P01-7 ID78

TYPE-SPECIFIC STEP CHARACTERISTICS OF SPRINTERS DURING ACCELERATION PHASE OF 100-M RACE

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The purpose of this study was to show the type-specific step characteristics during acceleration phase (0–30 m) of a 100-m race. Fifty-nine male varsity sprinters (10.68 ± 0.22 s) were recorded running in 100-m races using 10 high-speed cameras, and step variables in 0–30 m and maximum speed phase (MSP, 30–60 m) were calculated. Cluster analysis was used to classify the subjects into the step-frequency (SF) or -length (SL) reliant group (i.e., type-specific) as indicators for the ratio of the SF and SL in the MSP. Then, each group was divided into two sub-groups according to the mean speed in MSP (good and poor sprinters). As a result, the sprinters were classified into SL-, SF-, and Mid-groups. In SL-group, good sprinters showed a longer SL from the 7th step to MSP than the poor sprinters. In SF-group, good sprinters showed a higher SF from the 7th step to MSP than the poor sprinters.

KEY WORDS: athletics, type classification, step frequency, step length

INTRODUCTION: The 100-m sprint race can be generally divided into three main phases: acceleration (0–30 m), maximum speed (30–60 m), and deceleration (60–100 m) (Schiffer, 2009). The race time is strongly correlated with the maximum sprinting speed (SS_{max}) over 100-m (Mackala 2007), the kinematics and kinetics of sprinters during the SS_{max} phase have been widely studied (Bezodis et al., 2008; Kunz and Kaufmann, 1981). However, because SS_{max} is the result of the acceleration during previous phase (Schiffer, 2009), it is important to investigate the acceleration technique to develop SS_{max}. Sprinting speed (SS) is the product of step-frequency (SF) and -length (SL), and there were wide varieties of combination of SF and SL for homogeneous sprinters (Salo et al., 2011, Schiffer, 2009). Thus, the training should be varied based on whether the athlete is an SF or SL reliant sprinter (i.e., type-specific). However, there is no study that has investigated type-specific step characteristics during acceleration phase of sprinters who are able to achieve high SS_{max} during 100-m race. Therefore, the purpose of this study was to show the type-specific, based on the reliance of SF or SL, step characteristics in acceleration phase of sprinters who achieved higher SS_{max}.

METHODS: Data collection: Fifty-nine 100-m male university sprinters (the best record ranging from 10.22 to 11.28 s, 10.68 ± 0.22 s) were videotaped in 100-m races using 10 high-speed video cameras (CASIO, EX-F1, 300 fps, Tokyo, Japan). The recorded 100-m races took place in national- and regional-level competitions. Three cameras were set at the 30-, 60- and 90-m marks and were panned. To cover the section from start to 30-m mark, six cameras were fixedly set on the stand of stadium with approximately 6 m intervals. To calculate the SL of each step from those 6 cameras, 68–85 reference markers were placed every 2 m on the both sides of 3 or 4 lanes (from -2 to 30 m) and were videotaped before the competition (the number of reference markers and lanes depending on the race).
Data processing: From video images of these cameras, we calculated the split time at 30- and 60-m marks, as well as the SF at each step during the entire race. The mean of the SF and SL in the 0–30 m and 30–60 m sections were calculated by dividing 30 m by step numbers in each section ($SF_{0–30}$, $SL_{0–30}$, $SF_{30–60}$, $SL_{30–60}$). To standardize by stature, SL_{index} was calculated by dividing $SL_{30–60}$ by individual's stature. The foot strike and toe-off were

identified visually to calculate the SF at each step. The SF of each step was calculated as the inverse of the step duration. To calculate the SL at each step, the toe on the ground and four reference markers that were placed closest to the toe were manually digitized using the Frame-DIAS system (DKH Co., Tokyo, Japan). The actual coordinates of the toe were calculated using the position of the four digitized reference markers. The SL at each step was calculated as the horizontal distance that the toe moved over two consecutive steps. The SS was calculated as the product of the SF and SL of each step. The step variables of each step were filtered using a three-point moving average. As an indicator to classify the sprinters according to a combination of SF and SL during the maximum speed phase, we calculated the ratio of the SF to SL in the 30–60 m section ($RFL_{30–60}$). The $RFL_{30–60}$ was calculated by dividing $SF_{30–60}$ by $SL_{30–60}$. Through a cluster analysis with a Euclidean distance measure, the sprinters were classified in three groups based on their $RFL_{30–60}$. Each group was divided into two sub-groups according to the mean speed in the 30–60 m ($SS_{30–60}$, good and poor sub-groups). Pearson's correlation test was used to analyze the relationships of variables among $SS_{30–60}$, $SF_{30–60}$, and $SL_{30–60}$. One-way non-repeated measures (ANOVAs) were performed to identify the differences of step variables among the groups. When significant F-ratios were obtained, a post hoc Tukey-test was performed to identify the differences of step variables among the each two groups. Independent t-test was used to identify differences in the SF and SL between the good and poor sub-groups of each group. The significance level was set at $p < 0.05$, and the results were considered to be marginally significant at $p < 0.1$.

