FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 4, N° 2, 2006, pp. 103 - 114

Scientific Paper

THE BIOMECHANICAL MODEL OF THE SPRINT START AND BLOCK ACCELERATION

UDC 796-012.4

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Abstract. *The study analyzed and identified the major kinematic parameters of the phases of the sprint start and block acceleration that influence the results of sprint running. The biomechanical measurements and kinematic analysis were performed on the best world's best sprinter during his preparation for the European Athletics Championship in Goetebourg in 2006. In this competition, Matić Osovnikar won the bronze medal in the 100-metre run and set the Slovenian national record with 10.14 s. The kinematic parameters of the sprint start were established on the basis of a 2-D kinematic analysis, using a high-speed camera with a frequency of 200 frames/sec. The measurements of the block acceleration were made by means of the Opto Track technology and an infra-red photo cell system. The athlete performed five, 20m low-start sprints under constant and controlled measurement conditions. The subject of the study was the set position from the point of view of the height of the total body's centre of gravity (TBCG), the block time at the front and rear blocks, block velocity, the block face angle, the velocity of the TBCG in the first three meters and the kinematic parameters of block acceleration in the first ten steps. The study showed the following were the key performance factors in the two phases of sprint running: medium start block distance, block velocity, low block face angles, first step length, low vertical rise in the TBCG in the first three meters of block acceleration, contact phase/flight phase index in the first ten steps and the optimal ratio between the length and frequency of steps.*

Key words: *sprint start, block acceleration, technique, kinematics, top sprinter*

1. INTRODUCTION

The sprint start and block acceleration are two extremely important phases which directly generate the results in a 60 m, 100 m, 200 m and 400 m sprint. It is no coincidence that many authors have delved into the biomechanical factors of these two phases to ex-

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Received September 6, 2006

plain the phenomenon of sprint velocity (Hoster, 1981; Mero, Luhtanen & Komi, 1983; Moravec, Ružička, Sušanka, & Nosek, 1988; Tellez & Doolittle, 1984; Mero, 1988; Coppenolle & Delecluse, 1989; Coppenolle, Delecluse, Goris, Diels, & Kraayenhof, 1990; Bruggemann & Glad 1990; Mero & Komi, 1990; Guissard, Duchateau, & Hainaut, 1992; Delecluse, Coppenolle, Diels, & Goris, 1992; Korchemny, 1992; Schot & Knutzen, 1992; Mc Clements, Sanders, & Gander 1996, Harland & Steele, 1997). The results of the studies and their applicability depend on the relevance of the sample of subjects, the research technology used and the critical evaluation of the results. The development of modern biomechanical technologies adds to the accuracy of the measurement and analysis of the key performance factors in sprint velocity. Sprint start and block acceleration are the first two derivatives of sprint velocity where the athlete tries to assume maximal block velocity. One study (Tellez & Doolittle, 1984) showed that the two phases account for 64% of the total result for a 100m sprint.

Studies (Tellez & Doolittle, 1984; Mero, 1988; Coopenolle, 1989; Coppenolle et al., 1990; Schot & Knutzen 1992; Korchemny, 1992; Guissard, Duchateau, & Hainaut, 1992; Harland & Steele, 1997) concur that the efficiency of the sprint start depends primarily on the block positioning, the TBCG in the set position, the block time and the block velocity followed by block acceleration. The optimal coherence between the sprint start and block acceleration is a specific motor problem in which the athlete has to integrate – in terms of space and time – an acyclic movement into a cyclic movement.

Block acceleration is that phase of the sprint where the kinematic parameters of the sprint step change most dynamically. Owing to these changes the block acceleration of the TBCG of the athlete increases. Block acceleration is a complex cyclical movement defined predominantly by the progression of the frequency and length of steps, the duration of the contact and flight phases and the total body's centre of gravity position at the moment of contact with the ground. All of the aforementioned parameters are interdependent and each is conditioned by the central movement regulation processes, biomotor abilities, energetic processes and the morphological characteristics of the athlete (Cavagna, Komarek, & Mazzoleni, 1971; Mann & Sprague, 1980; Buhrle et al. 1983; Moravec et al., 1988; Mero & Komi, 1990; Coppenolle et al., 1990; Mero, Komi, & Gregor 1992; Locatelli & Arsac, 1995; Muller & Hommel 1997).

