The present study aimed to clarify kinematics among sprinters with similar step length but different step frequencies, and with similar step frequencies but different step lengths in sprinting. We collected kinematic data from 54 sprinters at approximately the 60 m point of a 100-m sprint using a high-speed camera. The sprinters within 0.5SD from the mean value of each of step frequency and length at top speed phase were included in the ‘SL-similar’ (n = 22, step frequency: 3.99-5.19 Hz, step length: 2.07-2.15 m) and the ‘SF-similar’ (n = 22, step frequency: 4.51-4.72 Hz, step length: 1.93-2.33 m) groups, respectively. In the SL-similar group, higher step frequency was correlated with shorter stance time (r = -0.899), and a more vertical thigh angle at take-off (r = 0.623). In the SF-similar group, longer step length was correlated with greater distance of the hip during flight phase (r = 0.847), and a larger vertical acceleration of the forward swinging leg relative to the hip (r = 0.438). In conclusion, leg kinematics at touchdown and take-off are important for high step frequency in similar step length, and forward swinging leg kinematics are important for long step length in similar step frequency.

**Keywords:** Sprint running velocity; Stance leg; Swing leg; 100 m race; Relative acceleration

1. Introduction

The track and field 100-m sprint can be divided into the acceleration, top speed, and deceleration phases (Delecluse et al., 1995; Mackala, 2007; Schiffer, 2009). In the top speed phase, the maximum sprint speed is produced, and Mackala (2007) have reported that this speed has a strong correlation with race times. Many previous studies have been reported kinematic characteristics of sprinters with high sprint speeds (Ae et al., 1992a; Ito et al., 1998; Kunz and Kaufmann, 1981; Mann and Herman, 1985; Novacheck, 1998). These kinematic researches are likely to be understood by sprinters and coaches, and be helpful for improving sprint performance in practical situation.

Sprinting speed is the product of step frequency and step length. Therefore, in order to increase sprinting speed, it is necessary to increase at least one of the two. Some previous studies (Mann and Herman, 1985; Ae et al., 1992a, Morin et al., 2012) showed that the higher the sprinting speed, the higher the step frequency. In contrast, in other previous studies (Gajer et al., 1999; Hunter et al., 2004), it was suggested that step length has a stronger association with the sprinting speed among sprinters at various speed levels. In addition, Salo et al. (2011) suggested that the degree of reliance of race time on step frequency or step length was different among sprinters. These reports do not lead to a definite conclusion on whether step frequency or step length is more important in high sprinting speed, or the relative importance of step frequency or step length for sprinting speed vary among sprinters. The factors associated with step frequency and step length should be understood in order to improve running speed at top speed phase. However,
sprinters should take note of the negative interaction between step frequency and step length (Hunter et al., 2004). That is, the factors which contribute to improving step frequency are likely to decrease step length, and vice versa. To improve sprinting speed, sprinters must improve one of step frequency or step length whilst maintaining the other. Therefore, it would be required to reveal characteristics of sprinters who have different step frequency but similar step length, and vice versa. Step frequency is composed of stance and flight time (Hay, 1993), and previous studies reported that short stance time was associated with small angle between both thighs, small horizontal distance between toe and centre of gravity at touchdown. (Kunz and Kaufmann, 1981) and less extension angle of hip joint at take-off (Mann and Herman, 1985). In contrast, it has been reported that step length was associated with vertical factors such as vertical ground reaction force (Weyand et al., 2000), and vertical jumping performance (Kale et al., 2009). However, in these reports, interaction between the step frequency and the step length did not considered. Knowledge from interindividual comparison may be able to be applied to the intraindividual increase of sprint speed. There is a possibility that we could get useful knowledge from characteristics of sprinters with high step frequency and with large step length.

Based on the above, the aim of the present study was to reveal kinematic characteristics of sprinters with high step frequency among similar step length sprinters, and sprinters with long step length among similar step frequency sprinters in the top speed phase of a 100-m sprint. We hypothesized that step frequency is associated with leg angle at touchdown and take-off, and step length is associated with vertical movement of the forward swing leg in the present study.

2. Methods

2.1. Participants

Fifty-four adolescent and adult men who had participated in a 100-m sprint at officially approved competitions were included as participants. The mean ± standard deviation (SD) of official record was 11.71 ± 0.48 s (range: 10.80-12.76 s). Their age, height and body mass were unidentified. According to Otsuka et al. (2016), sprinters achieve higher sprinting speed during a race than during speed training. Moreover, it is possible to collect a wider range of sprinters’ data at a competition. Therefore, performances in competition were analysed. Video data of participants during 100-m race were obtained after the purpose of the study, the research methods and the method of handling data were explained in writing to the organisers of the competitions.