RESULTS: The mean of the race times were 10.83 ± 0.23 s (range: 10.37–11.28 s, official wind: -0.2 ± 0.9 m). The correlation coefficients of $SS_{30–60}$ with both $SL_{30–60}$ and $SF_{30–60}$ were quite low ($SL_{30–60}$: r = 0.249, p = 0.058, R^2 = 0.062; $SF_{30–60}$: r = 0.289, p = 0.026, R^2 = 0.083). There was no significant correlation between $SS_{30–60}$ and $RFL_{30–60}$ (r = -0.024, p = 0.859). Through the results of the cluster analysis based on $RFL_{30–60}$, the sprinters could be classified into three groups; the SL- (n = 22), SF- (n = 24), Mid- (n = 13) group. Among three groups, the SL-group was taller and resulted in higher SL_{index} than the SF-group. In number of steps over 100-m, the SF-group took four steps larger than the SL-group (Table1). However, there were no differences in the 100-m race times and mean speeds of 0–30, 30–60, and 60–100 m sections.

Fig.1 shows the mean and standard deviation of the SF, SL, stance time, and flight time at each step of the three groups in acceleration and maximum speed phase. In all the steps and in 30–60 m, the SL of SL-group were significantly longer than those of the SF-group. On the other hand, the SF of SF-group was significantly higher than those of the SL-group. The SL-group showed significantly longer stance and flight time those of the SF-group (Fig.1-c, d).

Table 1 Comparison of selected variables in 100-m race and mean speed in each phase among three groups.

	All (n = 59)	SL-group (n = 22)	SF-group (n = 24)	Mid-group (n = 13)	Multiple comparison
Ratio of SF/SL	2.25 ± 0.19	2.05 ± 0.09	2.43 ± 0.10	2.25 ± 0.05	SF > Mid > SL
Stature (m)	1.74 ± 0.05	1.78 ± 0.04	1.71 ± 0.03	1.73 ± 0.02	SL > SF, Mid
100m time (s)	10.83 ± 0.23	10.85 ± 0.28	10.84 ± 0.20	10.77 ± 0.23	
All step (step)	49.78 ± 2.13	47.70 ± 1.33	51.69 ± 1.15	49.76 ± 1.06	SF > Mid > SL
Step length index [1)]	1.24 ± 0.04	1.27 ± 0.04	1.21 ± 0.03	1.25 ± 0.02	SL, Mid > SF
Sprint speed (m/s)					
0 – 30 m	7.39 ± 0.13	7.37 ± 0.16	7.39 ± 0.11	7.42 ± 0.13	
30 – 60 m	10.50 ± 0.25	10.47 ± 0.28	10.48 ± 0.22	10.58 ± 0.25	
60 – 100 m	10.25 ± 0.28	10.25 ± 0.32	10.22 ± 0.25	10.30 ± 0.28	

[1)] mean of the step-length in 30–60 m / stature

> : Statistically singnificant differences (p < 0.05) among the SL-, Mid-, and SF-group.

In the SL-group, the 100-m race times were 10.67 ± 0.16 s in good sprinters (n=14) and 11.16 ± 0.12 s in poor sprinters (n=8) ($p < 0.05$). In the SF-group, the times were 10.69 ± 0.10 s in good sprinters (n=13) and 11.02 ± 0.10 s in poor sprinters (n=11) ($p < 0.05$).

