Dynamics and energy of starting acceleration of sprinter students and the strongest runners in the world

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Dr. Hab. **V.D. Kryazhev**[1]
R.E. Petrova[2]
A.Yu. Sheveleva[3]
PhD, Professor **A.A. Karpushkin**[4]
[1]Federal Science Center of Physical Culture and Sport (VNIIFK), Moscow
[2]Yelabuga Institute (branch) of Kazan (Volga Region) Federal University, Kazan
[3]Russian State Social University, Moscow
[4]Penza State University, Penza

Corresponding author: kryzev@mail.ru

Abstract

Objective of the study was to compare the kinetic and dynamic indicators of the starting acceleration of student sprinters and the strongest athletes in the world.

Methods and structure of the study. The scientific work used experimental data on the spatio-temporal characteristics of the starting run at a distance of 100 m from eight students with results in the range of 11.08-11.45 s, as well as data from a report on the biomechanical study of the dynamics of running of participants in the finals of the 2017 World Championships in Athletics, having a result of 9.92–10.08 s. Using the least squares method, the constants (Vmax и Tau) of the running model equation $V(t) = Vmax \times (1-e^{-t/\tau})$ were selected. Based on this model, with the help of Newton's dynamics equations, the acceleration, force and mechanical power developed by athletes in time in the horizontal-longitudinal direction were calculated.

Results and conclusions. The greatest differences were found in the values of the maximum mechanical power developed in the horizontal-longitudinal direction. The strongest athletes of the world recorded an average value of 2435 ± 203 W, and for student runners - 1532 ± 224 W, which is 58.9% less, $p \leq 0.05$. The theoretical value of the maximum horizontal force at the initial moment of acceleration was 814±79 and 616±34 N for elite athletes and students, respectively. The difference is 32.1%, $p \leq 0.05$. Large amounts of strength and power allow world-class sprinters to reach a maximum speed in the range of 11.6–12.2 m/s, which is on average 17.2% higher than that of student runners.

Keywords: *100m run, starting acceleration, mathematical modeling, kinetics and energy of running, students, elite athletes.*

Introduction. The most significant factors that determine the result in sprinting are the value of the maximum speed achieved and the value of the mechanical power developed in the longitudinal direction, which depends on the forward force and its relation to the resulting support reaction [5].

For a long time, these data were recorded on the basis of a biomechanical analysis of the results of high-speed filming, the use of a laser speed meter and long strain gauge platforms [3].

Recently, these indicators can be obtained based on a simple method of calculating the kinetics from the data of the velocity dynamics, which can be obtained on the basis of the mathematical method of iteration - the selection of the parameters of the velocity equation until the coincidence, calculated using its data, with the spatio-temporal characteristics of the starting run [3].

Objective of the study was to compare the kinetic and dynamic indicators of the starting acceleration of student sprinters and the strongest athletes in the world.

Methods and structure of the study. Spatio-temporal characteristics of the starting run of eight sprint students aged 19-20 years (height - 177.4±2.1 cm, weight - 68.6±2.7 kg) with a sports result in the 100 m run 11 08-11.45 s. Athletes completed two attempts in the 100m race from a low start. Using the analysis of a video recording of a run made by an Apple 6 smartphone at a frequency of 240 fps and mounted on a rotating tripod, the time to overcome 5, 10, 15, 20 and 30 meter segments of the distance

Values of kinetic and energy indicators of starting acceleration in 100 m run among students and finalists of IAAFWCA2017 (M±SD)

Athletes	Constants models		Theoretically maximum values			Max Power	
	V_{max}		F_{H0}		V_0	P_{max}	
	m/s	s	N	N/kg	m/s	W	BW/kg
Students	9,9 **±0,15**	1,10 ±0,07	616 **±34**	8,9 ±0,5	10,2 **±0**,23	1532 **±224**	22,3 **±3**,3
Finalists WCA 2017	11,6 ± 0,11	1,15 ± 0,05	814 **±79**	10,2 **±0**,8	12,1 **±0**,15	2435 **±203**	30,5 ±2,5
Difference,%	17,2*	4,3	32,1*	14,6*	18,6*	58,9*	36,8*

