SPRINT STEP-TYPE SPECIFIC CHARACTERISTICS OF ANTHROPOMETRIC AND KINEMATIC VARIABLES IN SPRINTING ACCELERATION

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The purpose of this study was to compare the anthropometric and the kinematic characteristics during the acceleration phase between stride frequency (SF)-type and stride length (SL)-type sprinters. Seventeen sprinters participated in this study. The maximal 60-m sprints and anthropometric measures were obtained from subjects. Two sprints were recorded by using high-speed cameras. Sprint velocity, SL, SF and their underlying kinematic variables were calculated. Cluster analysis was used to classify the subjects into the SF or SL -type groups (step-type) as indicated by the ratio of the SF and SL at maximum velocity. The SF-type group showed shorter lower limbs length, flight time, lower the height of center of mass at takeoff, smaller swing motion and faster forward rotation of the shank and foot segments than the SL-type group. This study showed the noticeable differences between SF-type and SL-type sprinters were not only in swing motion but also in push-off motion.

KEY WORDS: sprint running, type classification, push-off motion

INTRODUCTION: Sprinting velocity (SV) is the product of step frequency (SF) and step length (SL) with maximum velocity being the result of an optimal relationship between these measures (Schiffer, 2009). High-level sprinters showed that the reliance on SF or SL was highly individual occurrence (Debaere et al., 2013; Salo et al., 2011). For an individual sprinter, this relationship could depend on both body height and leg length (Kunz and Kaufmann, 1981). A short limb can attain a greater velocity, whereas a long limb can generate more force. This trade off is known as “conservation of angular momentum” (Watts et al., 2012). Thus, the sprinting kinematic characteristics may be different according to individual step-type (SF- or SL-types), as indicated by the ratio of the SF and SL at maximal velocity. However, no studies have investigated sprinter step-type specific characteristics. Therefore, the purpose of this study was to compare the anthropometric variables (body height and leg length) and kinematic characteristics during the acceleration phase between SF-type and SL-type sprinters.

METHODS: Twenty-six male university sprinters participated in this study. To compare among the homogeneous athletes, data from seventeen sprinters within mean±1SD of 60-m sprinting time for the entire sample were analyzed (age, 20.94±1.39 years; height, 1.75±0.05 m; mass, 65.62±7.62 kg; 100-m sprinting personal best record, 11.06 ± 0.21 s).

After each individual warmed-up, all sprinters performed two maximal 60-m sprints from starting blocks. Sprinters were videotaped throughout the 60-m sprint using five panning high-speed video cameras (CASIO, EX-F1, 300 fps, Tokyo, Japan), which were set at the 5-, 15-, 25-, 35- and 45-m distance marks. Reference makers were also placed at 1-m increments on both sides of the running lane from 1 m behind the starting line to the 60-m mark.

The sagittal plane sprinting motion was evaluated at the 15-m mark using 23 body landmarks and four calibration markers which were digitized as VTR images during one sprinting cycle. The digitized coordinates were converted into real coordinates using four reference markers placed on the ground. The segment (thigh, shank and foot) angle and angular velocity data were calculated from these coordinates. These data was smoothed by a Butterworth digital filter with cut-off of 1.50 to 10.50 Hz.

The following variables were calculated from five video images. (1) The average SV, SF and SL for each 10m section: markers were placed at each 10 m section to measure interval time calculated by counting the video frames. For each subject, the step was determined. The SL was calculated by dividing distance by step count, while the SF was calculated by dividing step count by the split time in each 10m section. (2) The contact time (CT) and flight time (FT): CT was considered the duration of contacting the ground, and FT was the duration of neither foot contacting the ground. (3) The contact distance (CD) and flight distance (FD): CD was the horizontal distance the center of mass (CM) travelled during the stance phase, and FD was the horizontal distance the CM travelled during the flight phase. (4) The CM variables at takeoff (TO): the height, the vertical velocity. The height of TO and touchdown (TD) was standardized by body height. (5) The segment (thigh, shank and foot) angle and angular velocity during one cycle of sprinting motion. (6) The angle of trunk at TO. (7) The swing time: period of time in which a given foot was not in contact with the ground. (8) Displacement of thigh and shank segments during swing phase (Δ thigh and Δ shank segment during swing phase). (9) The ratio of the SF and SL in the maximal velocity section (RFL_{max}): the RFL_{max} was calculated by dividing SF by SL at the maximal velocity section, as an indicator to classify the step-type according to a combination of SF and SL during the maximum velocity phase. Through a cluster analysis with a Euclidean distance measure, the sprinters were classified in three groups based on their RFL_{max}.

The anthropometric characteristics of sprinters that were assessed included: body height, body mass, both the absolute value and the relative value of leg length, upper leg length and lower leg length. The relative values were standardized by body height.

One-way ANOVAs were performed to identify the differences in variables among the groups. When significant F-ratios were obtained, a Tukey post hoc test was performed to identify the differences in variables among the two groups. The significance level was set at $p < 0.05$, and the results were considered to be marginally significant at $p < 0.1$.

