THE POTENTIAL PHASE FOR HAMSTRING MUSCLE STRAIN INJURIES DURING OVERGROUND SPRINTING

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The purpose of this study was to examine the potential for hamstring injury during overground sprinting by investigating hamstring muscle strain. Twenty males and 20 females with sprint training experience participated this study. Isokinetic strength data, three-dimensional kinematic data in a hamstring isokinetic test, and kinematic and ground reaction forces data in a sprinting test were collected for each participant. The muscle strains and muscle elongation velocity of hamstring, lower extremity joint torques and power were determined. Hamstring muscle strains reach peaks during the late swing phase (89.2% - 90.6% gait cycle). The peak muscle strains of biceps long head and semitendinosus were greater than that of semimembranosus ($p = 0.002$ and $p = 0.029$). The potential for hamstring muscle strain injury may occur during late swing phase of overground sprinting. Biceps long head and semitendinosus may be at higher risk for muscle strain injury compared to semimembranosus.

KEYWORDS: Hamstring strain injury, muscle strain, risk factors.

INTRODUCTION: Hamstring muscle strain injury (hamstring injury) is one of the most common injuries in sports involving sprinting. The high injury and recurrence rates of hamstring injury result in significant time and financial loses and vicious consequences. Although tremendous efforts have been made to prevent hamstring injury and improve the rehabilitation of the injury, the injury and recurrence rates remain unchanged in the past three decades (Ramos et al. 2017).

To effectively prevent hamstring injury and improve the rehabilitation of the injury, understanding the mechanisms of the injury is critical. An understanding of the biomechanical conditions that cause the hamstrings to injury during sprinting is significant. Despite running activities accounted for more than 60% of hamstring injuries (Brooks et al. 2006), it remains debated whether the hamstrings are injured during the swing or stance phase of a sprinting gait cycle. Because of the neural delays between the occurrence of injury and the perception of injured, it’s different to identify the time of occurrence of a hamstring injury during sprinting upon athlete’s perception and video. Therefore, kinematic and kinetic analysis were the primary methods to investigate the biomechanical conditions that cause the hamstring injury during sprinting. Mann (1981) found that knee flexion and hip extension torques peaked in early stance during overground sprinting, and suggested that the potential for hamstring injury existed during the stance phase of running. Additionally, Sun et al. (2015) found greater knee flexion and hip extension torques occurred during late swing phase, and suggested that late swing phase was also a potential time for hamstring injury during sprinting. However, many studies using animal models demonstrated excessive muscle strain in eccentric contraction or stretching as the primary mechanism of muscle strain injury regardless of muscle force and strain rate (Yu et al. 2017). Thelen et al. (2005) found hamstring muscle contract eccentrically and reached peak length during the late swing phase of treadmill sprinting, and indicated that the potential for hamstring injury existed during the late swing phase. Yu et al. (2008) showed similar results in overground sprinting and suggested late stance phase and late swing phase were the potential phases. Nevertheless, above researches did not present muscle strain characteristics, and hamstring muscle length or muscle length normalized to muscle length in a given position cannot be used as an approximation of hamstring muscle strain (Wan et al. 2017).

The purpose of this study was to examine the potential for hamstring injury during overground sprinting by investigating hamstring muscle strain. We hypothesized that hamstring muscle strains reach peaks during the late swing phase. We also hypothesized that peak hamstring muscle strains in sprinting would be different for different hamstring muscles

METHODS: Forty sports-majored college students (20 males and 20 females) with sprint training experience regularly participating in exercise and sport volunteered to participate in this study. All participants had no history of hamstring injury or other lower extremity injuries that prevented them from performing the tasks in this study before participating in this study, and provided written consent before data collection. The study use of human subjects was approved by the Institutional Review Board of Beijing Sport University.

