COMPARISON OF TECHNIQUE CHARACTERISTICS OF SPRINT RUNNING AT MAXIMAL AND SUBMAXIMAL SPEEDS

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The purpose of this study was to compare the characteristics of athlete's movements when sprint running at maximal and submaximal speeds. Three male and six female sprinters took part in the investigation. Each of them performed 50 metres running: first at 95% of maximal speed, then at maximal speed. High-speed camcorder (240 Hz) was placed at the 40 metres mark of 50 metres track, perpendicular to the plane of athlete's motion. Paired t-test was used to assess the significance of the differences between considered variables. The study revealed significantly larger ankle vertical velocity along with center of gravity displacement during support phase when sprint running at maximal speed. Step frequency and length, ground contact time and a large number of other variables remained stable during sprint running at various speeds.

KEY WORDS: ankle vertical velocity, center of gravity support displacement, step length, step frequency.

INTRODUCTION: It is known that sprint running speed depends on step frequency and length, while the values of step frequency and length depend on the characteristics of athlete's support and flight movements. However, in practice, there are various dependencies between running speed and the most important characteristics of the running techniques. For example, Bezodis, Salo, & Kerwin (2008) showed a strong correlation (r = 0.886) between step frequency and running speed and only a weak correlation (r = – 0.192) between step length and running speed of a world class sprinter. At the same time, according to resulting regression equation of Delecluse, Ponnet, & Diels (1998), almost 85% of the variance in running speed can be explained by the variance in stride length. Also, Hunter, Marshall, & Mcnair (2004) found a strong dependency (r = 0.73) between sprint speed and step length and only a weak correlation (r = – 0.14) between sprint speed and step rate. Yada et al. (2011) observed significantly larger stride lengths of elite sprinters compared to student sprinters, and the same values of stride frequency in both groups of athletes. At the same time, our better understanding of the dependencies between sprint running speed and various characteristics of running techniques can provide us with the knowledge of how the parameters of athlete's movements in sprint running change at various speeds. The research in this area has shown (Wilson, Gittoes, & Heywood, 2008) that in sprint running at maximal speed and at 89 ± 6% and 77 ± 8% maximal speed there is a strong interdependency of stride velocity, stride length (R^2 = 0.7351) and stride frequency (R^2 = 0.8878). Stride length was found to be the primary factor at low speeds, while stride rate was the primary factor at high speeds (Yan and Jin, 2004; Bezodis, 2012 and other). However, very little is known about how other characteristics of human movements change during sprinting at different speeds. Also, there is not enough understanding of the changes in characteristics of a running technique at a speed close to maximal (over 90% of maximal speed). So, the objective of the present study was to compare kinematic characteristics of the athletes moving at maximal and submaximal speeds in sprint running.

METHODS: Three male (height 1.83 ± 0.09 m, body mass 79.7 ± 8.7 kg, age 21.4 ± 1.1, 100 metres season best 10.56 ± 0.24 s) and six female (height 1.66 ± 0.05 m, body mass 55.7 ± 5.7 kg, age 21.5 ± 2.4, 100 metres season best 12.23 ± 0.38 s) sprinters took part in the investigation. After a standard warming-up, each athlete performed two trials of 50 metres block start running: first at 95% of maximal speed, and then at 100% of maximal speed. Sprinters were to focus only on their own feelings about their running speed. No instrumental

method was used to achieve the given running speed ratio between the first and second trials. This allowed the athletes to demonstrate their usual running techniques without changing them in order to meet the requirements of the experiment.
Videotaping was done with high speed digital camcorder Casio EX-ZR700, operating at 240 Hz. The camera was placed perpendicular to running direction. The optical axis of the camera was aligned with 40 metres mark of the 50 metres distance.
SkillSpector (Version 1.3.2) software was used for 2D video analysis. Twenty-point Full Body model was used to evaluate the kinematic characteristics of athletes' movements and center of gravity (CG) position. Performance data between left and right leg touchdowns were calculated. The following measurements were taken (Figure 1): ground contact time (GCT), step length, step frequency, average horizontal velocity of CG, horizontal CG takeoff velocity, vertical CG takeoff velocity, takeoff angle, CG support displacement, vertical ankle velocity at touchdown (support leg), horizontal ankle velocity at touchdown (support leg), CG to heel distance in the horizontal plane, flight time, knee angle at touchdown (support leg), minimal knee angle during support phase (support leg), knee angle at takeoff (support leg), average angular thigh velocity of swing leg during support phase, maximal angular thigh velocity of swing leg during support phase, thigh angle of swing leg at touchdown, thigh angle of swing leg at takeoff. Data smoothing was done with the help of quintic spline filter. Paired *t*-test was used to assess the significance of the differences between considered variables.

