DIFFERENCES IN RUNNING BIOMECHANICS OF ELITE SPRINTERS, NON-ELITE SPRINTERS AND NON-RUNNERS

Svetlana Rezvanova[1], Alexey Bobyrev[1], Dmitriy Skvortsov[1]

Moscow Centre of Advanced Sport Technologies, Moscow, Russian Federation[1]

The aim of the study was to investigate key predictors of fast sprinting. For this purpose, three groups of subjects were evaluated: elite sprinters, non-elite sprinters and non-runners. The analyzed groups consisted of 7, 9 and 11 subjects, respectively. Biomechanical running parameters were collected during the 30-meter acceleration up to maximum speed achievable by the subject. The obtained results revealed clear differences in running biomechanics among the all groups (contact time and step length normalised to body height). Also group results for «step length>body height» and «RSI>1 showed, that the values of these parameters are available only for elite sprinters and non-elite sprinters groups. Date also showed step length normalised to body height to be a highly informative predictor of sprint performance (its correlation coefficient with maximum speed being 0.81).

KEYWORDS: sprint, running biomechanics, reactive strength index, step length normalised to body height.

INTRODUCTION: In sprint, the winner and the losers are separated by splits of seconds, and the running technique, along with other factors, is of critical importance. Therefore, it is essential to study the predictors and parameters of fast running in order to identify those with best correlation with maximum speed. According to earlier relevant studies (Mero et al.,1992; Bezodis, 2009), the most important speed-related parameters include contact time, step frequency, step length, etc. (Morin et al.,2012). Even in a short 30-m run, the subject's acceleration can be divided into two phases: rapid speed gain and slow speed gain. There is, however, little information in the literature as to what parameters characterise optimal running, and whether they differ significantly between good runners and non-runners.
The main objective of our study was to learn more about key predictors of fast sprinting, and to characterise in more detail the running biomechanics of people who are not highly qualified sprinters and those who are not runners at all, in order to understand how sprinter running pattern differs from the natural one developed as a result of human evolution.
Our study also aimed to better understand the concept of speed running. We were interested in the biomechanics of the second phase of running, where the speed is already more stable. There is a study that contains information that the body height and weight parameters of elite sprinters are less variable than in the normal population (Niels, 2005), but there are practically no data on the step length normalized to body height in the literature. However, it is known that the absolute step length plays one of the key roles for speed, along with the step frequency (Delecluse, 1998).
The study hypothesis was that the parameter *step length normalised to body height* would be associate with fast running.

METHODS: A total of 27 subjects participated in the study (weight = 63.2 ± 10.9 kg height = 1.76 ± 0.08 m),12 females, 15 males. Three groups of subjects were investigated. The first group included elite athletes who were top sprinters in the Russian Federation and winners of Russian national competitions in 2017-2019 (n=7). The second group included non-elite sprinters with at least 4-5 years' experience in athletics, but with moderate sprinting performance (n=9). The third group included ordinary physically active people without physical disabilities (n=11). Running biomechanics was assessed using a floor-based photocell system (Optogait, Microgate, Bolzano, Italy). Data were collected during 30-m acceleration runs, up to maximum speed achievable by the subject from the high-start position (same as the *on your marks* position in a 800-m run). The starting position was chosen because non-runners could not start successfully from the starting blocks. The start conditions, however, had to be the same for all study subjects. In this study, we only analysed running biomechanics (30-m acceleration) and excluded the start phase data. The following parameters were analysed for each subject: average contact time (avgCT[s]), average flight time (avgFT[s]), average step frequency (avgSF[step/sec]), average step length (avgSL[m]), average step length normalised to body height (avgSLN[BH%]), average reactive strength index (avgRSI[flight time/contact time]).The 30-m run was divided into two segments: 1) fast acceleration segment (with a fast gain of speed after start) and 2) a slower acceleration segment. The above parameters were averaged over the second segment, the one with slow acceleration. Average speed (avgS[m\s]), maximum step length (maxSL[m]), average acceleration (avgA[m/s²]), flight phase in % of run distance (FP[%]) and contact phase in % of run distance (CP[%]) were calculated over the entire run distance.The step number at which flight time exceeded contact time (RSI >1), the step number at which step length began to exceed the subject's hight (step length>body height), the length of fast start acceleration segment (FSAL[m]) and maximum speed (MS[m/s]) were also measured. Data correspond to normal distribution (Kolmogorov-Smirnov test). Statistical parameters such as mean and standard deviations of variables and intergroup differences were calculated using the Kruskal-Wallis test (with the Bonferroni adjustment). Spearman correlation coefficients were used to identify variables that contributed to maximum and mean speeds; the selected variables were tested at the 0.05 significance level.