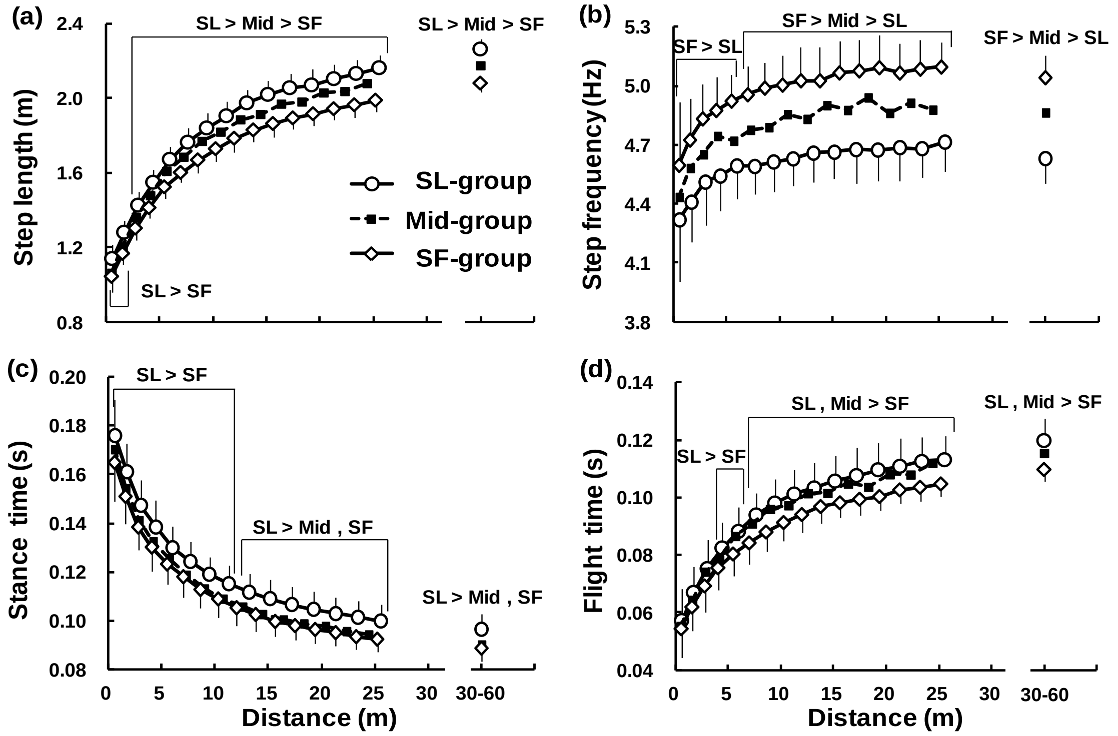

Fig.1 Comparison of changes in step length (a), step frequency (b), stance time (c) and flight time (d) at each step during acceleration phases among three groups.
> : Statistically singnificant differences ($p < 0.05$) among the SL-, Mid-, and SF-group.

Fig.2 shows the changes in the SS, SF, and SL at each step of both groups' good and poor sub-groups sprinters in acceleration phase. In the SL-group, the SS of good sprinters was higher than that of poor sprinters from the 2nd to 15th step and for 30–60 m section. Besides, the SF of good sprinters was higher than that of poor sprinters at the 5th and 15th, and the SL of good sprinters were longer than that of poor sprinters from the 7th to 15th step and 30–60 m section in SL-group. In the SF-group, the SS of good sprinters was higher than that of poor sprinters from the 2nd to 16th step and 30–60 m section. Moreover, there was no significant difference of the SL in SF-group. However, the SF of good sprinters was higher than that of poor sprinters from the 7th to 16th step and for 30–60 m section.