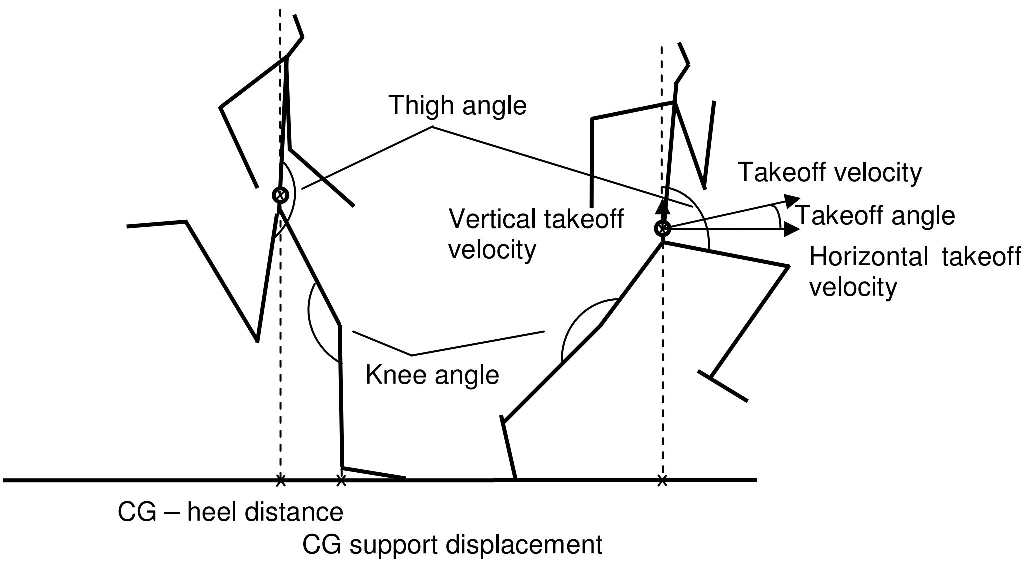

Figure 1: Some variables defined in the research.

RESULTS: In accordance with Table 1, all sprinters who participated in the experiment did fulfill the task of speed running. So, the differences between average CG horizontal velocity during left to right leg step at maximal and submaximal speeds were significant (p = 0.011). The value of the average velocity difference was 4.26%. This does not exactly correspond to the task (95 and 100% of possible running speed), yet suggests that running was indeed done at maximal and submaximal speeds. Also, horizontal CG takeoff velocity was significantly larger during sprint running at maximal speed. At maximal speed, both CG support displacement (p = 0.030) and landing speed of foot (differences in vertical ankle velocity, p = 0.014) were significantly larger.
However, change of speed did not affect the majority of running technique indicators. This is true for such major characteristics of sprint running techniques as GCT, flight time, step length and step frequency, takeoff angle (only non-significant differences, Table 1). Values of knee angle at touchdown and takeoff, and minimal knee angles during support phase proved to be very stable (Table 1). Only non-significant differences were registered for the indicators

of swing leg thigh movements: angular average and maximal thigh velocity during support time, swing leg thigh angle at touchdown and takeoff (Table 1).