RESULTS: A correlation analysis on the entire subject population (n=27), disregarding the group, showed that maximum speed and average speed correlated with mavgSLN, mavgCT and avgA better than with any other parameters under study (Table 1). Less significant correlations were noted for avgSF, avgRSI, maxSL.

Table 1: Results of correlation analysis for maximum speed and average speed

№	Independent parameters	Mean	±SD	r Maximum speed	r Average speed
1	average step frequency (avgSF[step/sec])	4.2	±0.3	**0.7***	**0.65***
2	average contact time (avgCT[s])	0.13	±0.118	**-0.86***	**-0.83***
3	average flight time (avgFT[s])	0.107	±0.112	-0.09	-0.05
4	average step length (avgSL[m])	1,62	±0.185	**0.49***	**0.53***
5	step length normalised to body height (avgSLN[BH%])	93.5	±16.9	**0.81***	**0.84***
6	average reactive strength index (avgRSI [flight time/contact time])	0.80	±0.16	**0.66***	**0.66***
7	flight phase, % of run distance (FP[%])	41.4	±5.9	**0.52***	**0.53***
8	contact phase, % of run distance (CP[%])	58.6	±5.9	**-0.51***	**-0.52***
9	average acceleration (avgA[m/s²])	0.48	±0.15	**0.92***	**0.90***
10	maximum step length (maxSL[m])	0.177	±0.020	**0.74***	**0.77***
11	fast start acceleration length (FSAL[m])	9.2	±1.8	0.23	0.24

* Values in bold mean that the correlations are significant at p <0.05.

After the correlation analysis we determined whether the groups differed in terms of parameters most closely related to running performance. AvgSLN, avgCT, avgSF, avgRSI, maxSL and avgA were tested for intergroup differences. Significant differences in avgSLN and avgCT were found among all the 3 groups, whereas avgRSI and avgA differed only between the elite sprinter group and the non-runner group (Table 2).

Table 2: Results of Kruskal-Wallis for parameters selected based on correlation analysis

Parameter	Kruskal-Wallis test ($p < 0.016$, with Bonferroni adjustment)
AvgSLN	$X^2(N=27)=13.04$; $p=0.005$
avgCT	$X^2(N=27)=18.17$; $p=0.001$
avgRSI	$X^2(N=27)=12.2$; $p=0.002$, the differences are significant only between the groups of elite sprinters and non-runners
avgA	$X^2(N=27)=13.1$; $p=0.001$, the differences are significant only between the groups of elite sprinters and non-runners

Since avgSLN was shown to be a reliable predictor of running performance, we also calculated at what step the length of running step began to exceed the subject's height in a 30-m running distance. According to our findings, this happened at step 10.8 ± 2.3 in the elite-sprinter group, at step 12.8 ± 0.8 in the non-elite sprinter group, and never in the non-runner group (Table 3).