2.2. Data collection

Fixed photography (sampling rate: 300 Hz, shutter speed: 1/2000 s) was conducted using a high speed camera (EX-F1: Casio, Tokyo, Japan) to obtain the kinematics data. According to Ae et al. (1992a) and Gajer et al. (1999), many sprinters reach their maximum speed in 50-60 m. Therefore, the camera was located 20 m to the right side of the 60 m point of the track such that the optical axis was perpendicular to the plane of movement. The camera was angled to capture the 55.5-64.0 m section of all lanes. The images in order to calibrate coordinates at each lane were obtained before races: a pole 2.0 metres long was stood at the 55.5, 60.0, and 64.0 m points in the centre of the lane, and was photographed by the camera.

2.3. Measurement and data treatment

The moments that a foot touches and leaves the ground were defined as touchdown and take-off, respectively. The duration from the touchdown of a foot to the next touchdown of the opposite foot was defined as ‘1 step’. Our analysis period consisted of two steps from the right foot touchdown. In addition, ‘stance phase’ was the period when either the left or right foot was in contact with the ground, and ‘flight phase’ was the period when neither foot was in contact with the ground. The position of the right greater trochanter, knee joint, lateral malleolus, heel, and toe during the analysis period and 20 frames before and after the analysis period were digitised by using the Frame DIAS V system (DKH Co., Tokyo, Japan). The running direction and upward vertical direction were defined as the X-axis and Y-axis, respectively. The actual coordinates of each sprinter were calculated using a two-dimensional direct linear transformation (2D-DLT) on the X-Y plane of each lane (e.g., when we analyse a
sprinter in 1 lane, the calibration data for that lane was used). Calibrated errors of X in each lane (from lanes 1 to 8) were 0.006, 0.008, 0.004, 0.009, 0.000, 0.001, 0.004 and 0.005 m, respectively. Those of Y were 0.007, 0.005, 0.006, 0.008, 0.009, 0.009, 0.009 and 0.006 m, respectively. The coordinate data were smoothed at a cut-off frequency of 7 Hz (Ito et al., 2008) using a fourth order Butterworth low-pass filter.

From the obtained data, step frequency, step length, sprint speed, stance time, flight time, stance hip distance, flight hip distance, and kinematic variables of the right leg were calculated. Except for right leg kinematics, we calculated these parameters for each step, and average values of 2 consecutive steps were calculated as representative values of each sprinter for analysis. We defined step frequency as the reciprocal of the time required for a 1-step. Because video data were at 300 Hz, 1/300 s errors of time were possible at start and end of each step. The errors at the end of the first step and at the start of the second step cancelled each other out. Thus, the required timing error of the 2-steps was within 2/300 s. When this error was considered, the error range of step frequency was approximately 0.05-0.08 Hz (e.g. 120 frames of 2 steps is transformed to 5.00 Hz whereas 122 frames of 2 steps is transformed to 4.92 Hz). The step length was the horizontal distance from the toes of the foot touching the ground to the toes of the next foot touching the ground. Sprint speed was defined as the product of step frequency and step length. Stance and flight times were defined as the periods of stance and flight phases, respectively. Stance hip and flight hip distances were defined as the horizontal distance travelled by the greater trochanter during the stance and flight phases, respectively. These distances are different from stance and flight distances using centre of mass (Hay, 1993). However, the difference between the centre of mass and the great trochanter was expected to be small (Nagahara et al., 2014). Moreover, step length had a strong positive correlation with sum of the stance and flight hip distances \( r = 0.983, \ y = 0.975x + 0.053, \ x: \text{sum of the stance and flight hip distances, } y: \text{step length, mean of absolute residual } = 0.02 \text{ m}. \) Therefore, the movement distances of the hip were analysed as a spatial factor related to step length. As for the kinematics of the right leg, we calculated the angles and the angular velocities of the thigh, shank, knee joint, and ankle joint at the touchdown of right foot (right touchdown), take-off of right foot (right take-off), and the touchdown of left foot (left touchdown), respectively. Thigh and shank angles were defined as the angle formed by each segment and the vertical line, to which a positive value was assigned when the distal end of the segment was positioned in front of the proximal end (Fig. 1). Moreover, the leg length of each sprinter was defined as sum of the right thigh and shank length, which were calculated using coordinate data of the greater trochanter, knee and ankle.

