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# Differences in activation properties of the hamstring muscles during overground sprinting

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ABSTRACT

The purpose of this study was to quantify activation of the biceps femoris (BF) and medial hamstring (MH) during overground sprinting. Lower-extremity kinematics and electromyography (EMG) of the BF and MH were recorded in 13 male sprinters performing overground sprinting at maximum effort. Mean EMG activity was calculated in the early stance, late stance, mid-swing, and late-swing phases. Activation of the BF was significantly greater during the early stance phase than the late stance phase ($p < 0.01$). Activation of the BF muscle was significantly lower during the first half of the mid-swing phase than the other phases ($p < 0.05$). The MH had significantly greater EMG activation relative to its recorded maximum values compared to that for the BF during the late stance ($p < 0.05$) and mid-swing ($p < 0.01$) phases. These results indicate that the BF shows high activation before and after foot contact, while the MH shows high activation during the late stance and mid-swing phases. We concluded that the activation properties of the BF and MH muscles differ within the sprinting gait cycle.

## 1. Introduction

The hamstring muscle group comprises the biceps femoris (BF), semimembranosus (SM), and semitendinosus (ST) muscles. Several investigators have described their morphological differences, including variations in weight, pennation angle, volume, physiological cross-sectional area, and fibre length [1–3]. Studies have reported that the electromyographic (EMG) activity of each hamstring muscle varies with knee flexion and hip extension, and have suggested that activation differences exist among these muscles due to their morphological and architectural differences [4–7].

The ST muscle is a parallel fibred muscle with long fibre lengths that demonstrates an eminent potential to contract over long distances, such that this muscle produces knee flexion torque at deeper angles compared to the BF and SM muscles [4]. In addition, the ST muscle is selectively recruited during the intensive eccentric knee flexion exercise because of its morphological property of effectively handling strain during lengthening contraction [5,6]. On the other hand, the BF and SM muscles are unipennate muscles that are characterised by their short fibre lengths and pennation angles, which have large cross-sectional areas and are more suitable than fusiform muscles for torque production [3,8,9]. Another study also reported that because of their morphological and architectural properties, the BF and SM muscles are selectively recruited to manage hip extension exercise, as these movements demand a high muscle torque [7]. On the basis of these observations, it is conceivable that activation differences in the hamstring muscles might also exist during dynamic movements such as sprinting.

Many studies of EMG activation in the hamstring muscles have reported amplitude changes that occur during a stride cycle [10–12], onset and offset times [13,14], and mean relative EMG activities for each of the divided phases [14,15]. However, no study has compared EMG activation characteristics in the lateral and medial hamstring (MH) muscles by analysing it along with the changes in the knee and hip joints during a sprinting gait cycle.

One study examined the EMG activation of the BF and ST muscles during treadmill sprinting at different speeds and found different characteristics of EMG activation between these two muscles within the gait cycle at near-maximum sprinting speed [16]. However, treadmill sprinting differs from overground

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sprinting both biomechanically [17–19] and metabolically [17]: e.g. the moving treadmill belt reduces the runner's energy requirements by bringing the supporting leg back under the body during the support phase of running [17]. In addition, a previous study showed differences of the BF muscle activity between overground and treadmill running during the ground contact phase [19]. Considering these observations, characteristics involved in the neural activation of the hamstring muscles likely for differ overground and treadmill sprinting, especially during the stance phase, primarily because of the moving treadmill belt. Furthermore, overground sprinting is more ecologically appropriate than treadmill sprinting because athletes compete and train overground for the most part.

Therefore, further investigations with overground sprinting are required to provide a better understanding of the functional characteristics of the biarticular hamstring muscles. Thus, the purpose of this study was to clarify the activation patterns of the lateral and MH muscles during overground sprinting and provide scientific data to estimate the functional characteristics of the different hamstring muscles.

## 2. Methods

### 2.1. Subjects

Thirteen healthy, young male track and field athletes (100-, 200-, and 400-m sprints and 400-m hurdles) participated in this study (age, 20.2 ± 0.6 years; height, 173.5 ± 5.0 cm; weight, 64.9 ± 5.8 kg). This study was approved by the Human Research Ethics Committee and was consistent with their requirements for human experimentation. This study conforms to the Declaration of Helsinki. Written informed consent was obtained after each participant read the information sheet for volunteers and questions related to the study were answered to their satisfaction.