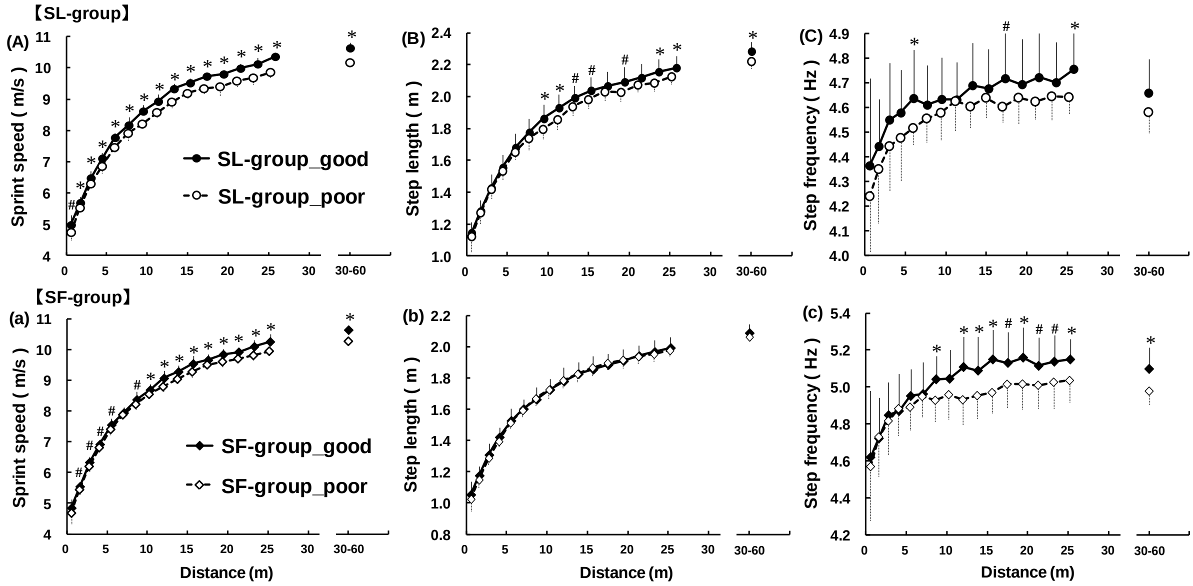

Fig.2 Comparison of changes in sprint speed (A,a), step length (B,b), and step frequency (C,c) at each step during acceleration phase between good and poor sub-groups in SL- (above) and SF- (below) group. * ($p < 0.05$), # ($p<0.1$) : Statistically singnificant differences between the good and poor sprinters in the SL- and SF-group.

DISCUSSION: The results of the present study confirmed that there are the varied combinations of SF and SL in maximum speed (Salo et al., 2011), and revealed that there are differences in the step characteristics during acceleration phase of 100m race by on SF- and SL-reliant group (Fig.1). The group classification was conducted using an analysis of inter-individual performance level rather than an intra-individual level (Salo et al., 2011), since this analysis clarifies the general trends of sprinters who have similar reliance on SF or SL. As a result, the SL-group showed longer both the stance and flight times than the SF-group. Hunter et al. (2004) suggested that long-legged athletes tended to have longer a stance distance and stance time, and therefore a longer time to produce a ground reaction force. In the present study, the stature was larger in the SL-group than in the SF-group. Thus, the SL-group presumably has longer-legs, the SL-group showed longer contact and flight times than SF-group due to the greater moment of inertia of long legs (Hunter et al., 2004). Furthermore, the SL_{index} which was standardized by stature was higher in SL-group than SF-group. This means that difference of step characteristics between these two reliance-groups is based on not only morphological disparity but also techniques of sprinting. Therefore, additional research is required to understand the difference in running technique in terms of kinematics and kinetics among different type-specific groups.
The sprint performance depends on different step characteristics in SF- and SL-group, respectively. In the SL-group, good sprinters showed relatively high the SF from the 1^{st} to the 5^{th} step, and they had longer the SL after the 7^{th} step and for 30–60 m. In the SL-group, it is important to increase the SL gradually while maintaining high the SF after the 7^{th} step for achievement of a higher SS_{max}. On the other hand, in the SF-group, good sprinters showed higher the SF than poor sprinters after the 7^{th} step and for 30–60 m. In the SF-group, it is important to further increase the SF after the 7^{th} step, while increase the SL gradually for achievement a higher SS_{max}. Both SF- and SL-group showed the difference of the SF or SL between good and poor sub-groups from the 7^{th} step. The 7^{th} step occurred at approximately 9m mark in both groups (SL-group: 9.45 ± 0.45 m, SF-group: 8.62 ± 0.40 m). Delecluse et al. (1995) reported that the 100-m sprint performance can be considered to be a multidimensional skill with three components. These are the ability to achieve a high initial acceleration (0–10m), continue increasing the running speed to a high maximum speed following the initial acceleration phase (from 10 m to the maximum speed), and then maintain a high speed. Based on their idea, it seems that the 7^{th} step is the transition point during the acceleration phase. This means that there is possibility that the step characteristics after around the 7^{th} step influence the acceleration ability to develop SS_{max}.

CONCLUSION: The important results of this study are as follows: (1) there are differences in the step characteristics in acceleration phase by on SF- and SL-group; (2) The sprint performance depends on different step characteristics in SF- and SL-group, respectively. These findings could be useful for making training methods to improve a sprinter's 100-m sprint performance according to the type-specific based on SF- or SL-reliance.

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