated. The mean of the maximal hip angles in three trials was used as the hamstring flexibility score of the given leg.

In the hamstring isokinetic strength test, participants sit on the IsoMed 2000 strength testing system (D&R Ferstl GmbH, Hemau, Germany) with a hip flexion of 90°. The thigh and lower leg of the test leg were secured on the seat and dynamometer arm of the strength testing machine, respectively, in such a way that only knee flexion/extension movements were allowed, and the knee flexion/extension axis was aligned with the rotation axis of the dynamometer. The rotation speed and range of the dynamometer arm were set 10°/s and 110°, respectively, with the dynamometer arm position at leg fully extension as 0°. The participant had three isokinetic knee flexion trials with maximum effort for each leg with a 90 sec rest between trials. The knee flexion torque data measured by the dynamometer in the strength testing system were collected using a MegaWin 2.4 system (Mega Electronics Ltd., Kuopio, Finland) at a sample rate of 100 sample/channel/sec.

The peak knee flexion torque was identified for each trial. The trial with the highest peak knee flexion torque was used for data analysis. The peak knee flexion torque in this trial was used as a measure of hamstring strength while the corresponding knee flexion angle was referred to as optimal knee flexion angle.

To test our first hypothesis, linear regression analysis with dummy variable was performed to express the optimal knee flexion angle as a function of hamstring flexibility score and hamstring strength

$$y = a_0 + a_1 x_1 + a_2 x_2 + a_3 \beta + e$$

where y was the optimal knee flexion angle; x_1 was the hamstring flexibility score, x_2 was hamstring strength; β was the dummy variable representing gender ($\beta = 0$ for males, $\beta = 1$ for females); and a_0 to a_3 were regression coefficients. The best regression equation was determined through a backward selection procedure. A regression coefficient was kept in the best regression equation if (1) the contribution of the corresponding term to the regression measured by partial R^2 was greater than 0.03, and (2) the overall regression is statistically significant.

Linear regression analysis with dummy variable was also performed to testing our second hypothesis by determining the relationship between hamstring strength and flexibility score. The full regression model was

$$y = a_0 + a_1 x + a_2 \beta + e$$

where y and x were hamstring strength and flexibility score, respectively, and β was the dummy variable representing gender. The best regression equation was determined using the same procedure and criteria as used in data analysis for testing the first hypothesis.

RESULTS: The best regression equation for the optimal knee flexion angle (y) as a function of flexibility score (x_1) and gender (β) was

$$y = 72.09 - 0.31x_1 + 6.20\beta \qquad (R^2 = 0.4071, P = 0.001)$$

The contributions of flexibility score and gender to the overall regression were 0.3004 (P = 0.001) and 0.1068 (P = 0.012), respectively (Figure 1). Strength had no significant contribution to the overall regression (Partial R^2 = 0.001, P = 0.972).
Hamstring flexibility score was not significantly correlated to hamstring strength (R^2 = 0.006, P = 0.622).

DISCUSSION: The results of this study partially support our first hypothesis. The optimal knee flexion angle was significantly correlated to hamstring flexibility score and gender, but not to hamstring strength. The greater the flexibility score was, the smaller the knee optimal flexion angle was. With the same flexibility score, female participants tended to have a greater optimal knee flexion angle in comparison to male participants (Figure 1). With knee flexion angle fixed in the flexibility test, the greater the hip flexion angle was, the longer the hamstring muscle was, and the better the flexibility was. With hip flexion angle fixed in strength testing in this study, the greater the knee flexion angle was, the shorter the muscle length was. Therefore, results of this study are consistent with those reported in previous study (Alonso et al, 2009), and suggest that the greater the hamstring flexibility score was, the greater the optimal hamstring muscle length was, and that, with the same flexibility score, female participants had shorter optimal hamstring muscle length in comparison to male participants. As previous studies showed, muscle strain injury was only related to active muscle strain, not muscle force (Brooks & Faulkner, 2001; Garrett et al., 1987; Lieber & Friden, 1993). Muscle strain is defined as the ratio of muscle length deformity to muscle optimal length. Therefore, with the same muscle length deformity, the shorter the muscle optimal length is, the greater the muscle strain will be. The results of this study showed that the hamstring flexibility and the optimal length are proportional to each other. These results combined together suggest that increasing the hamstring flexibility may decrease risk for hamstring strain injury in the same movement, and that poor flexibility may be a risk factor for hamstring strain injury. An extensive literature review failed to find an explanation for the gender difference in optimal knee flexion angle.

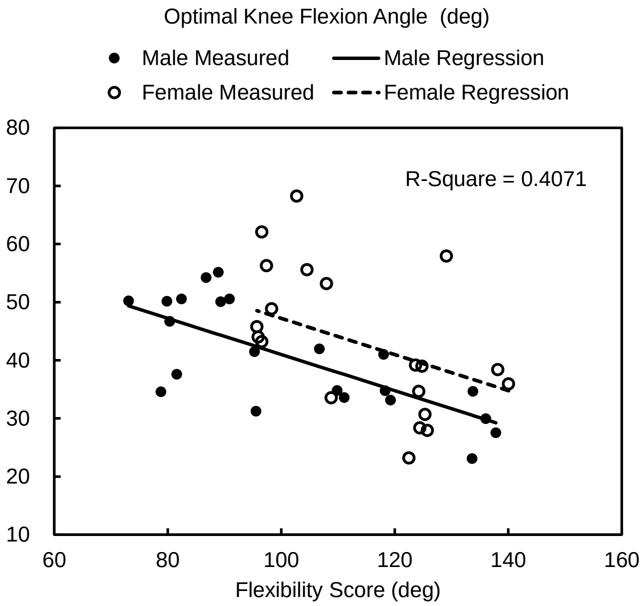

Figure 1. The relationship between harmstring flexibility score and optimal knee flexion angle for maximal knee flexion moment

The results of this study do not support our second hypothesis. The hamstring flexibility and strength were not correlated. This result further suggests that hamstring strength does not affect hamstring muscle optimal length, and thus may not be a risk factor for hamstring strain injury.
Future studies are needed to determine hamstring force and optimal muscle lengths to further confirm the results of this study. Hamstring muscle torque is the production of hamstring muscle force and moment arm. Both hamstring muscle moment arms is a function of knee

flexion angle, which may make the relationships between hamstring muscle torque and knee flexion angle and between hamstring force and knee flexion angle different.

CONCLUSION: Hamstring optimal muscle length may be a function of hamstring muscle flexibility. Hamstring strength and optimal muscle length are not correlated. Hamstring strength and flexibility are not correlated. These results set a theoretical basis for future studies on hamstring strain injury.

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