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Morphologic and Kinematic Characteristics of Elite Sprinters

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A B S T R A C T

The purpose of the study was to ascertain the basic morphologic and kinematic characteristics of elite sprinters. The sample included 24 sprinters, with times over a 100 m distance between 10.21 s and 11.19 s. Morphologic characteristics of the sprinters were measured with a test battery of 17 measures, obtained according to the methodology prescribed by the International Biologic Programme (IBP). The kinematic variables were obtained from a flying start 20 m run and a 20 m run with a low start, with the technology of a contact carpet (ERGO TESTER – Bosco). Stride frequency and length, duration of contact and flight phases were registered. Time parameters were measured with a system of infrared photocells (BROWER Timing System). T-test showed that elite sprinters do not differ significantly in morphologic characteristics (p > 0.05) from the 100 m results point of view. However, statistically significant differences were obtained in starting acceleration and maximal velocity. The most important kinematic parameters for generating differences between the elite sprinters are contact time and stride frequency.

Introduction

Sprinting velocity is the product of stride rate and stride length. Both parameters are interdependent and individually conditioned with the processes of central regulation of movement, morphologic and physiologic characteristics, motor abilities and energy factors[1–7]. Sprint, as a motor stereotype of human locomotorics, consists of repetitions of strides. The length of the stride depends mainly on body height or leg length and the force developed by the extensors of the hip, knee and ankle joints in the contact phase. On the other hand, stride rate depends on the functioning of the central nervous system on the cortical and sub -cortical level and is strongly genetically determined[8–10]. The ratio between both parameters is individually defined and automated. Increasing stride rate results

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in shorter stride length and vice-versa. Maximal sprinting velocity is actually the result of an optimal relation between the stride length and stride rate of the athlete.

The result in sprint depends on the integration of four phases: starting block phase (reaction time + pushing phase on the blocks), starting acceleration phase, constant – maximal velocity and deceleration phase[10]. From the biomechanical point of view, the rate, length, contact time and flight time of the strides change in these phases[11–14]. Some studies[3,9,10,15–17] show that the duration of the contact phase is one of the most important factors defining the rate and length of the strides and consequently also maximal sprinting velocity.

The aim of our study was to find which morphologic and kinematic characteristics most differentiate sprinters in the competitive 100m sprint results. The flying 20m test was used to measure the kinematic parameters of maximal velocity and the low start 20m run for the kinematic characteristics of the starting acceleration.

Material and Methods

Twenty-four sprinters participated in the experiment. They were divided into two groups of twelve subjects each, according to their competitive 100m sprint time. In the first, better group (group A), the average age was 23.9 3.88 years, average length of training was 7.5 4.42 years, average 100m sprint time 10.52 0.19s, the best athlete's time 10.21s. In the second, worse group (group B), the average age was 22.7 4.05 years, average length of training 7.33 2.10 years, average 100m result 11.09 0.12s, the best 100m time 10.92s.

Measurements of the 100m sprint were performed on a track with a tartan surface. The two 20m tests were performed indoors on a tensiometric carpet (ERGO TESTER – BOSCO) of length 20m and width 0.80m. Each subject performed four runs. Specially written software (SPRINT) was used to obtain the following kinematic parameters: stride rate and frequency, contact times and flight times. The flying start and low start 20m times were measured with a system of infrared photocells (BROWER Timing System). The morphologic characteristics of the sprinters were assessed with a battery of seventeen measures, obtained by the procedures proposed in the International Biologic Programme (IBP) and measured by a professionally trained medical team. The SPSS statistical package was used for data analysis.

Results

The results in Table 1 (T-test) show that the two groups of elite sprinters do not differ significantly in the morphological parameters. Only the diameter of the knee measure is on the verge of statistical significance. The athletes are equal in body height, leg length, body mass, thigh and calf circumferences. The differences in skin-folds are somewhat more noticeable but not statistically significant. Sprinters in the better group have in general a little less subcutaneous fat in the stomach, thigh and forearm areas. This can be seen also from the proportion of fat (after Matiegka)[18], which is 0.4% larger in group B than in group A. The better sprinters group has 1.59% more muscular mass (after Matiegka)[18] than the group with worse sprinting times. The groups are almost completely equal in the bone mass index.