Luhtanen and Komi (1980) divided the contact phase of the sprint step in block acceleration into a braking phase and a propulsion phase. The sum of both parts constitutes the total contact time. Owing to the changing biomechanical conditions, the contact phase/flight phase index also changes. Total ground contact times decrease and flight phases increase. The length of the step depends on body height and/or leg length and the force developed by the extensor muscles of the hip (m. gluteus maximus), knee (m. vastus lateralis, m. rectus femoris) and ankle joint (m. gastrocnemius) in the contact phase. Execution of the contact phase is one of the most important generators of sprint velocity efficiency (Mero & Komi, 1987; Lehmann & Voss, 1997). The contact phase has to be as short as possible with an optimal ratio between the braking phase and the propulsion phase. Step frequency depends on the functioning of the central nervous system and is largely genetically predetermined (Mero, Komi, & Gregor, 1992). The higher the frequency, the shorter the step length, and vice versa. The efficiency of block acceleration is in fact defined by an optimal ratio between the length and frequency of the athlete's steps.

The aim of our study was to identify and analyze the most relevant kinematic parameters that positively contribute to the efficiency of the start and block acceleration in one athlete, namely a world class sprinter. The currently available, cutting-edge biomechanical technology was used for the analysis of this phenomenon. The subject of the study was the set position from the point of view of the height of the total body's centre of gravity (TBCG), the block time at the front and rear blocks, the block velocity, the block face angle, the velocity of the TBCG in the first three meters and the kinematic parameters of the block acceleration in the first ten steps. A 20m low-start sprint test was carried out to assess block acceleration efficiency. The kinematic parameters of the start were analyzed by means of a high-speed digital camera with a frequency of 200 frames/sec. The measurements of the block acceleration parameters were made by means of the Opto Track technology and an infra-red photo cell system. This enabled the quantification of the key biomechanical parameters of the movement in the start and block acceleration, an identification of potential errors based on these data and the search for optimal solutions. The study is based on the measurements of one sprinter who is presently in the world's top class. Owing to the sophisticated methodology and technology of the measurement procedure, there are relatively few biomechanical studies of this type in professional literature. The findings of the study cannot be generalized; nevertheless, the results have an influential cognitive value in the objectivisation of the two key phases of sprint running.

2. METHODS

Subjects

The study involved M.O., a member of the national team of the Republic of Slovenia for the 100 m sprint (aged 27, body mass 76.7 kg, personal record in the 100 m sprint: 10.14 sec.). The biomechanical measurements were carried out in May 2006 during which period the athlete was preparing for the European Athletics Championship in Goetebourg in 2006.

Testing procedures

The kinematic measurements of the start and block acceleration were carried out in the sports hall of the Track and Field Centre of Slovenia in Šiška, Ljubljana, under constant and optimal climatic conditions. The 2-D kinematic analysis of the start was performed with the high-speed camera MIKROTRON MOTION BLITZ CUBE ECO-1 and the DIGITAL MOTION ANALYSIS RECORDER, which is able to capture 6 seconds of movement at a frequency of 1,000 frames/second at a resolution of 640 × 512 pixels. This study was conducted using a frequency of 200 frames/sec. The area was calibrated with two referential cubes with 1-metre sides. The processing and analysis of the data obtained were carried out by using the Ariel Performance Analysis System (APAS). The method of automatic digitalization was applied, using high-contrast passive markers. The seven-segment anthropometric model was also used (foot, shank, thigh, trunk, upper arm, forearm and head – according to Dempster via Miller and Nelson: Biomechanics of Sport, Lea & Febiger, Philadelphia, 1973). The coordinates of the nine digitized points thus obtained and the tenth point calculated on their basis (point of the TBCG) were smoothed out with a digital filter set at 12 Hz.

The new technology OPTO-TRACK–Microgate was applied for the analysis of the kinematic parameters of block acceleration. The measuring system is based on interconnected rods (100 cm × 4 cm × 3 cm) fitted with optical sensors and a computer program for data storing and processing. Each rod is fitted with 32 sensors – photocells, arranged at a distance of 4 cm from one another and 0.2 cm above the ground. The length of the interconnected rods was 20 meters (Figure 1). The rods were distributed along the width of the sprint athletic track (1.22 m). The measuring chain enabled the measuring of the following sprint parameters: contact time, flight time, step length, step frequency, velocity in every step and change of velocity. In addition to the OPTO-TRACK measuring system, the infrared photocell timing system (BROWER) was also used in the block acceleration test in a 20 m low-start sprint to measure the sprint time. The subject performed the 20 m low-start sprint test five times, interrupted by 12-minute breaks. The SPSS software package was used for statistical data processing.