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 iliaca, the lateral and medial femur condyles, the lateral and medial malleolus, the tibial tuberosity, the center of the second and third metatarsals and the posterior calcaneus. The participant completed three acceptable sprinting trials for each leg with maximum effort with a 2-minute rest between two consecutive trials. The trajectories of the reflective markers in the sprinting test were recorded using a Motion Analysis videographic acquisition system with eight cameras at a sample rate of 200 frames per second. Ground reaction forces were collected with a force platform (Kistler 9281CA) at a sample rate of 1000 frames per second. A running gait cycle was defined as the time period between 2 two consecutive foot strikes of the same foot. Running speed was represented by the averaged horizontal velocity of the L4-L5 marker during a gait cycle. Maximal lengths of hamstring in sprinting were determined from the lower extremity kinematic data (Wan et al. 2017). Muscle elongation velocity was determined as the first time derivative of the muscle length. Joint torques were calculated from inverse dynamics methods. Joint power was determined by taking the product of the joint torque and the joint angular velocity.

After sprinting test, the participant had a bilateral isokinetic strength test, participants sit on the IsoMed 2000 strength testing system 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, 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 at a sample rate of 100 sample/channel/sec. The trajectories of the reflective markers in isokinetic strength test were recorded using a Qualisys videographic acquisition system with ten video cameras at a sample rate of 100 frames per second. Muscle optimal length of a hamstring muscle was identified as the muscle length corresponding to the calculated peak muscle force of the given hamstring muscle in the isokinetic strength test in which the participant generated the maximal peak hamstring force. Instantaneous force of each hamstring muscle was calculated from instantaneous moment generated by hamstring muscles, physiological cross-sectional areas, and moment arms of hamstring muscles. The detailed calculation of hamstring muscle force was described in detail in our previous study (Wan et al. 2017). The maximal strain of each hamstring muscle was determined as the ratio of maximal length in sprinting deformation to the optimal length of the hamstring.

Two-way ANOVA with mixed design were performed to determine the effects of muscle and gender on the magnitudes of peak muscle strains, with muscle treated as a repeated measure while gender as independent measure. Tukey's test was performed as post hoc analysis to locate significant differences when a main effect was significant. All data analyses were performed using SPSS Version16.0 (SPSS, Chicago, IL, USA). Statistical significance was defined as the probability of type I error rate lower than or equal to 0.05.

RESULTS: The mean running speeds were 8.16 ± 0.52 m/s and 6.78 ± 0.55 m/s for the male and female participants, respectively. The muscle strain–time curves of the three hamstring muscles reach peaks during the late swing phase (Fig. 1, Table 1). The muscle elongation velocity–time curves of the three hamstring muscles and lower extremity joint torque and power–time curves are shown in Figure 1.
The ANOVA showed no significant interaction effect of muscle and gender and no significant main effect of gender on peak muscle strain ($p = 0.507$, and $p = 0.387$), but a significant main effect of muscle on peak muscle strain ($p = 0.003$). Post hoc analyses revealed that the peak muscle strains of biceps long head and semitendinosus were greater than that of semimembranosus ($p = 0.002$ and $p = 0.029$) (Table 1). Peak muscle elongation velocities were greater than muscle elongation velocities at peak muscle strain for all three hamstring muscles ($p < 0.001$).

Table 1: Hamstring muscle kinematical parameters during sprinting.

	Peak muscle strain	Time of occurrence of peak muscle strain (% gait cycle)	Muscle elongation velocity at peak muscle strain (m/s)	Peak muscle elongation velocity (m/s)
Biceps Long Head	0.060 ± 0.053	90.6 ± 3.2	0.008 ± 0.054	1.310 ± 0.230
Semimembranosus	0.054 ± 0.049	91.2 ± 3.5	-0.002 ± 0.060	1.321 ± 0.296
Semitendinosus	0.058 ± 0.050	89.2 ± 3.6	-0.007 ± 0.046	1.340 ± 0.258

