KINEMATIC ANALYSIS OF RESIST-AND-RELEASE SPRINT RUNNING

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The objective of this study was to compare the kinematic characteristics of athlete's movements at the resistance and release phases of resist-and-release sprint running and free maximal sprint running. Five female sprinters and heptathletes and three male sprinters took part in the study. Videotaping was done at 240 Hz. 2D video analysis was performed using SkillSpector software. It was found that horizontal takeoff velocity, step length, ground contact time, knee angle at touchdown and trunk tilt at touchdown and takeoff had significant differences between release and resistance phases of resist-and-release sprint running, along with constant speed phase of free sprint running. Most studied characteristics were the same in both the release phase of resist-and-release sprint running and in the acceleration phase of free sprint running.

KEY WORDS: horizontal velocity, step length and frequency, ground contact time.

INTRODUCTION: Different types of resisted sprint running (such as sprint running resisted by weight sleds, belt or vest, parachute, elastic bands, or uphill incline) make an important part of specific sprint training. Previous studies investigated the specificity of athlete's movements in sprint running resisted by weight sleds, belt, and parachute (Alcaraz et al., 2008; Martínez-Valencia et al., 2014 et al.). Also, some research had been done on the influence of different varieties of resisted sprint training on running performance at different phases of sprint distances (Martinopoulou et al., 2011; Bachero-Mena & Gonzalez-Badillo, 2014 et al.). One of the main problems of resisted sprint training is the need to effectuate athlete's improved force abilities in free sprint. For this purpose, various types of resisted sprint training and free sprint might be combined within one training session (Zafeiridis et al., 2005 et al.). However, there is an exercise which integrates the resisted and free sprint in one performance, i.e. resist-and-release sprint: partner provides resistance for athlete through a rope put around a waist, then after specified distance partner lets go of the rope and athlete finishes without resistance (Horton, 2016). At the same time, the kinematic features of resist-and-release sprint running have been much less investigated than those of other types of resisted sprint. This fact obscures the meaning of resist-and-release sprint in the training of sprinters. So, the objective of this study was to compare the kinematic characteristics of athlete's movements at the resistance and release phases of resist-and-release sprint running and free sprint running at maximal speed.

METHODS: Eight sprinters and heptathletes took part in the study (three males: age 20.5 ± 1.5, height 1.84 ± 0.02 m, weight 78.7 ± 6.1 kg, 100 m personal best 11.40 ± 0.62 s, and five females: age 22.2 ± 3.0, height 1.70 ± 0.07 m, weight 58.4 ± 7.8 kg, 100 m personal best 12.64 ± 0.61 s). Each athlete performed 40 meter maximal speed free sprint running followed by resist-and-release sprint running, separated by 5-7 minutes of rest. All athletes used a three point start. In resist-and-release sprint running, the assistant created resistance using non-elastic rope fixed to the belt of the athlete. The resistance phase lasted from the start until the athlete reached the 24 meter point; then the assistant let go of the rope, thus initiating the release phase.

The kinematic data were collected using Casio EX-ZR700 speed cameras located 25 m away in a perpendicular direction from the centre of the sprinting lane, opposite 5, 20, and 30 meter marks from the start. Videotaping was carried out at a rate of 240 Hz. 2D video analysis was performed using SkillSpector (Version 1.3.2) software. Twenty-point Full Body model was used to evaluate the kinematic characteristics of the athletes' movements. The following measurements were taken (accounted were the data of the support period after the fifth step and the step nearest to the 30 meter mark in free sprint, and the steps nearest to the 20 and 30 meter marks in resist-and-release sprint running): vertical ($VV_{takeoff}$) and horizontal ($HV_{takeoff}$) velocities of the centre of gravity (CG) at takeoff, takeoff CG velocity, takeoff angle, step length and step frequency, ground contact time (GCT), landing time, takeoff time, leg angle at touchdown (angle between half-line from an ankle of takeoff leg through a hip joint and horizontal half-line from an ankle to opposite of running direction), knee angle at touchdown (KneeAT) and at midstance (KneeAM), trunk angle at touchdown (TrunkATD) and at takeoff (TrunkATO), thigh angle of non-support leg at touchdown and at takeoff, CG support displacement (CGS displacement) (Figure 1). Coordinate data were smoothed with quintic spline filter. Descriptive statistical methods were used to calculate the mean and standard deviation (SD). The differences in kinematic data were determined through the analysis of variance with repeated measures. A paired sample t-test was used as a post hoc test to identify where statistical differences occurred (compared data of the release phase of resist-and-release sprint running (at the 30 meter mark), on the one hand, and the resistance phase of resist-and-release sprint running (at the 20 meter mark), of the acceleration (at the 5 meter mark) and constant speed phases (at the 30 meter mark) of free sprint, on the other hand). Because three t-tests were used, the critical alpha level was adjusted using Bonferroni adjustment from $p = 0.05$ to $p = 0.0166$.