Fig. 1. Measuring system for the kinematics parameters of the sprint start and block acceleration

3. RESULTS AND DISCUSSION

The figures outlined in Table 1 suggest that the height of the total body's centre of gravity (TBCG) in the set position was 54 ± 0.01 cm. The horizontal distance of the projection of the TBCG from the start line was 32 cm. Schot and Knutzen (1992) defined this set position as a medium start type, which offers elite competitors optimal conditions for generating block velocity. The higher the force impulse on the front block, the shorter the motor reaction time and the more efficient the execution of the first step and, consequently, block acceleration. In such a position the mass is distributed evenly between the legs and the arms. The set position of the sprinter in the blocks is individually conditioned and primarily depends on the athlete's anthropometric characteristics and motor abilities. The height of the subject's TBCG represents 32% of his standing height.

Table 1. The kinematic parameters of the set position, sprint start and block acceleration in the first two steps

Variable	Unit	1	2	3	4	5	AS SD
SET POSITION							
Distance between the TBCG and the start line	cm	32	33	33	32	32	32 ± 0.00
TBCG height	cm	54	53	54	54	54	54 ± 0.01
SPRINT START							
Reaction time – right foot	s	0.275	0.285	0.295	0.285	0.305	0.29 ± 0.01
Reaction time – left foot	s	0.405	0.420	0.440	0.410	0.440	0.43 ± 0.02
Block face angle	°	41.0	39.4	41.1	42.3	39.3	40.8 ± 1.19
Vertical block velocity	m.s^{-1}	0.85	0.78	0.74	0.91	0.83	0.77 ± 0.14
Horizontal block velocity	m.s^{-1}	4.27	4.08	3.95	4.28	4.19	4.11 ± 0.17
Block velocity – resultant	m.s^{-1}	4.36	4.15	4.02	4.37	4.28	4.18 ± 0.19
ACCELERATION – STEP 1 (BRAKING PHASE)							
Vertical velocity	m.s^{-1}	–0.89	–0.89	–0.86	–0.96	–0.92	–0.89 ± 0.04
Horizontal velocity	m.s^{-1}	1.99	2.02	2.10	1.82	1.91	2.00 ± 0.12
Velocity – resultant	m.s^{-1}	2.18	2.21	2.27	2.05	2.12	2.19 ± 0.09
ACCELERATION – STEP 1 (PROPULSION PHASE)							
Vertical velocity	m.s^{-1}	1.12	0.91	0.97	1.23	0.93	0.99 ± 0.16
Horizontal velocity	m.s^{-1}	4.48	4.39	4.45	4.22	4.59	4.41 ± 0.13
Velocity – resultant	m.s^{-1}	4.62	4.48	4.56	4.40	4.68	4.52 ± 0.12
ACCELERATION – STEP 2 (BRAKING PHASE)							
Vertical velocity	m.s^{-1}	0.31	0.35	0.36	0.36	0.32	0.33 ± 0.04
Horizontal velocity	m.s^{-1}	6.00	6.07	6.14	5.96	5.95	5.98 ± 0.12
Velocity – resultant	m.s^{-1}	6.20	6.08	6.15	5.97	5.96	6.03 ± 0.15
ACCELERATION – STEP 2 (PROPULSION PHASE)							
Vertical velocity	m.s^{-1}	0.05	0.10	0.43	0.41	0.53	0.24 ± 0.25
Horizontal velocity	m.s^{-1}	5.75	5.91	6.15	6.06	6.21	6.00 ± 0.17
Velocity – resultant	m.s^{-1}	5.75	5.91	6.17	6.07	6.24	6.05 ± 0.18
TBCG ACCELERATION							
TBCG velocity at a distance of 3 m	m.s^{-1}	4.49	4.60	4.41	4.47	4.56	4.52 ± 0.07
TBCG rise at a distance of 3 m	m	0.68	0.66	0.67	0.68	0.68	0.67 ± 0.01