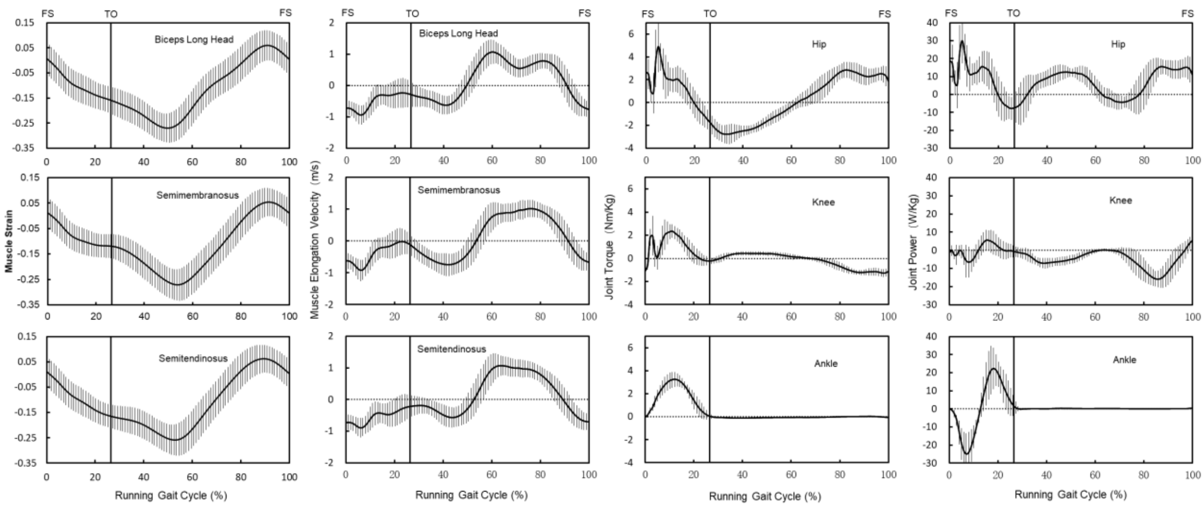

Figure 1: Hamstring muscle strain, muscle elongation velocity, joint torque and power of lower extremity during a running cycle (FS = foot strike, TO = toe off).

DISCUSSION: Potential for hamstring muscle strain injury exists during the late swing phase of sprinting. The results of this study showed that 3 hamstring muscles had peak muscle strains during the late swing phase. These results are consistent with previous studies that demonstrated that hamstring muscle lengths peaked during the late swing phase of treadmill sprinting (Thelen et al. 2005) and over-ground sprinting (Yu et al. 2008, Wood 1987). As previously studies showed, the direct cause of muscle strain injury is muscle strain during muscle eccentric contraction (Yu et al. 2017). The results of this study and previous studies therefore indicate that risk for hamstring muscle injury in sprinting exists during late swing phase. However, previous studies (Yu et al. 2008, Wood 1987) also indicated a potential for hamstring injury during the late stance phase because hamstring lengths also peaked during the late stance phase. A careful examination of the setups for experiments in current study and the study by Yu et al. leads to a belief that the participants in the study by Yu et al. might have been still accelerating as the distance between the starting line and the motion capture area was only 10 m. A study showed the anterior tilt angle of the pelvis and the hip flexion angle are increased when accelerating with trunk in a forward lean in comparison to sprinting with a consistent speed with trunk in an upright position (Higashihara et al. 2015). This would result in an increased hamstring muscle length deformation during the late stance phase.

The results of this study do not support that stance phase is a potential for hamstring injuries during overground sprinting. As the studies by Mann (1981) and Sun et al. (2015) showed, this study also found the knee flexion and hip extension torques peaked in early stance. While the negative hamstring muscle elongation velocity and positive joint power (Fig. 1) indicate that hamstring muscles were in concentric contraction during stance phase. Although the peak knee flexion moment during the early stance phase suggested a greater hamstring muscle force, hamstring muscles do not seem to be in a danger of strain injury because the hamstring muscles were not in eccentric contraction during this phase as the current study and literature showed.

The results of this study support our second hypothesis that injury risk in sprinting would be different for different hamstring muscles. The results of this study showed that the peak muscle strains of biceps long head and semitendinosus were greater than that of semimembranosus in sprinting. These results indicate that biceps long head and semitendinosus may be at higher risk for muscle strain injury compared to semimembranosus in sprinting, which is consistent with the results of epidemiological studies. Epidemiologic studies demonstrated that biceps long head was the most frequently injured muscle among the hamstring muscles, and some studies also showed that the injury rate of semitendinosus was higher than that of semimembranosus (De Smet and Best 2000).

CONCLUSION: Hamstring muscle strains reach peaks during the late swing phase, which indicate that the potential for hamstring muscle strain injury may occur during late swing phase of overground sprinting. The magnitudes of peak muscle strains are different among hamstring muscles in sprinting, which may explain biceps long head and semitendinosus are at higher risk for muscle strain injury compared to semimembranosus.

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