In order to clarify kinematics of the swing leg in detail, the acceleration of the centre of mass of the right leg relative to the greater trochanter was calculated, and we investigated the relationship between the acceleration at left touchdown and step frequency, step length. To calculate the position of the centre of mass of leg, we used body segment parameters for Japanese athletes, as provided in Ae et al. (1992b).

The frames corresponding to touchdown and take-off were visually identified 2 times at different day. The maximum difference between 2 identification at the same event was 2 frame. All variables were calculated based on both of 2 identification. Then, its average values were used for analysis. The intraclass correlation coefficient for step frequency and step length were 0.990 and 0.986, respectively (95% confidence interval: 0.981-0.994, 0.974-0.993).

### 2.4. Grouping method and its relevance

Fig. 2 shows the grouping for the analysis based on step frequency and length. Sprinters whose step lengths were within ±0.5 SD from the mean value were extracted for the analysis. These sprinters were labelled ‘SL-similar group’. The range of the step length in the SL-similar group was 2.07-2.15 m.
Similarly, sprinters whose step frequencies were within ±0.5SD from the mean value were labelled ‘SF-similar group’. The range of the step frequency in the SF-similar group was 4.51-4.72 Hz. The number of sprinters in each group was 22.

The range of ±0.5SD was chosen because non-significant correlation between step frequency and step length within both group was found (Table 1). Moreover, if step lengths are similar, difference of speed among sprinters depend on only difference of step frequencies. Similarly, if step frequencies are similar, difference of speed among sprinters depend on only difference of step lengths. It was confirmed that these requirements were met in both of the SL-similar and SF-similar group (Table 1). By contrast, if range of ±0.75SD was chosen, there was significant negative correlation between step frequency and step length in SF-similar group. This relationship means that there was a measureable spread of step frequency as well as step length. In addition, correlation coefficient between step length and sprint speed decreased to 0.887 (in the case of ±0.5SD was 0.957). That case was not suitable to investigate the relationship between step length and kinematic factors excluding the effect of step frequency. From the above, it was assumed that these groups based on ±0.5SD were suitable as the analysis subject to reveal factors relevant to step frequency and step length considering the negative interaction.

2.5. Statistics

Relationships between step frequency and kinematics in the SL-similar group and relationships between step length and kinematics in the SF-similar group were assessed. For this purpose, Pearson product-moment correlation coefficients were calculated. However, it was possible that sprinters’ body height influenced their step frequencies and step lengths (Paruzel-Dyja et al., 2006). Therefore, when the leg length had significant correlation with step frequency or step length within each group, partial correlation coefficient analysis to control the leg length was conducted. The significance level was set at $p < 0.05$.

3. Results

3.1. The relationship among spatiotemporal parameters

In the SL-similar group, there were significant negative correlations between step frequency and stance time (Fig. 3 a: $r = -0.899, p < 0.001$), flight time (Fig. 3 a: $r = -0.669, p < 0.01$), and stance hip distance (Fig. 3 c: $r = -0.693, p < 0.001$), and no significant correlation between stance hip and flight hip distance (Fig. 3 c: $r = 0.358, p = 0.102$). In the SF-similar group, step length had a non-significant correlation with stance time (Fig. 3 b: $r = -0.406, p = 0.061$), whereas step length had a positive correlation with flight time (Fig. 3 b: $r = 0.465, p < 0.05$) and flight hip distance (Fig. 3 d: $r = 0.847, p < 0.001$). No significant correlation was observed between step length and stance hip distance (Fig. 3 d: $r = 0.323, p = 0.142$).

3.2. The relationship between step frequency or length and leg kinematics

In the SL-similar group, there was no significant correlation between step frequency and leg length ($r = -0.099, p = 0.661$).
Table 2 shows the average value (±SD) of each kinematics variable for right touchdown, right take-off, and left touchdown and their correlation coefficients with step frequency in the SL-similar group and with step length in the SF-similar group. In the SL-similar group, at the right touchdown, step frequency had significant negative correlations with angular velocities of the thigh ($r = -0.626, p < 0.01$) and shank ($r = -0.701, p < 0.001$). At the right take-off, step frequency had significant positive and negative correlations with the thigh ($r = 0.623, p < 0.01$) and the knee angles ($r = -0.638, p < 0.01$), respectively. At the left touchdown, step frequency had significant positive correlations with the angles of the thigh ($r = 0.576, p < 0.01$) and shank ($r = 0.461, p < 0.05$), and angular velocities of the thigh ($r = 0.524, p < 0.05$).