– **p**≤0.05. FH0 is the value of the forward force at the initial moment of time.
V0 is the value of the maximum running speed in the absence of air resistance.

was recorded [1]. Then, based on the least squares method, the values of the constants (Vmax and Tau) were selected in the velocity modeling equation V (t) = Vmax*(1-e ($^{-t/\tau}$). Based on Newton's equations of dynamics, the values of velocity, acceleration, horizontal force, and mechanical power were calculated [1, 3]. Starting acceleration data of the strongest runners in the world, taken from the protocol of biomechanical analysis of the final 100 m race at the 2019 World Championships in London [2] (n=6, height - 183.2 ± 3.6 cm; weight - 79.8 ± 4.1 kg; sports result - 9.98±0.03 s) were subjected to the same calculation procedure.

Results of the study and their discussion. The most significant differences are observed in the indicators of maximum running speed, in the magnitude of the forward force, in the magnitudes of mechanical power developed in the horizontal direction (see table).

Differences in acceleration and instantaneous speed are already observed in the initial section of acceleration. These differences increase as the distance is covered, and at the 6th second, the differences in running speed reach a maximum value of 1.5 m/s (Fig. 2).

The analysis of the "strength-speed" profile shows that at the start, the best sprinters, although they are superior in terms of strength registered among students, but these differences are most significant at a speed of 10 m/s, which makes it possible for them to further increase their speed (Fig. 1). At this time, the force developed by the students becomes equal to the force of air resistance and the acceleration stops. The advantages of world-class sprinters are due not only to greater power capabilities, but also to the most efficient use of the repulsive force, directing most of it compared to forward students to move forward [5]. The energy of starting acceleration in the strongest

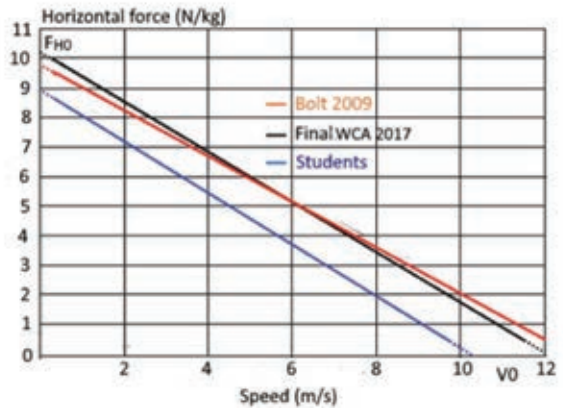

Figure 1. *Constructed average strength-speed profiles of students and participants in the finals of the World Championship 2017 and U. Bolt when setting a world record in 2009 (according to [4])*

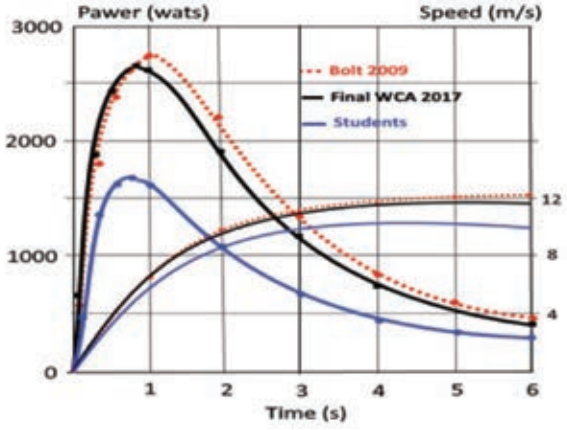

Figure 2. *Models of the dynamics of running speed and mechanical power developed in the horizontal direction by students and the strongest athletes of the world in the starting acceleration of 100 m running*

athletes of the world is characterized by a significantly greater value of mechanical power developed in the horizontal direction, which is in good agreement with previously obtained data [4, 5].

Conclusion. The obtained results confirm the prevailing notion that the most important indicators of achieving a sprint result are the maximum speed and maximum power developed by runners in the starting run. In addition, the running of the world's strongest athletes is characterized by a higher efficiency of using the resulting repulsion force, which makes it possible to develop large efforts in the longitudinal direction even at high running speeds.

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