The time from the sound of the gun to the moment the foot leaves the rear block (i.e. the total reaction time) is 0.29 ± 0.01 sec. The total reaction time of the front lower extremity is 0.43 ± 0.02 sec. These values of reaction times point to a certain deficit of the competitor in this element. Mero and Komi (1990) found shorter reaction times in the case of elite sprinters, namely by 0.09 sec. The total reaction time is a result of a two-component ability defined by the 'premotor time' (i.e. the time from the sound of the gun to the beginning of the EMG muscle activation) and the 'motor time' (i.e. time from the beginning of the EMG muscle activation to the moment the foot leaves the rear – front block). In the final 60m run at the World Indoor Championship in Moscow, M.O. had the fifth best reaction time – 155 ms. Reaction time has been dealt with by many researchers (Tellez & Doolittle, 1984; Moravec et al., 1988; Coppenolle et al., 1990; Bruggemann & Glad, 1990; Mero & Komi, 1990; Delecluse et al., 1992; Martin & Buonchristiani, 1995; McClements et al., 1996; Ferro et al., 2001). In most of these studies, no correlation could be established between the reaction time and the final time in a 100-metre run. Reaction time accounts for only 2-3% of the total result in a 100-metre run (Bruggemann & Glad, 1990). The reaction time in the 60m sprint is more important. The winner of the final 60m sprint in Moscow, L. Scott (USA), recorded the shortest reaction time in absolute terms, namely, 124 ms. This involves a specific, genetically conditioned ability enabling the rapid transmission of afferent and efferent nerve impulses which, to some extent, depends on the sprinter's competitive experience and anticipation.

The resultant of the velocity of the sprinter (M.O.) at the moment his foot broke contact with the front block, which is defined by block velocity, is 4.18 ± 0.19 $m.s^{-1}$. A comparison of the results of some other studies (Mero, 1988; Coppenolle et al., 1989; Mero & Komi, 1990) involving elite sprinters reveals that the block velocity of our subject was 0.18 $m.s^{-1}$ higher. This exceptional capability of generating a high velocity following block clearance is a consequence of exerting high impact force in the horizontal direction, the good co-ordination of the base of support (hands), the effective action of the rear lower extremity and low block face angle, measuring only 40.8 ± 1.19°. A low block face angle guarantees the athlete a high horizontal start velocity and adequate vertical block velocity used to balance the effects of gravity. An average vertical rise in the TBCG in the first three meters of the block acceleration is 0.67 ± 0.01 m, suggesting that the athlete's trunk during the run leans forward strongly with respect to the horizontal line. Thus, the horizontal component of velocity is maximized.

The quality of the transition from the sprint start to block acceleration is mainly seen in the velocity parameters of the sprinter's TBCG in the first two steps (Table 1, Figure 2). At the end of the first step (propulsion phase) the horizontal velocity of the TBCG was 4.41 ± 0.13 $m.s^{-1}$ and at the end of the second step 6.00 ± 0.17 $m.s^{-1}$, showing an increase in velocity of more than 1.5 $m.s^{-1}$. In the first two steps the projection point of the TBCG is located behind the ground contact point of the foot. It is not until the third and fourth steps that the TBCG projection point moves in front of the ground contact point of the foot. The consequence of the TBCG position in the first two steps is manifested in a reduction of velocity in the braking phase of the running step. In the first step, which is 103.6 ± 1.34 cm long, the velocity in the braking phase is 2.00 ± 0.12 $m.s^{-1}$. The horizontal velocity has decreased by 45.3% in regards to the velocity in the propulsive phase of the first step. The length of the second step is almost identical to that of the first step (103.8 ± 3.42 $m.s^{-1}$). Nevertheless, the reduction of velocity in the braking phase is substantially lower (1.2%) compared to the first step. The critical point is the propulsion phase in the first step following clearance of the block. It may be established that the subject of our study executes an overly long first step, resulting in the negative reaction force of the ground which is exerted in the opposite direction of the movement.

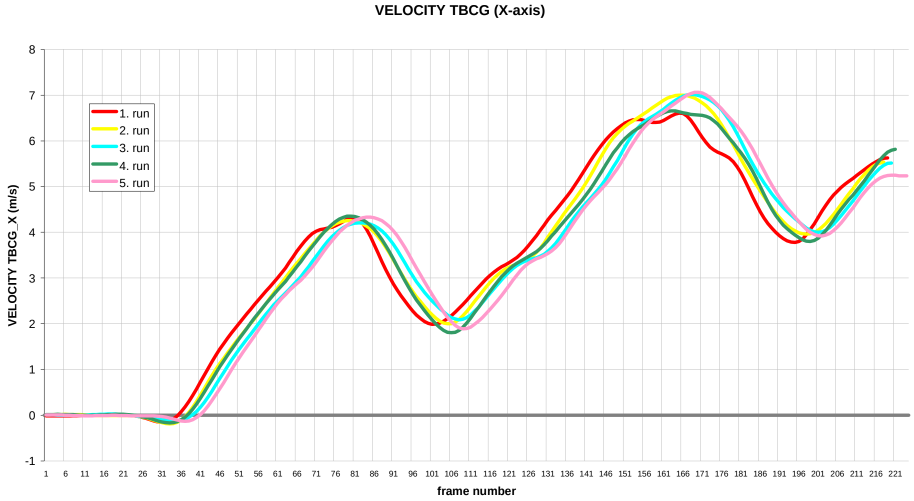

Fig. 2. Velocity of TBCG on the X-axis in the first two steps of the block acceleration

