INTRODUCTION
Coaches and sprinters generally aim to reduce deceleration during the foot contact phase in order to obtain a higher sprint running velocity. The purpose of the present study was to investigate whether this effort is reasonable, and whether deceleration does play a specific role during sprint running.

METHODS
The subjects were seven female and twenty-one male well trained sprinters. They sprinted at their maximal velocity, and the ground reaction forces were recorded. At the same time, they were video-taped (100 fps) in side view. Three of the sprinters (one female and two male) began from a crouching start and the same measurements were executed at the 1st, 3rd, 5th, 9th, 13th and 19th steps. Here the 1st step indicates the phase from the release of the front foot from the starting block to the release of the next foot contact (similar in the other steps). The horizontal deceleration and acceleration of the body’s center of mass were calculated from the horizontal ground reaction force. The transverse component of whole-body angular momentum around the body’s center of mass was computed from the video analysis, and the angular momentum was divided by the moment of inertia of the whole body (normalized angular momentum; radian/s). Furthermore, the transverse component of rotational force generated from the horizontal and vertical ground reaction forces was computed.

RESULTS AND DISCUSSION
1) Deceleration and acceleration of the body’s center of mass
Deceleration increased and acceleration decreased according with each successive step after the start (Figure 1-left), until finally both parameters attained the same value at the maximal sprint velocity (about 0.3 m/s; Figure 1-right). The velocity change of 0.3 m/s was common among all the subjects, despite the wide range of maximal sprint velocity (7.6 – 10.2 m/s). These results suggest that it is not productive to reduce deceleration in order to obtain a higher maximal sprint running velocity. On the other hand, the ability to apply a faster backward force to the ground relative to the body’s center of mass determines the maximal sprint running velocity.

Fig.1 Acceleration and deceleration during the foot contact phase at each step after the start dash and at maximal velocity
2) Normalized angular momentum around the transverse axis (H/ML^2)

The backward H/ML^2 observed during the 1st step decreased and the forward H/ML^2 appeared at the 3rd step (Figure 2). The backward H/ML^2 during the 1st step worked to raise the body from a crouching position to an upright position. On the other hand, the forward H/ML^2 observed during the 19th step (maximal sprint running velocity) cancelled out the backward H/ML^2 developed from the strong movement of the limbs.

Normalized Angular Momentum (rad/s)

![Normalized Angular Momentum Graph](image)

Fig.2 Normalized angular momentum at each step after the start dash.

3) Rotational force and rotational velocity around the transverse axis developed from the ground reaction force

In Figure 3, changes in the rotational force (upper) and rotational velocity (lower) are shown. During the 1st step, although the horizontal acceleration force generated the backward rotational force, the vertical force conversely generated the forward rotational force. As a result, the backward rotational velocity remained at the moment of foot release. The rotational velocity worked to raise the body from a crouching to an upright position. During the 19th step, although the deceleration and vertical force generated the forward and backward rotational force, respectively, during the first half of the foot contact phase, the acceleration force and vertical force generated the backward and forward rotational force, respectively during the latter half of the foot contact phase. As a result, all rotational components were cancelled out, and no rotational velocity remained at the moment of foot release.

4) Attempt to reduce deceleration force

If a sprinter’s feet touch down under the body’s center of mass to reduce deceleration, almost no rotational force is generated because the first half of the foot-contact phase become extremely short. However, during the latter half of the foot-contact phase, the vertical ground reaction force generates a forward rotational force about twice as large as that during normal sprint running, since the vertical force has to generate a vertical displacement similar to that during normal sprint running. Moreover, the
backward rotational force required to cancel the forward rotational force cannot be generated during the same phase, since the sprinter cannot apply a backward acceleration force to the ground faster than that during normal sprint running because the muscle behaves according to the Force-Velocity relationship. As a result, the sprinter rotates forward and falls down. In conclusion, human bipedal sprinters require a deceleration of about 0.3 m/s at the maximal sprint running velocity.

**Rotational force (Nm)**

<table>
<thead>
<tr>
<th>1st</th>
<th>3rd</th>
<th>9th</th>
<th>Full stride</th>
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**Rotational velocity (rad/s)**

**Time (s)**

**Fig.3** Rotational force (upper) and rotational velocity (lower) developed from the horizontal (Hor.), vertical (Ver.) and resultant (Res.) ground reaction forces at each step after the start dash.