In the SF-similar group, leg length had a significant positive correlation with step length. Therefore, partial correlation coefficients controlling leg length were calculated.

At right touchdown, there were significant negative correlations between step length and angular velocities of the shank ($r = -0.603, p < 0.01$) and the knee ($r = -0.517, p < 0.05$). At right take-off, there were significant negative correlation between step length and shank angle ($r = -0.452, p < 0.05$), shank angular velocity ($r = -0.463, p < 0.05$) and ankle angular velocity ($r = -0.467, p < 0.05$). At left touchdown, step length had a significant negative correlation with the knee joint angle ($r = -0.500, p < 0.01$).

The acceleration of the centre of mass of the right leg relative to the hip at left touchdown was investigated (Table 3). In the SL-similar group, there were no significant correlation between step frequency and both horizontal and vertical acceleration (horizontal: $r = -0.181, p = 0.421$; vertical: $r = 0.101, p = 0.655$). In the SF-similar group, horizontal acceleration was not associated with step length ($r = -0.043, p = 0.853$). In contrast, there was a significant positive correlation between the
At right touchdown and right take-off, right leg is stance leg. At left touchdown, right leg is forward swing leg. The short stance and flight time, the high angular velocity of the backward swing leg relative to the body. In fact, previous studies indicated that if sprint speed is similar among different trials, high step frequency is caused by not short stance time but short flight time at top speed phase. In contrast, in the SL-similar group, the high step frequency was associated with the short stance and flight time, the high angular velocity of the backward swing leg relative to the greater trochanter. Each characteristics of the high step frequency sprinters in the SL-similar group and long step length sprinters in the SF-similar group are discussed in the below.

### 4.1. Characteristics of high step frequency sprinters in the SL-similar group

Step frequency is composed of stance time and flight time (Hay, 1993). That is, when step frequency is high, at least one of stance time or flight time is short. Toyoshima et al. (2015) indicated that if sprint speed is similar among different trials, high step frequency is caused by not short stance time but short flight time at top speed phase. In contrast, in the SL-similar group, the high step frequency was associated with the short stance time as well as the short flight time. The relationship between the step frequency and the stance time seems to be caused by the difference of sprint speed among sprinters. Running at high speed is likely to induce a short stance time because the grounding point moves backward rapidly relative to the body. In fact, previous studies

<table>
<thead>
<tr>
<th>Table 2: Average and standard deviation values of each kinematic variables of right leg, and the correlation coefficients between the SL-similar group and between the SF-similar group.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step frequency [Hz] in the SL-similar group</strong></td>
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<tr>
<td><strong>Right touchdown</strong></td>
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<td><strong>(Partial correlation analysis)</strong></td>
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<td><strong>Step frequency [Hz] in the SL-similar group</strong></td>
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<td><strong>Right touchdown</strong></td>
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<td><strong>Step length [m] in the SF-similar group</strong></td>
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<tr>
<td><strong>Step length [m] in the SL-similar group</strong></td>
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<tr>
<td><strong>Thigh angle</strong></td>
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<tr>
<td><strong>Right touchdown</strong></td>
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<tr>
<td><strong>Step length [m] in the SF-similar group</strong></td>
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<tr>
<td><strong>Step length [m] in the SL-similar group</strong></td>
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</tbody>
</table>

* ***p < 0.001, **p < 0.01, *p < 0.05. Mean (SD) and Pearson’s correlation coefficients (partial correlation coefficients in the SF-similar group) are shown in the upper and lower rows, respectively. Units of angles and angular velocities are degree and degree/s, respectively. At right touchdown and right take-off, right leg is stance leg. At left touchdown, right leg is forward swing leg.*

**Table 3: Average and standard deviation values of relative acceleration of right leg at left touchdown, and the correlation coefficients between the SL-similar group and between the SF-similar group.**

<table>
<thead>
<tr>
<th><strong>Horizontal</strong></th>
<th><strong>Vertical</strong></th>
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<tbody>
<tr>
<td><strong>Step frequency [Hz]</strong></td>
<td><strong>Step length [m]</strong></td>
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<tr>
<td><strong>in the SL-similar group</strong></td>
<td><strong>in the SF-similar group</strong></td>
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<tr>
<td><strong>mean (SD)</strong></td>
<td><strong>mean (SD)</strong></td>
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<tr>
<td><strong>14.4 (7.3)</strong></td>
<td><strong>10.9 (12.8)</strong></td>
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<tr>
<td><strong>2.6 (12.2)</strong></td>
<td><strong>4.4 (13.2)</strong></td>
</tr>
<tr>
<td><strong>r</strong></td>
<td><strong>r</strong></td>
</tr>
<tr>
<td><strong>−0.181</strong></td>
<td><strong>−0.043</strong></td>
</tr>
<tr>
<td><strong>0.101</strong></td>
<td><strong>0.438</strong>*</td>
</tr>
</tbody>
</table>