Table 3: Group results for «step length>body height» and «RSI>1»

Independent variables	Elite sprinters	Non-elite sprinters	Non-runners
step number at which step length began to exceed subject's height (step length > body height)	10.8±2.3	12.8±0.8	no
step number at which the RSI exceeded 1 (RSI >1)	9.3±1.4	In 5 subjects RSI did not exceed 1; In 4 subjects RSI exceed 1 at step 13.5±1	no

DISCUSSION:

Our findings related to the avgCT maximum speed and average speed correlation are consistent with earlier data (Morin et al., 2012). However, we also obtained new data on predictors of fast running. Since frequent and long steps are most effective for running, avgSLN is a very important indicator of running performance. It is much more informative than average step length (avgSL correlation coefficient with maximum speed being 0.49) and can be used to assess the running performance of elite and non-elite sprinters as well as non-runners. It was shown that professional sprinters could reach a step length that exceeded their height much earlier than non-runners and hence they needed fewer steps to make the distance and did it at a higher speed.

The most informative running parameters also include average acceleration: only good sprinters can develop high acceleration when running 30 m.

As expected, the informative value of other parameters, such as average step frequency, average reactive strength index and maximum step length, was confirmed and not only for elite and non-elite sprinters, but also for subjects never engaged in professional sprinting. Therefore, these parameters can also be used to assess the running performance of non-sprinter athletes for whom fast running is an important part of successful performance rather than the main activity (e.g., team sports such as football and basketball).

In earlier studies, it was shown that between elite and non-elite sprinters there are significant differences in reater take-off swing leg hip flexion and trunk lean; longer duration start time; and longer first step length in elite sprinters (Lockie et al., 2013). The parameters avgSLN and avgCT not only showed a strong correlation with maximum speed and average speed, but also differed significantly among the three groups. Since avgRSI and avgA differed significantly only between the groups of elite sprinters and non-runners, they probably reflect to some extent the difference between elite sprinting and normal running.

This is confirmed by the data on "step length > body height" and "RSI > 1" for groups. Apparently, the biomechanics of natural running differs from that of professional sprinting.

While all elite sprinters reached a running step length that exceeded their height, only 5 of 9 non-elite sprinters showed a similar result. Apparently, this can be explained by the difference in strength between elite and non-elite sprinters, and strength is among the key determinants of speed (Maughan et al., 1983).

CONCLUSION:

The results of the study suggest that *step length normalised to body height* (an indicator not previously described in the studies of running biomechanics) is a quite reliable indicator that can be used to assess the sprinting performance of professional runners as well as athletes in other sports that use running. Presumably, this data can be used for running training for each athlete, using mini-hurdles at a given individual distance. Also, RSI data confirms the effectiveness of its use for stage performance testing. Also, it should be noted that sprinting biomechanics is not innate to humans but can only be acquired by training and appropriate physical conditions.

REFERENCES

Bezodis, N. E. (2009). Biomechanical investigations of sprint start technique and performance. A thesis submitted for the degree of Doctor of Philosophy.

Delecluse, C.h., Ponnet, H., Diels, R. Stride characteristics related to running velocity in maximal sprint running.[w:] Riehle, H.J., Vieten, M/M. (red) Proceedings II of XVI International Symposium on Biomechanics in Sports. ISBS. 1998:146–148

Lockie, R.G., Vickery, W.M. (2013). Kinematics That Differentiate the Beach Flags Start Between Elite and Non-Elite Sprinters. Biol Sport, 30 (4), 255-61.

Maughan, R.J., Watson, J.S., Weir, J. (1983). Relationships between muscle strength and muscle cross-sectional area in male sprinters and endurance runners. European Journal of Applied Physiology and Occupational Physiology, 50(3), 309–318.

Mero, A., Komi, P.V., Gregor, R.J. (1992). Biomechanics of sprint running. Sports Medicine,13(6), 376–392.

Morin, J.B., Bourdin, M., Edouard, P., Peyrot, N., Samozino, P., Lacour, J.R. (2012). Mechanical determinants of 100-m sprint running performance. J Appl Physiol,112(11), 3921–3930.

Morin, J.B., Samozino, P., Zameziati, K. Belli, A. (2007). Effects of altered stride frequency and contact time on leg-spring behavior in human running. Journal of Biomechanics, 40(15), 3341-3348.

Niels, Uth. Anthropometric comparison of world-class sprinters and normal populations. Journal of Sports Science and Medicine (2005) 4, 608-616.