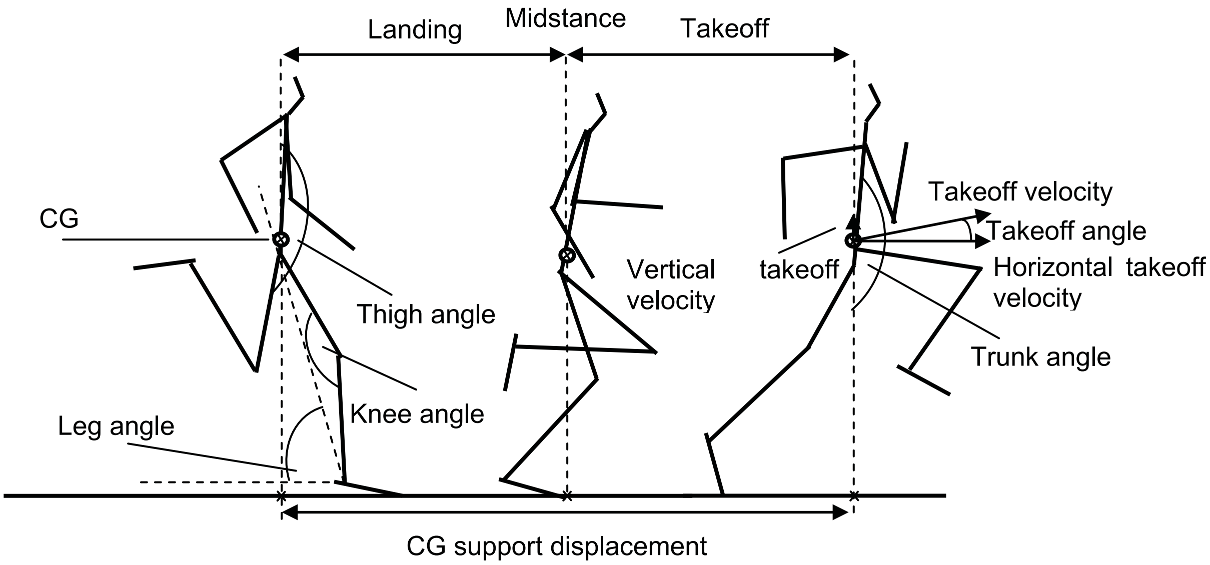

Figure 1: Variables defined in the research.

RESULTS: The kinematic characteristics of athletes' movements were very different during release and resistance phases in resist-and-release sprint running. The release phase revealed significantly higher takeoff velocity, horizontal and vertical velocities, larger step length, knee angle at touchdown, trunk angle at touchdown and takeoff, CG support displacement (Table 1). The resistance during the resistance phase resulted in significantly longer ground contact time and takeoff time, as well as in significantly shorter landing time compared to the release phase. Leg angle was significantly larger during the resistance phase (Table 1).

Significant differences were found between kinematic characteristics of the release phase and constant speed phase in free sprint running. Horizontal and takeoff velocities were significantly higher during the constant speed phase (Table 1). These differences are primarily due to significantly larger step length in the constant phase of free sprint running (1.97 ± 0.13 m versus 1.63 ± 0.14 m), because step frequency was the same in both cases. In the phase of constant speed in free sprint, as it usually happens when running at a higher speed, the ground contact time (125 ± 10 ms versus 144 ± 13 ms) was significantly shorter, and this difference was due to significantly shorter takeoff time during free sprint (70 ± 6 ms versus 93 ± 9 ms), whereas the landing time was the same. In the constant speed phase of free sprint, the support leg at touchdown was bent at the knee significantly less (knee angle 155 ± 5° and 144 ± 5° respectively, see also Figure 2) than in the release phase. In the constant speed phase of free sprint running, the trunk was tilted forward significantly less than in the release phase of resist-and-release sprint running (Table 1, Figure 2).