* ***p < 0.001, **p < 0.01, *p < 0.05. Mean (SD) and Pearson’s correlation coefficients (partial correlation coefficients in the SF-similar group) are shown in the upper and lower rows, respectively. Unit of the acceleration is m/s².**

step length and the vertical acceleration (*r* = 0.438, *p < 0.05).

### 4. Discussion

The aim of the present study was to reveal kinematic characteristics of sprinters with high step frequency among similar step length sprinters, and sprinters with long step length among similar step frequency sprinters in the top speed phase of a 100-m sprint. As a main results, in the SL-similar group, the high step frequency was associated with the short stance and flight time, the high angular velocity of the backward swing leg relative to the body. In fact, previous studies
indicated that high sprint speed is associated with short stance time during top speed phase (Fukuda and Ito, 2004; Kunz and Kaufmann, 1981; Morin et al., 2012). The high step frequency meant the high running speed in the SL-similar group. That is, it is suggested that if step lengths are similar among different sprinters, sprinter whose step frequency is higher has both shorter stance and flight time compared with other sprinters at top speed phase. Moreover, in researches about intraindividual changes of running speed, it is reported that increase of running speed at high speed is associated with increase of the step frequency and decrease of the short stance time without decrease of the step length (Otsuka et al., 2016; Weyand et al., 2000). Therefore, when step lengths are similar among different trials, a high step frequency is likely to be associated with a short stance time at top speed phase even if longitudinal variations are analysed.

In the SL-similar group, sprinters with higher step frequency had a shorter stance hip distance. A short stance hip distance could lead to a short step length because sum of the stance and flight hip distances of each sprinter is nearly equal with the step length. However, the step length was similar among sprinters in the SL-similar group. It is likely that the difference of the stance hip distance in the SL-similar group was cancelled out by the difference of the flight hip distance or by the slight difference between the step length and sum of the stance and flight hip distances. In addition, it is possible that the difference of stance hip distance influenced the slight difference of step length in the SL-similar group (2.10-2.16 m). In the SL-similar group, the sprinter whose step frequency was higher did not have shorter flight hip distance although they had shorter flight time compared with the other sprinters. The similar flight hip distance during shorter flight time compared with that of the other sprinter may achieve higher running speed.

The differences in stance and flight times as well as stance and flight hip distances mentioned above were influenced by differences in leg motion. In the previous study, short stance time is associated with less extension of thigh at take-off (Mann and Hermann, 1985) and early recovery of thigh at touchdown (Kunz and Kaufmann, 1981; Kigoshi, et al., 2015). In light of these knowledge, the large right thigh angle (i.e. less extension position) at right take-off and the large right thigh angle at left touchdown of the sprinter whose step frequency was higher compared with other sprinter in the SL-similar group may result in short stance time. These relationships were consistent with the hypothesis. Moreover, the high step frequency in the SL-similar group was associated with the high backward angular velocities of the right thigh and shank at right touchdown, and the small right knee angle at right take-off. Minimizing knee joint extension during the latter part of stance phase is important in order to enhance the extension velocity of the swing leg (the vector from the hip to the ankle) effectively (Ito et al., 1998; Ito et al., 2008). This suggests that step frequency at top speed phase in the case of similar step length among different sprinters is associated with angular velocity. Fukuda and Ito (2004) demonstrated that the decreases of running speed at the stance phase during top speed phase were similar among different speed sprinters, and the short deceleration duration was associated with the high running speed. It is likely that fast extension motion of backward swing leg during the stance phase associates to the high running speed with the short stance time.

4.2. Characteristics of long step length sprinters in the SF-similar group

In the SF-similar group, there was no significant correlation between stance hip distance and step length, with differences of step length in the SF-similar group largely dependent on the difference in flight hip distance. Weyand et al. (2000) reported that contact length (the estimated horizontal movement distance of the body during the stance phase) is irrelevant to top speed whereas step length is relevant to that. The report is supported by the results of the present study. Weyand et al. (2000) mentioned that unnaturally long contact length is disadvantage for the ability of the active muscles to apply the ground force. It may cause the short flight hip distance, and step length seems not to be lengthened. Therefore, the sprinter whose step length was larger compared with the other sprinter in the SF-similar group did not have longer stance hip distance.

