HOSTED BY
ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Journal of Sport and Health Science xx (2016) 1–8
www.jshs.org.cn

Original Article

Relationships among hamstring muscle optimal length and hamstring flexibility and strength

Xianglin Wan [a], Feng Qu [a], William E. Garrett [b], Hui Liu [a,*], Bing Yu [c,*]

[a] *Biomechanics Laboratory, Beijing Sport University, Beijing 100084, China*
[b] *Duke University Sports Medicine Center, Durham, NC 27710, USA*
[c] *Center for Human Movement Science, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA*

Received 6 September 2015; revised 11 November 2015; accepted 20 January 2016
Available online

Abstract

Background: Hamstring muscle strain injury (hamstring injury) due to excessive muscle strain is one of the most common injuries in sports. The relationships among hamstring muscle optimal lengths and hamstring flexibility and strength were unknown, which limited our understanding of risk factors for hamstring injury. This study was aimed at examining the relationships among hamstring muscle optimal lengths and flexibility and strength.

Methods: Hamstring flexibility and isokinetic strength data and three-dimensional (3D) kinematic data for hamstring isokinetic tests were collected for 11 male and 10 female recreational athletes. The maximal hamstring muscle forces, optimal lengths, and muscle lengths in standing were determined for each participant.

Results: Hamstring muscle optimal lengths were significantly correlated to hamstring flexibility score and gender, but not to hamstring strength. The greater the flexibility score, the longer the hamstring muscle optimal length. With the same flexibility score, females tend to have shorter hamstring optimal muscle lengths compared to males. Hamstring flexibility score and hamstring strength were not correlated. Hamstring muscle optimal lengths were longer than but not significantly correlated to corresponding hamstring muscle lengths in standing.

Conclusion: Hamstring flexibility may affect hamstring muscle maximum strain in movements. With similar hamstring flexibility, hamstring muscle maximal strain in a given movement may be different between genders. Hamstring muscle lengths in standing should not be used as an approximation of their optimal lengths in calculation of hamstring muscle strain in musculoskeletal system modeling.

Keywords: Injury risk factor; Muscle biomechanics; Muscle length-tension relationship; Muscle optimal length; Muscle strain; Muscle strain injury

1. Introduction

Hamstring muscle strain injury (hamstring injury) is one of the most common injuries in track and field, soccer, Australian football, rugby, and American football involving high-speed running, jumping, and kicking, accounting for up to 29% of all injuries in these sports.[1,2] Although most hamstring injuries do not require surgical treatment, athletes typically need 2 to 8 weeks to recover from the injuries and get back to their preinjury level of activity,[3–6] which results in substantial time and financial losses.[7–9] Athletes who sustained hamstring injuries have a high reinjury rate of 12%-31%.[10–11] Reinjured hamstrings take an even longer time to recover.[12] Repeated hamstring injury may result in longer rehabilitations, chronic pain, disability, and even the end of an athletic career.[13] Because of the significant financial and time loss and significant consequences of hamstring injuries, intensive efforts have been made to prevent hamstring injuries and improve rehabilitation in the past 3 decades. A recent extensive review of literature with detailed injury rates, however, revealed that injury and reinjury rates remained unchanged,[14] which indicate a need for further studies on hamstring injury prevention and rehabilitation.

To effectively prevent and rehabilitate hamstring injury, identifying risk factors for the injury is critical. Flexibility and strength are 2 proposed risk factors for hamstring injury. However, the results of clinical studies on the effects of hamstring flexibility and strength on the risk of hamstring injury are inconsistent. Several studies showed that the risk of hamstring injury negatively correlated to hamstring flexibility,[15–17]

Peer review under responsibility of Shanghai University of Sport.
* Corresponding authors.
E-mail addresses: liuhuibupe@163.com (H. Liu); byu@med.unc.edu (B. Yu).

http://dx.doi.org/10.1016/j.jshs.2016.04.009

Please cite this article in press as: Xianglin Wan, Feng Qu, William E. Garrett, Hui Liu, Bing Yu, Relationships among hamstring muscle optimal length and hamstring flexibility and strength, Journal of Sport and Health Science (2016), doi: 10.1016/j.jshs.2016.04.009

whereas other studies showed no correlation.[18–20] In addition, studies showed that the risk of hamstring injury negatively correlated to the ratio of hamstring to quadriceps muscle strength,[19,21,22] whereas other studies showed no correlation.[16,23,24]

Several studies using animal models demonstrated that a muscle strain injury occurs when the muscle is stretched or during an eccentric contraction, and active muscle strain reaches a certain magnitude regardless of muscle force and strain rate.[25–30] These results suggest that the direct cause of muscle strain injury is muscle strain instead of muscle force and strain rate. Like other materials, muscle strain is defined as the ratio of muscle length deformation to muscle resting length, which itself is defined as the maximum muscle length at which the parallel elements are not generating force.[31] Muscle resting length can be approximated as the muscle optimal length, which is defined as the muscle length at which the force generated by muscle contractile elements is maximal.[32,33] The greater the hamstring optimal lengths, the lower the maximal hamstring muscle strains in a given athletic task with similar range of lower extremity motion.