RESULTS: Through the results of the cluster analysis based on RFL_{max}, the sprinters classified into three groups; the SL (n = 6), SF (n = 6), Mid (n = 5) -type groups. There were no significant differences in the 60-m sprinting time between groups (SL-type: 7.36±0.10s, SF-type: 7.34±0.08s, Mid-type: 7.38±0.12s, F = 0.195).

Table 1 presents the mean (M) and SD of the anthropometric characteristics among the three step-type groups. The SF-type group showed a significantly shorter absolute values for body height, leg length and lower leg length than the SL-type group. The SF-type group showed a less relative value for lower leg length than the SL-type group.

Table 1

Comparison of the anthropometiric variables among the step-type groups

Variables	SL-type (n=6)		SF-type (n=6)		Mid-type (n=5)		Multiple comparison
	M	SD	M	SD	M	SD	
Body height (m)	1.78	0.01	1.71	0.06	1.77	0.04	SL > SF
Body mass (kg)	69.35	5.37	61.75	9.48	66.32	5.18	
Leg length (m)	0.94	0.01	0.89	0.04	0.93	0.03	SL > SF
Upper leg length (m)	0.50	0.01	0.49	0.02	0.51	0.02	
Lower leg length (m)	0.47	0.01	0.44	0.03	0.46	0.01	SL > SF
% Leg length (%)	52.70	0.56	52.02	0.85	52.70	0.76	
% Upper leg length (%)	28.05	0.40	28.52	0.50	28.67	0.57	
% Lower leg length (%)	26.61	0.55	25.49	0.75	26.05	0.44	SL > SF

>: $p < 0.05$

Table 2

Comparison of the sprinting kinematic variables at 15-m among the step-type groups

Variables	SL-type		SF-type		Mid-type		Multiple comparison
	M	SD	M	SD	M	SD	
Contact time (s)	0.112	0.003	0.111	0.006	0.111	0.007	
Flight time (s)	0.109	0.01	0.095	0.006	0.104	0.007	SL > SF
Contact distance (m)	0.91	0.04	0.88	0.06	0.89	0.06	
Flight distance (m)	1.00	0.08	0.90	0.08	0.97	0.08	
TD distance (m)	0.20	0.03	0.20	0.03	0.19	0.02	
TO distance (m)	0.68	0.04	0.66	0.03	0.69	0.05	
Height at TO (%)	0.55	0.01	0.53	0.01	0.54	0.02	SL > SF
Height at TD (%)	0.54	0.02	0.52	0.02	0.53	0.01	
Vertical velocity at TO (m/s)	0.63	0.23	0.50	0.12	0.43	0.09	

>: $p < 0.05$

Table 2 shows the differences among three step-type groups in the sprinting kinematic variables during the acceleration phase (calculated at the 15-m distance mark). The SF-type group showed a significantly shorter FT and a lower relative CM height at TO than the SL-type group.

Figure 1 presents the averaged patterns of the segment angle and segment angular velocity for the thigh, shank, and foot segments at the 15-m distance mark in the SF-type and SL-type groups. The SF-type group demonstrated significantly greater forward lean angles of the shank segment than the SL-type group before TO (80 – 100% of normalized time). The SF-type group showed significantly greater backward lean angles of the foot segment than the SL-type group at TD (0 – 10% of normalized time). The SF-type group showed faster forward rotation of the shank and foot segments than the SL-type group during the middle and early stance phase, respectively. The angle and angular velocity of the thigh segment was not significantly different between the SF-type and SL-type groups. Table 3 shows the comparison of selected sprinting kinematic variables (angle of trunk at TO, the range of extension motion about knee and ankle joints during the late stance phase, the swing time and the range of swing motion of thigh and shank segments during swing phase) at 15-m mark among the three step-type groups. The SF-type group showed significantly smaller trunk angle at TO, Δ knee joint extension, swing time and Δ thigh segment of swing phase than the SL-type group.