Table 2 gives the differences between the two groups of athletes in the kinematic parameters of maximal sprinting velocity and starting acceleration. They differ significantly ($p < 0.01$) in the starting acceleration ability and in maximal velocity. The contact time of maximal ve-

TABLE 1
MORPHOLOGIC CHARACTERISTICS OF ELITE SPRINTERS

Variable	Unit	Group A (n = 12)		Group B (n = 12)		T-Test	
		M	SD	M	SD	T	P(T)
Body height	cm	180.78	6.00	181.86	4.94	0.149	0.883
Body weight	kg	80.98	6.43	80.52	8.53	–0.049	0.637
Body mass index (BMI)	kg/m^2	24.72	1.76	24.31	1.64	–1.342	0.185
Length of leg	cm	102.28	5.38	104.48	3.65	–1.172	0.254
Thigh circumference	cm	60.90	3.00	59.60	3.72	0.942	0.357
Shank circumference	cm	40.73	2.17	40.02	2.70	0.717	0.481
Shoulder diameter	cm	40.92	1.56	41.89	1.50	–1.559	0.133
Pelvic diameter	cm	28.14	1.58	29.07	1.49	–1.476	0.154
Knee diameter	cm	9.58	0.59	10.01	0.46	–1.973	0.061
Ankle diameter	cm	7.68	0.54	7.71	0.40	–0.129	0.899
Triceps skin-fold	mm	4.80	1.93	5.83	1.84	–1.344	0.193
Abdominal skin-fold	mm	7.30	2.77	8.45	3.74	–0.856	0.401
Front thigh skin-fold	mm	6.80	2.74	7.87	2.41	–1.012	0.322
% fat -Matiegka	%	7.81	1.20	8.28	1.72	–0.771	0.449
Muscular mass – Matiegka	kg	45.31	4.14	43.83	5.87	0.715	0.482
% muscular mass-Matiegka	%	55.93	2.20	54.34	2.83	1.539	0.138
Bone mass – Matiegka	kg	16.31	1.16	16.77	0.94	–1.054	0.303
% bone mass – Matiegka	%	20.20	1.37	20.95	1.45	–1.314	0.202

TABLE 2
KINEMATIC PARAMETERS OF MAXIMAL VELOCITY AND STARTING ACCELERATION OF ELITE SPRINTERS

Variable	Unit	Group A (n = 12)		Group B (n = 12)		T-Test	
		M	SD	M	SD	T	P(T)
Sprint 100m	s	10.52	0.19	11.09	0.12	–8.844	0.000**
20m with flying start	$m.s^{-1}$	10.22	0.22	9.73	0.27	4.914	0.000**
Stride length	m	2.21	0.12	2.17	0.07	0.908	0.374
Stride rate	Hz	4.64	0.23	4.49	0.14	1.950	0.064
Contact time	ms	89.76	5.33	95.58	4.68	–2.889	0.009**
Flight time	ms	126.25	9.83	127.75	6.18	–0.448	0.659
Proportion of contact time	%	41.53	2.25	42.84	1.80	–1.573	0.130
Proportion of flight time	%	58.47	2.25	57.16	1.80	–1.576	0.131
20m from low start	$m.s^{-1}$	6.74	0.09	6.54	0.15	3.863	0.001**
Stride length	m	1.73	0.14	1.69	0.12	0.766	0.452
Stride rate	Hz	4.52	0.22	4.40	0.14	1.655	0.112
Contact time	ms	120.92	9.34	127.25	5.34	–2.039	0.054*
Flight time	ms	98.80	7.16	98.25	6.93	0.203	0.841

* $p < 0.05$; ** $p < 0.01$

locity and starting acceleration is that factor which significantly ($p < 0.01$) differentiates between better and worse sprinters. The maximal stride rate parameter is on the verge of statistical significance ($p = 0.05$). Better sprinters have a 4 cm longer stride than worse ones, but this difference is not statistically significant, nor is the difference between the groups in stride length and rate in the starting acceleration.

Discussion

The results of the study lead us to find that morphologic characteristics are not an important generator of differences between sprinters, according to their success in the 100m sprint. The groups are very equal in the basic constitutional parameters, such as body height, leg length, body mass, shoulder and pelvic diameter. This is also confirmed by the body mass index (BMI = body mass / body height^2) of both groups. For the better group, BMI is 24.72, for the worse one 24.31. In spite of having 2.2 cm longer lower extremities, sprinters in the worse group have a stride length 4 cm shorter than the better group. Stride length is obviously defined also by other factors besides leg length, among these especially the force of the extensors of the ankle and knee joints[3,10] is important since it produces the push-off impulse in the contact phase. However, we also find that the differences between the two groups in the circular measures of the lower extremities (thigh and calf circumferences), where force is generated, prove to be non-significant. Certain authors[2,19] have found a positive correlation between thigh circumference and results in the 100m sprint. The only morphologic parameter, which differentiates (on the verge of statistical significance) better sprinters from worse ones is knee diameter, with worse sprinters having knees 0.43 cm wider. They also have a larger proportion of bone mass. We can therefore conclude that elite sprinters are distinguished by »light bones« and an optimal amount of muscular mass. Better sprinters in our sample have, on the average, 1.6% more muscular mass than the ones in the worse group. The proportion of muscular mass is of course not the only relevant factor of developing velocity, so is the efficiency of the bio-chemical energy processes in the participating muscles of the sprinters and intra-muscular co-ordination of agonists and antagonists[20].