Table 1
Comparison of kinematic characteristics (Mean ± S.D. $_{p\ value}$) between release phase and resistance phase in resist-and-release sprint running, acceleration and constant speed phases in free sprinting (critical level of p value = 0.0166).

Characteristics	Acceleration	Constant speed	Resist	Release
TOV ($m \cdot s^{-1}$)	7.10 ± 0.53 $_{0.984}$	8.31 ± 0.61 $_{0.000}$	4.84 ± 0.60 $_{0.000}$	7.10 ± 0.53
$HV_{takeoff}$ ($m \cdot s^{-1}$)	7.07 ± 0.53 $_{0.984}$	8.28 ± 0.61 $_{0.000}$	4.83 ± 0.60 $_{0.000}$	7.06 ± 0.52
$VV_{takeoff}$ ($m \cdot s^{-1}$)	0.67 ± 0.11 $_{0.631}$	0.63 ± 0.09 $_{0.416}$	0.32 ± 0.09 $_{0.004}$	0.71 ± 0.23
Takeoff angle (°)	5.4 ± 1.0 $_{0.669}$	4.4 ± 0.7 $_{0.104}$	3.8 ± 1.1 $_{0.059}$	5.7 ± 1.9
Step length (m)	1.54 ± 0.08 $_{0.149}$	1.97 ± 0.13 $_{0.000}$	1.16 ± 0.04 $_{0.000}$	1.63 ± 0.14
GCT (ms)	140 ± 10 $_{0.403}$	125 ± 10 $_{0.001}$	163 ± 19 $_{0.012}$	144 ± 13
Landing time (ms)	45 ± 9 $_{0.098}$	55 ± 8 $_{0.373}$	16 ± 13 $_{0.000}$	52 ± 6
Takeoff time (ms)	96 ± 6 $_{0.301}$	70 ± 6 $_{0.000}$	147 ± 12 $_{0.000}$	93 ± 9
Leg angle (°)	83 ± 3 $_{0.013}$	72 ± 4 $_{0.045}$	95 ± 6 $_{0.000}$	77 ± 4
KneeAT (°)	136 ± 7 $_{0.039}$	155 ± 5 $_{0.002}$	129 ± 6 $_{0.000}$	144 ± 5
KneeAM (°)	134 ± 5 $_{0.549}$	140 ± 6 $_{0.030}$	131 ± 5 $_{0.022}$	135 ± 4
TrunkATD (°)	168 ± 8 $_{0.105}$	180 ± 4 $_{0.000}$	161 ± 9 $_{0.000}$	172 ± 7
TrunkATO (°)	149 ± 3 $_{0.658}$	159 ± 6 $_{0.000}$	143 ± 7 $_{0.001}$	150 ± 5
CGS displacement (m)	0.88 ± 0.06 $_{0.056}$	1.00 ± 0.10 $_{0.155}$	0.71 ± 0.12$_{0.000}$	0.95 ± 0,12

The smallest differences were found between the running techniques in the release phase of resist-and-release sprint and the acceleration phase of free sprint. The values of takeoff velocity and its horizontal (7.06 ± 0.52 $m \cdot s^{-1}$ in the release phase and 7.07 ± 0.53 $m \cdot s^{-1}$ in the acceleration phase) and vertical components, takeoff angle, and ground contact time remained very similar (Table 1). Non-significant differences were found between the values of step length and frequency, landing and takeoff time, knee angle at touchdown and midstance, CG support displacement, and trunk tilt at touchdown and takeoff. Only leg angle was found significantly larger at about five meters from the start mark in free sprint running than after six meters in the release phase of resist-and-release sprint running (83 ± 3° and 77 ± 4° respectively, p = 0.013). No significant differences were found for step frequency and thigh angle at touchdown and takeoff between release and resistance phases in resist-and-release sprint running and free sprint running phases (ANOVA).