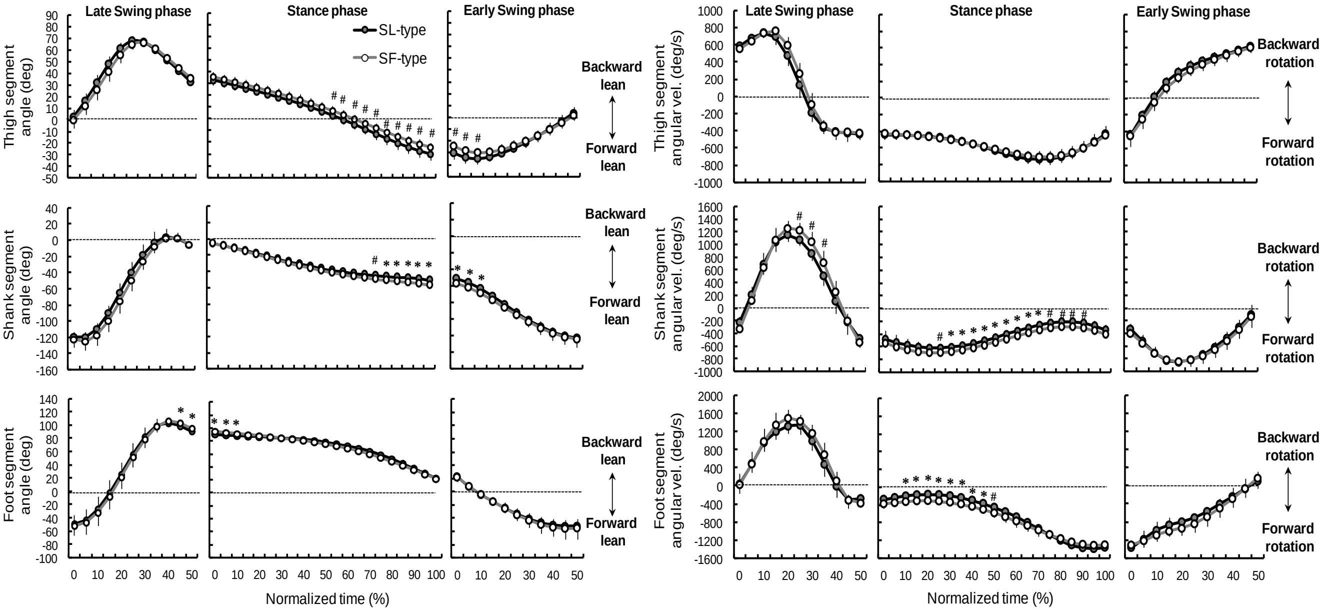

Figure 1: Averaged patterns of segment angle (right) and segmet angular velocity (left) of thigh, shank and foot segments during swing and stance phase at 15-m. [*: p<0.05, #: p<0.1]

Table 3
Comparison of selected sprinting kinematic variables at 15-m

Variables	SL-type		SF-type		Mid-type		Multiple comparison
	M	SD	M	SD	M	SD	
Trunk angle at TO (deg)	-18.38	3.12	-24.62	2.64	-20.08	3.32	SL > SF
Δ knee joint extension (deg) [a]	22.80	3.50	16.69	5.06	18.42	3.24	SL > SF
Δ ankle joint extension (deg) [a]	39.99	2.34	35.95	3.12	34.08	7.90	
swing time (s)	0.33	0.02	0.30	0.01	0.32	0.01	SL > SF
Δ thigh segment of swing phase (deg)	104.03	3.45	96.93	3.89	102.53	5.79	SL > SF
Δ shank segment of swing phase (deg)	128.31	12.38	128.52	10.12	125.72	10.13	

a) the variables were calculated by substracting the minimum angle during stance phase from angle at the TO of each joint. >: p < 0.05

DISCUSSION: The results of the present study confirmed that there are varied combinations of SF and SL in sprinting (Hunter et al., 2004), and also revealed that there are differences in the anthropometric characteristics and sprinting motion during the acceleration between step-type groups. The SF-type group had shorter body height, leg length and lower leg length than the SL-type group. On the other hand, there was no difference in upper leg length between the SF-type and SL-type groups. Hoffman (1971) indicates that if a sprinter's limbs are longer, it becomes increasingly difficult to produce rapid leg cadence. Namely, the shorter limbs can move with greater SF, while the longer limbs have a lower SF (Schiffer, 2009). Furthermore, this "conservation of angular momentum" influences sprinting in terms of heel swing motion (Watts et al., 2012). With consideration for swing motion, the SF-type utilized shorter swing times and smaller range of motion about the thigh segment than the SL-type group.

Interestingly, there were significant differences between the SF-type and SL-type groups in segment angle and segment angular velocity of the shank and foot segment during the stance phase. The SF-type group presented greater forward lean of shank segment before TO and faster forward rotation of both the shank and foot segments during the stance phase. Moreover, the SF-type group exhibited greater forward lean of the trunk at TO and lower knee joint range of extension motion in the late stance phase. These characteristics of the SF-type group likely influenced the height of CM at TO. Hay (1993) pointed out that the time a sprinter spends in the air is determined by the velocity and the height of the CM at TO. Indeed, the SF-type group showed a lower height of the CM at TO and a shorter FT. The extension motion of the knee joint with forward lean of the shank segment would allow the CM to project more in the horizontal direction. Besides, the greater forward lean, body positions would also be directly affected by the further forward oriented the ground reaction force during accelerated sprinting (Kugler and Janshen, 2010). From these points of views, the push-off motion shown by the SF-type group may lead to suppression of the vertical rise of CM at TO. Before concluding, we must highlight a limitation of this study. Since the group we tested was homogeneous with selecting ±1SD of 60-m time, the sprinters that were eliminated may contribute real performances for analysis. Therefore, additional research is required to examine a group with more variability.

CONCLUSION: The main differences between the SF-type group and SL-type group were leg length, lower leg length, FT and height of CM at TO in the acceleration phase of sprinting. The SF-type group presented faster forward rotation of the shank and foot segments during the stance phase, and greater anterior leaning of the shank and trunk segments at TO. Therefore, the SF-type sprinters showed that the push-off motion likely suppresses the vertical rise of CM at TO. These results indicate that the noticeable differences among step-types were not only in swing motion but also in push-off motion.

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