The results in Table 2 show that the most important generator of differences ($p < 0.01$) in sprinting quality among the kinematic parameters is contact time. Luhtanen and Komi[17] divide the contact phase of the sprinting stride into two parts: braking phase and propulsion phase. The sum of both is total contact time, amounting for elite world-class sprinters to 80–85ms[21–24]. The most important role in economical sprint running goes to the ratio between the braking phase and the propulsion phase, which should be 40:60. The shorter the braking phase, the lesser the reduction in horizontal velocity of the body center of gravity – BCG[10]. The average contact time of the better group of our sprinters is 89.7ms, the worse group 95.6ms. The fastest athlete of our sample, with a personal best of 10.21s, has a contact time of 86.7ms. The duration of contact depends mostly on vertical force, which amounts for elite sprinters in the maximal velocity phase to 1778 76 N[23]. The largest surface reaction force in the contact phase happens 10 to 40ms after contact of the foot with the surface. In order for the muscles of the leg to be able to withstand such force, they must be adequately pre-activated and at the same time the stretch-reflex mechanism, which ensures proper stiffness of the muscles, must be activated. The muscle rectus femoris has a key role in this[20].

In the duration of the flight phase parameter the groups do not differ. Better sprinters have on the average only a 1.5ms shorter flight time. However, it is the ratio between the contact time and the flight time that is important in the kinematic structure of the sprinting stride. For better runners (group A) this ratio is 41:59, for worse sprinters (group B) 43:57. Better sprinters are therefore characterized by a shorter contact phase and longer flight phase and worse sprinters the opposite.

The second kinematic parameter of maximal velocity, which is on the verge of statistical significance ($p = 0.06$) and differentiates sprinters according to quality, is stride rate. Better sprinters have on the average a rate 0.15 strides/s higher than worse ones. The fastest sprinter in our sample has also the highest absolute stride rate of 4.93 strides/s. The results of this study confirm the findings of certain authors[8,12,16,25], that stride rate has a more important role in realizing maximal velocity than stride length. There is no statistically significant difference between the groups in our experiment in the average stride length. Stride length is a complex kinematic parameter, dependent on numerous factors, among these the morphologic characteristics of the sprinter are important, especially leg length. Maximal sprinting velocity is the result of an optimal model of stride rate and stride length[26,27] for the individual athlete. This model is fixated in a motor program in the central nervous system and is very individually defined. Donatti (1995)[8] gives a formula for computing the optimal stride length (stride length = leg length   2.60 / 100m + 10%; ex: 1.02   2.60 = 2.652, 100m/ 2.652 = 37.70 strides + 10% = 41.47 strides/ 100m). The optimal theoretic model of the 100m sprint is, according to this formula, for the better group 41.47 strides and for the worse group 40.66 strides. The actual number of strides of the better group was 45.24 and the worse group 46.08. The worse group of sprinters therefore shows a greater departure from their ideal number of strides (5.42) than the better group, where the difference is on the average just 3.67 strides over the 100m distance.

In the starting acceleration, where the two sub-samples significantly differ in quality ($p < 0.01$), the kinematic parameters change very dynamically, from the stride length and rate point of view, as well as according to the duration of the stride contact and flight phases[28,29]. The stride rate and length increase, the contact times shorten and the flight times lengthen. Average contact time is the only one that significantly differentiates the sprinters in the starting acceleration. Better sprinters have on the average contact times 6.33ms shorter than worse sprinters. It is quite surprising that the two sub-samples do not differ in stride rate, since it would be logical to suppose that shorter contact times generate higher stride rates. Obviously this phase of sprinting does not depend only on the biomechanical structure of the strides but equally on an efficient start and proper inter-muscular co-ordination of agonists and antagonists while increasing sprinting velocity.

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MORFOLOŠKE I KINEMATIČKE KARAKTERISTIKE ELITNIH SPRINTERA

S A Ž E T A K

Cilj ovog istraživanja bio je ustanoviti osnovne morfološke i kinematičke karakteristike elitnih sprintera. Uzorak je uključio 24 sprintera, s vremenima na 100 m između 10.21s i 11.19s. Morfološke karakteristike sprintera izmjerenu su najboljom baterijom testova od 17 mjera, prema metodologiji Međunarodnog biološkog programa (IBP). Kinematičke varijable dobivene su mjerenjem letećeg starta s 20 m trčanja i 20 m trčanja s niskim startom, tehnologijom kontaktnog tepiha (ERGO TESTER – Bosco). Zabilježeni su: učestalost i duljina koraka, vrijeme faze kontakta i faze letenja. Vremenski parametri mjereni su sustavom infracrvenih fotoćelija (BROWER Timing System). T-test je pokazao kako se elitni sprinteri ne razlikuju značajno u morfološkim karakteristikama ($p > 0.05$) ako se usporede prema rezultatima trčanja na 100 m. Međutim, statistički značajne razlike dobivene su u startnoj akceleraciji i najvećoj brzini. Najvažniji kinematički parametar po kojemu se elitni sprinteri razlikuju je vrijeme kontakta i učestalost koraka.