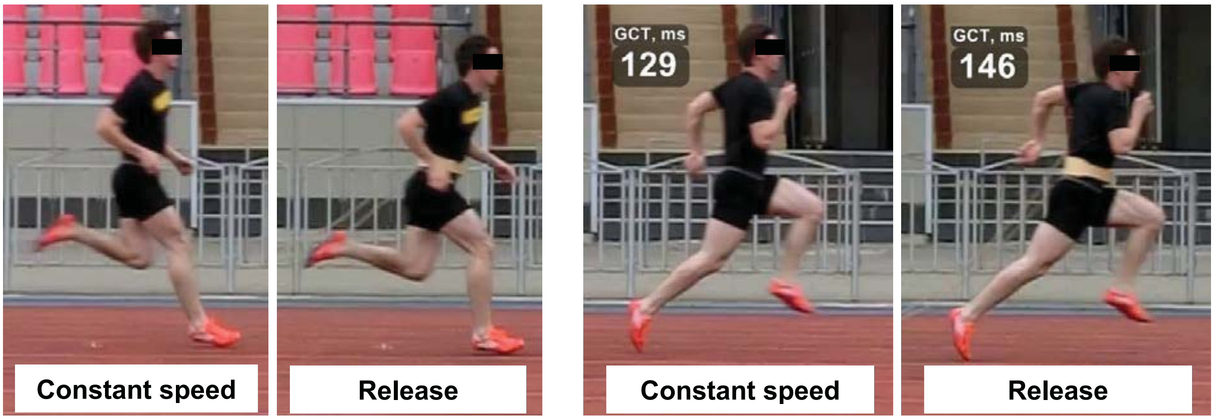

Figure 2: Typical differences in running technique between constant speed phase in free sprint running and release phase in resist-and-release sprint running at touchdown and takeoff.

DISCUSSION: This study revealed significant changes in running technique during the resistance phase of resist-and-release sprint running due to the resistance value created by an assistant; however, these changes only partially coincide with the results of the previous studies. Thus, Martínez-Valencia et al. (2014) established that increasing the load by 30 % of

body mass in sled-towing sprints entails significant decrease in stride length, from 1.58 ± 0.11 m in free sprint to 1.40 ± 10 m. However, sled-towing running also revealed significant decrease in stride frequency, compared to unloaded sprint, from 4.40 ± 0.31 Hz to 4.15 ± 0.25 Hz, whereas in the present study the differences in step frequency between loaded and unloaded parts of resist-and-release sprint running were only non-significant. Alcaraz et al. (2008) found the significant decrease of stride length in both male and female sprint groups, and only non-significant decrease of stride frequency in sled-resisted sprint loaded by 16% of body mass, compared to free sprint; however, trunk position at touchdown and takeoff in sled-resisted sprint significantly changed only in the male group, whereas the present study showed significant differences of trunk position between loaded and unloaded phases of resist-and-release sprint running in the mixed male-female group.
Low horizontal velocity at takeoff, short step length and significant trunk tilt in the resistance phase of resist-and-release sprint found by the present study suggest a large resistance produced by assistant. In these conditions, after six meters of running without the assistant resistance, the technique of running was similar to the running technique after the fifth step in free sprint. The increase of running speed after the removal of resistance was no bigger than in the free sprint acceleration phase: the athletes had the same horizontal takeoff velocity after the fifth step in free sprint and after six meters from the beginning of the release phase in resist-and-release sprint (4-5 steps); however, in the first case the increase in horizontal velocity started from zero, whereas in the second case – from 4.83 ± 0.60 $m \cdot s^{-1}$. The present study did not investigate the features of the running technique after the sixth meter of the release phase in resist-and-release sprint; it is probable that the sprinter's movements would become more similar to running in the constant speed phase of free sprint.

CONCLUSION: Thus, the present study showed that the running technique in the resistance phase of resist-and-release sprint running looks like the one in other types of resisted running, especially sled-resisted running. The release phase of resist-and-release sprint running did not reveal any immediate increase in horizontal velocity more than in free sprint after the removal of assistant's resistance: after six meters of unloaded running, the kinematic characteristics of the sprinter's movements are the same as after five steps in the free sprint acceleration phase (except leg angle: in resist-and-release sprint the support leg is placed much further ahead). Many kinematic characteristics of sprinter's movements after six meters of running in the release phase significantly differ from those in the constant speed phase of free sprint. The information in this paper makes it possible to better understand the influence of resist-and-release sprint running when training on sprinter's performance at different phases of free sprint running and the place of this exercise in a year cycle of training.

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