Longer step length sprinters had longer flight time compared with the other sprinters in the SF-similar group. This relationship corresponded with the result of the previous study (Toyoshima et al., 2015), which showed the characteristics of long step
length and low step frequency sprints at top speed phase. These facts indicate that long step length is associated with long flight time regardless of whether step frequencies are similar or different among sprinters at top speed phase. The long flight time is likely to cause the long flight hip distance.

The stance time of the sprinter whose step length was longer tended to be shorter compared with the other sprinter in the SF-similar group ($r = -0.406$) although it was not significant. When the relationship between stance and flight time in the SF-similar group was investigated, strong negative correlation was detected (Fig. 4). It is assumed that step frequencies in the SF-similar group became similar as a result of the fact that the difference of the flight time was cancelled by the difference of the stance time.

In order to achieve both short stance time and long flight time, sprinters must gain large vertical impulse during short stance phase by exerting a large force against the ground. This ability is likely to be associated with high leg stiffness considering the equation to estimate leg stiffness from a few simple mechanical parameters (body mass, forward velocity, leg length, flight time and stance time) indicated by Morin et al. (2005). Kuitunen et al. (2002) showed that high ankle joint stiffness is associated with short stance time during sprint running at top speed. Ito and Ishikawa (2000) and Ito et al. (1998) claimed that immobilizing ankle joint by high stiffness of triceps surae during stance phase induces efficient transmission of force toward the ground. Based on these reports, high ankle joint stiffness which induce high leg stiffness may contribute to obtain large vertical impulse during short stance time. The sprinter whose step length was longer had the lower plantar flexion velocity of the right ankle joint at right touchdown compared with the other sprinter in the SF-similar group. There is a possibility that this ankle joint property was associated with high stiffness of the ankle joint, and contributed to the large ground reaction force although it could not be proved in the present study.

The large vertical ground reaction force may be caused by the forward swing leg as well as the stance leg. As predicted, the step length was relevant to the vertical movement of the forward swing leg. The long step length associated with large vertical acceleration of the centre of mass of the right leg relative to the right greater trochanter at left touchdown in the SF-similar group. Kigoshi et al. (2015) investigated the horizontal movement of the forward swing leg, and reported that relative acceleration to the centre of gravity could have influence on the ground reaction force. Our results supported the findings of Kigoshi et al. (2015) from the aspect of vertical component. A vertical ground reaction force could be changed by the vertical acceleration of each segment of the body. Therefore, it is likely that the vertical acceleration of the leg relative to the greater trochanter influenced the vertical ground reaction force. The leg linear acceleration is result from various factors (e.g., angle, angular velocity and angular acceleration of each lower limb segment). Although there was a possibility that the smaller knee angle was related to larger acceleration, the main factor of the larger vertical acceleration in the present study could not be clear. Further studies are required in order to demonstrate relationships between leg kinematics and ground reaction force.

The sprinter whose step length was longer had higher shank angular velocity of the stance leg at right touchdown compared with the other sprinter in the SF-similar group. This characteristics was common with the sprinter whose step frequency was high in the SL-similar group. Other similar characteristics between high step frequency and long step length sprinters was short stance time. Therefore, rapid backward swing of shank might be associated with short stance time, and have influence on both step frequency and step length.

5. Conclusions

The aim of the present study was to reveal kinematic characteristics of sprinters with high step
frequency among similar step length sprinters, and sprinters with long step length among similar step frequency sprinters in the top speed phase of a 100-m sprint.

Characteristics of the sprinter whose step frequency was high in the SL-similar group were the short stance time, the short flight time, short stance hip distance. These factor seem to be associated with rapid angular velocity of backward leg at touchdown, small thigh and knee angle at take-off, and early recovery of forward swing leg. In contrast, characteristics of the sprinter whose step length was long in the SF-similar group were long flight hip distance, and long flight time which was compensated by short stance time. These factors seem to be associated with low angular velocity of the ankle joint at take-off, and large relative vertical acceleration to the hip of the forward swing leg at touchdown of opposite leg.

It is not clear whether results of the present study could be applied to improvement of sprint speed. Further researches are required in order to reveal whether these characteristics correspond or not with longitudinal changes of step frequency and step length.

References


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