Table 1
Techniques characteristics (Mean ± S.D.) of sprint running at various speeds

Kinematic data	max speed	submax speed	*p*
GCT (s)	0.112 ± 0.012	0.113 ± 0.012	0.817
Step length (m)	2.09 ± 0.23	2.09 ± 0.22	0.936
Step frequency (Hz)	4.21 ± 0.28	4.12 ± 0.33	0.543
Average CG horizontal velocity (m/s)	8.79 ± 1.04	8.43 ± 0.96	0.011
Horizontal CG takeoff velocity (m/s)	9.26 ± 1.12	8.79 ± 1.20	0.007
Vertical CG takeoff velocity (m/s)	0.79 ± 0.22	0.67 ± 0.24	0.232
Takeoff angle (deg)	5.0 ± 1.6	4.4 ± 1.5	0,363
CG support displacement (m)	0.995 ± 0.096	0.959 ± 0.084	0.030
Vertical ankle velocity (m/s)	-2.54 ± 0.78	-2.05 ± 0.66	0.014
Horizontal ankle velocity (m/s)	2.61 ± 1.46	2.37 ± 0.94	0.562
CG-heel distance (m)	0.169 ± 0.044	0.167 ± 0.041	0.875
Flight time (s)	0.123 ± 0.013	0.130 ± 0.014	0.197
Knee angle at touchdown (deg)	155.3 ± 3.5	155.3 ± 5.1	0.987
Min knee angle (deg)	137.8 ± 5.6	137.7 ± 4.8	0.848
Knee angle at takeoff (deg)	162.2 ± 6.5	162.2 ± 7.5	0.982
Average thigh velocity (deg/s)	469.6 ± 24.2	474.3 ± 33.9	0.496
Max thigh velocity (deg/s)	758.2 ± 94.8	785.9 ± 81.2	0.443
Thigh angle at touchdown (deg)	181.7 ± 14.0	181.7 ± 13.1	0.995
Thigh angle at takeoff (deg)	116.0 ± 8.4	114.8 ± 7.0	0.516

DISCUSSION: It may seem strange that this investigation has revealed no significant differences between step lengths and especially between step frequencies in sprint running at various speeds. Five sprinters demonstrated larger step frequency values when sprint running at maximal speed, yet, four athletes had larger step frequency values when they ran at submaximal speed (including the most qualified athlete who participated in the experiment, 100 metres season best 10.28 s). Obviously, the surveyed sprinters used different tactics to increase their running speed. This does not well agree with the opinion of Wilson, Gittoes, & Heywood (2008) and other that the step length is more important in slower sprint running, whereas step frequency is more important in faster sprint running. However, in the compared studies the changes in running speeds were greater than in the present study.

One might also assume that the increase of running speed could result in more active movements of the thigh of the swing leg. However, the study revealed no significant differences of the variables of angular thigh velocity and thigh position at touchdown and takeoff in sprint running at maximal and submaximal speeds. Perhaps, the differences in running speeds in this investigation were not large enough to be significant.

At the same time, it is worth to mention that the sprinters reported they strove to set foot on support more actively to increase their running speed (differences in vertical ankle velocities were significant, Table 1). It is interesting that significant increase of CG average speed and ankle vertical velocity depended only on non-significant change of ankle horizontal velocity (Table 1). Significantly larger horizontal CG takeoff velocity of sprinting at maximal speed found in this study indicates more active push-off. The increase of CG displacement during support phase at maximal speed revealed by this research may be due to more active forward movement of the torso. However, a more accurate conclusion needs special investigation. In this connection, it may be noted that Yada et al. (2011) showed elite sprinters (running velocity 10.99 ± 0.47 m/s) to have support distance (1.00 ± 0.05 m) significantly larger than that of student sprinters (running velocity 9.86 ± 0.25 m/s, support distance 0.92 ± 0.05 m). This indirectly proves the CG displacement increases when running at a higher speed.

CONCLUSION: The results of this study demonstrate that different sprinters have various tactics of changing their step length and frequency to increase their running speed from submaximal to maximal values. However, the general tendency in this case is the increase of vertical ankle velocity at touchdown and CG support displacement, while the characteristics of support and swing legs segments movements during ground contact time remain relatively stable with the increase of running speed from 95% to maximal possible values. This knowledge will allow us to estimate the possibility of running at submaximal speed at various stages of training sprinters.

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