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Original article

The effect of hamstring flexibility on peak hamstring muscle strain in sprinting

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 Sports Medicine, Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC 27710, USA*
[c] *Center for Human Movement Science, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA*

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Abstract

Background: The effect of hamstring flexibility on the peak hamstring muscle strains in sprinting, until now, remained unknown, which limited our understanding of risk factors of hamstring muscle strain injury (hamstring injury). As a continuation of our previous study, this study was aimed to examine the relationship between hamstring flexibility and peak hamstring muscle strains in sprinting.
Methods: Ten male and 10 female college students participated in this study. Hamstring flexibility, isokinetic strength data, three-dimensional (3D) kinematic data in a hamstring isokinetic test, and kinematic data in a sprinting test were collected for each participant. The optimal hamstring muscle lengths and peak hamstring muscle strains in sprinting were determined for each participant.
Results: The muscle strain of each of the 3 biarticulated hamstring muscles reached a peak during the late swing phase. Peak hamstring muscle strains were negatively correlated to hamstring flexibility ($0.1179 \le R^2 \le 0.4519$, $p = 0.001$) but not to hip and knee joint positions at the time of peak hamstring muscle strains. Peak hamstring muscle strains were not different for different genders. Peak muscle strains of biceps long head (0.071 ± 0.059) and semitendinosus (0.070 ± 0.055) were significantly greater than that of semimembranosus (0.064 ± 0.054).
Conclusion: A potential for hamstring injury exists during the late swing phase of sprinting. Peak hamstring muscle strains in sprinting are negatively correlated to hamstring flexibility across individuals. The magnitude of peak muscle strains is different among hamstring muscles in sprinting, which may explain the different injury rate among hamstring muscles.

Keywords: Hamstring flexibility; Hamstring muscle strain injury; Injury risk factor; Muscle biomechanics; Muscle strain; Muscle strain injury

1. Introduction

Hamstring muscle strain injury (hamstring injury) is one of the most common injuries in sports involving sprinting.[1–3] The high injury and recurrence rates of hamstring injury result in significant time and financial loses and unfortunate consequences. Although tremendous efforts have been made to prevent hamstring injury[4,5] and improve the rehabilitation of the injury,[6] the injury and recurrence rates have remained unchanged in the past 3 decades.[7,8]

Identifying risk factors is critical for effective prevention of hamstring injury and improvement of rehabilitation outcomes of the injury. Although hamstring flexibility is one of the potential risk factors for hamstring injury many studies were focused on,[8] the results of epidemiologic studies of effects of hamstring flexibility on hamstring injury or re-injury rate were contradictory.[9–14] A recent systematic literature review with meta-analysis failed to show evidence to support flexibility as a risk factor.[15]

Many theoretical studies, however, have provided evidences that support hamstring flexibility as a risk factor for hamstring injury. Several animal studies demonstrated muscle strain as the direct cause of muscle strain injury.[16–21] Muscle strain is defined as the ratio of muscle length deformation to muscle resting length and can be approximated using muscle optimal length.[22,23] Alonso et al.[24] reported that the legs with less flexible hamstring muscles have greater optimal knee flexion angles at which isokinetic knee flexion moment was maximal, indicating that less flexible hamstring muscles have less hamstring optimal

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* Corresponding authors.
E-mail addresses: liuhuibupe@163.com (H. Liu); byu@med.unc.edu (B. Yu)

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muscle lengths. Our previous study found that hamstring muscle optimal lengths were positively correlated to hamstring flexibility.[25] These results combined together indicate that hamstring muscles with good flexibility may have lower muscle strains in a given movement such as sprinting and support flexibility as a risk factor for hamstring injury. However, the effect of hamstring flexibility on the peak hamstring muscle strains in sprinting, until this study, remained unknown.