Hamstring flexibility and strength should be correlated to hamstring optimal lengths if they are risk factors for hamstring injury. However, the relationships of hamstring muscle optimal lengths with hamstring flexibility and strength are still unknown. An *in vivo* study that investigated the optimal knee flexion angle at which isokinetic knee flexion moment was maximal showed that legs recovered from hamstring injury had a greater optimal knee flexion angle in comparison to legs without the injury for the same athletes.[34] This result indicates that legs with hamstring injury may have shorter muscle optimal length in comparison to legs without injury. Alonso et al.[35] reported that the mean optimal knee flexion angles were 75° for legs with tight hamstring muscle and 65° for legs with more flexible hamstring muscles. Other studies showed that 6 to 8 weeks of stretching training improved hamstring flexibility and decreased optimal knee flexion angle by 4° to 10°.[36,37] These results indicate that hamstring muscle optimal lengths may be correlated to hamstring flexibility. However, the relationships of hamstring muscle optimal lengths with flexibility have not been established. Our literature review also did not reveal any association between hamstring strength and muscle optimal lengths. Furthermore, several studies indicated that muscle flexibility and strength were correlated,[38–40] whereas our literature review revealed that these indications have not been confirmed. In addition, hamstring muscle lengths in standing were used as an approximation of hamstring muscle optimal lengths to estimate hamstring muscle strains in athletic tasks.[41–43] Obtaining hamstring muscle length in standing is easier than obtaining hamstring muscle optimal lengths. However, the relationships of hamstring muscle lengths in standing with their optimal lengths are still unknown.

The purpose of this study was to determine the relationships among hamstring muscle optimal length, flexibility, and strength, and the relationship between hamstring muscle optimal length and hamstring muscle length in standing. We hypothesized that hamstring muscle optimal length would be positively correlated to hamstring flexibility and strength. We also hypothesized that hamstring strength and flexibility would be significantly correlated. In addition, we hypothesized that hamstring muscle optimal length would be significantly different from but significantly correlated to hamstring muscle length in standing.

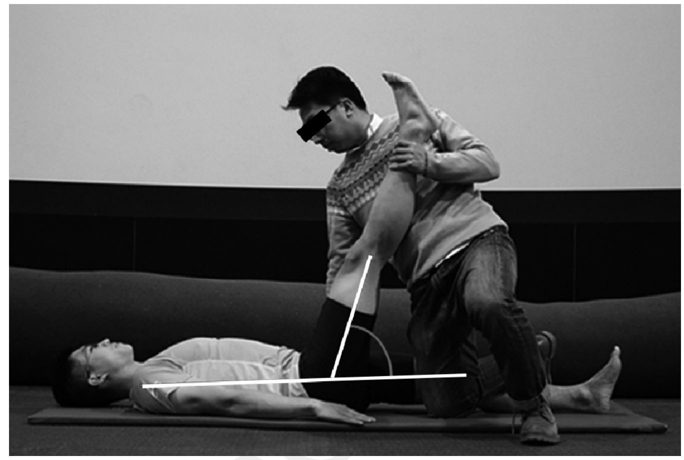

Fig. 1. Passive straight leg raise (PSLR) test and hip flexion angle.

2. Materials and methods

2.1. Participants

Twenty-one college students (11 males and 10 females) regularly participating in exercise and sport activities volunteered to participate in this study and all participants gave written consent. The means of ages, standing heights, and body masses were 24.7 ± 2.9 years, 174.0 ± 3.1 cm, and 65.6 ± 5.9 kg, respectively, for male participants, and 23.6 ± 0.9 years, 163.8 ± 3.8 cm, and 53.5 ± 4.4 kg, respectively, for female participants. All participants had no history of hamstring injury or other lower extremity injuries that prevented them from performing the tasks in this study. The use of human subjects was approved by the Institutional Review Board of Beijing Sport University.

2.2. Protocol

Each participant had a 5- to 10-min warmup including jogging and stretching, then underwent a passive straight leg raise (PSLR) test[44] (Fig. 1) to evaluate hamstring flexibility and an isokinetic strength test to determine hamstring muscle optimal length for each leg. Each participant had three PSLR trials for each leg. The body position in maximum hip flexion angle in each PSLR trial was recorded. In the hamstring isokinetic strength test, retroreflective markers were placed bilaterally at the anterior superior iliac spine (ASIS), the top of the crista iliaca, the greater trochanter, the lateral and medial femur condyles, the lateral and medial malleolus, the tibial tuberosity, and the center of the second and third metatarsals. An additional marker was placed on the L4-L5 interface. The participant performed a calibration trial in a standing position, then the marker on L4-L5 was removed. The participant was

Please cite this article in press as: Xianglin Wan, Feng Qu, William E. Garrett, Hui Liu, Bing Yu, Relationships among hamstring muscle optimal length and hamstring flexibility and strength, Journal of Sport and Health Science (2016), doi: 10.1016/j.jshs.2016.04.009