### 2.2. Data collection

The measurement area was set on a straight 100-m section of an athletics track. Three-dimensional kinematic data of 34 reflective markers were recorded at 200 Hz using a 12-camera passive marker system (MAC3D system, Motion Analysis Corporation, Santa Rosa, CA, USA). Reflective markers were placed on both the upper and lower extremities of each subject using a modified Helen-Hayes marker set [20] for a total of 29 anatomical landmarks.

The surface EMG of the BF muscle and MH muscles on the right leg were recorded using a portable EMG system (MQ16, KISSEI COMTEC Co. Ltd., Japan). Bipolar surface Ag/AgCl electrodes were placed over the muscle belly of the selected muscle with an interelectrode distance of 20 mm. For the BF muscle, surface electrodes were positioned on the midpoint of a line connecting the ischial tuberosity and the lateral epicondyle of the tibia. For the MH muscles, surface electrodes were positioned at the midpoint of a line connecting the ischial tuberosity and medial epicondyle of the tibia. Additionally, the positions of the surface electrodes were determined by palpation of each muscle belly during isometric contraction. A reference electrode was placed on the fibular head. The sampling frequency was 2 kHz. The area of each electrode site was shaved using a disposable razor and cleaned with rubbing alcohol-soaked cotton wool. In addition, electrode cables were fixed with an elastic tape. This fixing of electrode cables minimised motion artefacts. All recorded analogue data were stored on a personal computer using a 16-bit A/D converter data acquisition system (Power Lab.; AD Instruments Co. Ltd., Japan). The EMG data were synchronised with the kinematics data.

After sufficient warm-up, each participant performed a maximal-effort sprint from the starting line set approximately 40 m from the centre of the measurement area with attached passive markers and electrodes.

### 2.3. Data analysis

Each trial consisted of a sprinting gait cycle of the right leg. A stride was defined as the time from ground contact of the right foot to the next ground contact of the same foot. The sprinting velocity was calculated by computing the horizontal speed of the centre of mass during a sprinting gait cycle. The hip and knee flexion angles in the sprinting gait cycle were calculated (nMotion musculous; NAC Image Technology, Inc., Japan). To adequately describe the relationship between the joint angles and the EMG data, the sprinting motion was divided into seven phases according to the hip and knee movement of the right leg (Fig. 1a): the early stance phase, beginning at foot strike and ending at maximum knee flexion during stance; late stance phase, beginning at maximum knee flexion during stance and ending at toe-off; the early-swing phase, beginning at toe-off and ending at maximum knee flexion during swing; the mid-swing phase, beginning at maximum knee flexion during swing and ending at maximum hip flexion; and the late-swing phase, beginning at maximum hip flexion and ending at foot strike. Furthermore, the mid-swing and late-swing phases were divided into first and latter halves.

A computer software programme (Kine Analyzer; KISSEI COMTEC, Co Ltd, Japan) was used for the EMG analysis. EM Mean normalised EMG activity was calculated in the early stance, late stance, and the first and latter halves of the mid-swing and late-swing phases.

### 2.4. Statistical analysis

The EMG activities during each phase were determined using repeated-measures analysis of variance (ANOVA) (muscle × phase). Bonferroni's post hoc analysis was conducted if the ANOVA showed statistically significant main or interaction effects. Statistical significance was set at $p < 0.05$.

## 3. Results

Mean sprinting velocity was 9.52 ± 0.23 m/s. Mean hip and knee flexion angles and the normalised EMG signals during a sprinting gait cycle are shown in Fig. 1.

Mean relative EMG activities during each phase are shown in Fig. 2. Two-way ANOVA indicated statistically significant interaction effects (muscle × phase; $p < 0.001$). Activation of the BF muscle was significantly greater during the early stance phase than the late stance phase ($p < 0.01$). Activation of the BF muscle was significantly lower during the first half of the mid-swing phase than the early stance phase ($p < 0.001$), the late stance phase ($p < 0.05$), the first half of the mid-swing phase ($p < 0.01$), and the first and latter halves of the late-swing phase ($p < 0.001$). Activation of the MH muscles during the latter half of the mid-swing phase tended to have a greater value than that during the latter half of the late-swing phase ($p = 0.063$). The MH muscles had a significantly smaller relative reduction from its recorded maximum value compared to the reduction observed for the BF muscle during the late stance phase ($p < 0.05$), the first half of the mid-swing phase ($p < 0.01$), and the latter half of the mid-swing phase ($p < 0.01$).

## 4. Discussion

The purpose of this study was to demonstrate the activation of the lateral and MH muscles during overground sprinting and provide scientific data to clarify the functional characteristics of