As a continuation of our recent study that showed the relationship between hamstring muscle optimal lengths and hamstring flexibility, the purpose of this study was to examine the relationship of hamstring flexibility with actual peak hamstring muscle strains in sprinting. We hypothesized that peak hamstring muscle strains in sprinting would be negatively correlated to hamstring flexibility. We also hypothesized that peak hamstring muscle strains in sprinting would be positively correlated to hip and knee joint positions at the time of peak muscle strains, which reflects the comprehensive effects of hip flexion and knee extension on hamstring lengths. We further hypothesized that peak hamstring muscle strains in sprinting would be different for different genders. We finally hypothesized that peak hamstring muscle strains in sprinting would be different for different hamstring muscles. The results of this study should provide further theoretical evidence of the role hamstring flexibility plays in hamstring muscle strain injury and set a theoretical basis for future studies on the prevention and rehabilitation of hamstring as well as other muscle strain injuries.

2. Materials and methods

2.1. Participants

Twenty sports-majored college students (10 males and 10 females) with sprint training experience who regularly participate in exercise and sport and participated in our previous study[25] volunteered to participate in this study. The activities these subjects are involved in include basketball, soccer, and running. The means ± SD of ages, standing heights, and body masses of these participants were 24.6 ± 3.1 years, 173.9 ± 3.3 cm, and 65.9 ± 6.1 kg for male participants and 23.6 ± 0.9 years, 163.8 ± 3.8 cm, and 53.5 ± 4.4 kg for female participants, respectively. All participants had no history of hamstring injury or other lower extremity injuries before participating in this study that prevented them from performing the tasks in this study, and each provided written consent before data collection. The study was approved by the Institutional Review Board of Beijing Sport University.

2.2. Protocol

After sufficient warm-up, each participant underwent a passive straight leg raise (PSLR) test to determine hamstring flexibility bilaterally, a sprinting test to obtain lower extremity kinematic data of both legs in sprinting, and then an isokinetic strength test to determine hamstring muscle optimal lengths bilaterally. In the PSLR test, the participant had 3 trials for each leg as described in our previous study.[25] 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 with a straight knee to a hip flexion angle at which the tester clearly felt the resistance to further hip flexion or a pelvis posterior rotation. The body position with this maximum hip flexion was recorded for each leg.

In the sprinting test, retroreflective markers were placed at the L4-L5 interface and bilaterally at the anterior superior iliac spine; the top of the crista iliac, the lateral and medial femur condyles, the lateral and medial malleolus, the tibial tuberosity; and the center of the second and third metatarsals and the posterior calcaneus. The participant completed 3 acceptable sprinting trials for each leg with maximum effort with a 2 min rest between 2 consecutive trials. An acceptable trial was a trial in which trajectories of all markers were collected in a full running gait cycle. The distance from the starting line and near edge and the center of the motion capture area was 20 m and 25 m, respectively. All participants used a standing start technique to start sprinting.

After the sprinting test, the participant had a bilateral isokinetic strength test in which the markers were remained on the body landmarks and the marker on L4-L5 was removed. The participant was seated on the IsoMed2000 strength-testing system (D&R Ferstl GmbH, Hemau, Germany) with a hip flexion of 90°. The thigh and the lower leg of the testing leg were secured on the seat and the dynamometer arm, respectively, of the strength-testing machine. The participant had 3 isokinetic knee flexion trials at an angular speed of 10°/s with maximum effort for each leg. The detailed setup of the isokinetic strength test was described in our previous study.[25]

2.3. Data collection

The body position with maximum hip flexion angle in the PSLR test was recorded using a high definition digital camera (SONY HVR-V1C; Sony Corp., Tokyo, Japan) with its optical axis perpendicular to the sagittal plane of the participant's body. The trajectories of the reflective markers in the sprinting test were recorded using a Motion Analysis videographic acquisition system with 8 cameras (Raptor-4; Motion Analysis Inc., Santa Rosa, CA, USA) at a sample rate of 200 frames per second. The trajectories of the reflective markers in the isokinetic strength test were recorded using a videographic acquisition system (Oqus 400; Qualisys, Gothenburg, Sweden) with 10 video cameras at a sample rate of 100 frames per second. 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 per channel per second, and the videographic and dynamometer data collections were time synchronized by the Qualisys Track Manager computer program package (Version 2.9; Qualisys).

2.4. Data reduction

The maximal hip flexion angle in the PSLR test trail was reduced from the digitized digital photo of the maximal hip