The results in Table 2 show that the average result of the subject in a 20m low-start sprint was 3.07 ± 0.08 $m.s^{-1}$. The average contact time in the first ten steps of the block acceleration was 126.40 ± 1.52 ms and the flight time 94.20 ± 4.76 ms. The activity index (contact time/flight times) was 1.34 ± 0.11, suggesting that the contact phases lasted 25% longer on average than the flight phases in the first ten steps of the block acceleration.

Block acceleration is one of the most complex segments of the development of sprint velocity (Mero, Luhtanen, & Komi, 1993; Luhtanen & Komi, 1980; Donatti, 1995; Hunter et al., 2004) characterized by the most manifest changes in the dynamic and kinematic structure of the running technique. The step length and frequency increase, the contact phases shorten and the flight phases lengthen. In the first ten steps the athlete's step length increased by 46.9%. The ground contact time of the first step was 177.2 ± 7.73 ms. In view of the total step time (contact + flight times) the contact phase accounted for 77.4%. Similar values were identified on a sample of elite sprinters (Mero, 1988; Mero & Komi 1990; Harland & Steele, 1997). In the second step the ground contact time represented 65.8% of the total step time. Owing to the altering biomechanical conditions and increasing velocity, the contact phase/flight phase index is subject to change. The contact phases are becoming shorter and the flight phases longer (Tables 2 and 3). The athlete's contact phase time equals the flight phase time in the eighth step. This is the end of the first phase of block acceleration and the beginning of the second phase of pick-up acceleration, representing the transition to maximal velocity. The step length stabilizes in the ninth step (189.0 ± 2.12 m) and the contact time (CT = 103.40 ± 5.22 ms) is shorter than the flight phase time of the sprinting step for the first time (FT = 104.80 ± 7.76 ms).

Table 2. The kinematic parameters of block acceleration at 20 meters

Variable	Unit	1	2	3	4	5	AS SD
20M SPRINT	**s**	**3.08**	**2.98**	**3.07**	**3.03**	**3.19**	**3.07 ± 0.08**
Step number	n	12	12	12	12	12	12.00 ± 0.00
Step frequency	Hz	4.5	4.4	4.6	4.6	4.6	4.54 ± 0.09
Step length	cm	165	166	162	163	163	163.80 ± 1.64
Ground contact time	ms	125	126	126	126	129	126.40 ± 1.52
Flight time	ms	96	100	93	95	87	94.20 ± 4.76
Activity index – contact/flight		1.30	1.26	1.35	1.32	1.48	1.34 ± 0.11
STEP ONE							
Length	cm	103	103	103	103	106	103.60 ± 1.34
Ground contact time	ms	172	178	184	167	185	177.20 ± 7.73
Flight time	ms	62	37	56	55	43	50.60 ±10.26
STEP TWO							
Length	cm	99	105	108	102	105	103.80 ± 3.42
Ground contact time	ms	142	179	154	154	166	159.00 ± 9,04
Flight time	ms	86	80	80	92	74	82.40 ± 6.84
STEP THREE							
Length	cm	133	136	130	130	133	132.40 ± 2.51
Ground contact time	ms	141	129	135	129	148	136.40 ± 8.17
Flight time	ms	80	92	86	80	73	82.20 ± 7.16
STEP FOUR							
Step length	cm	136	140	143	136	133	137.60 ± 3.91
Ground contact time	ms	130	130	130	136	130	131.20± 2.68
Flight time	ms	110	92	104	92	98	99.20 ± 7.82
STEP FIVE							
Step length	cm	158	155	158	158	158	157.40 ± 1.34
Ground contact time	ms	111	129	123	123	117	120.60 ± 6.84
Flight time	ms	86	86	93	87	92	88.80 ± 3.42
STEP SIX							
Step length	cm	155	164	164	161	158	160.40 ±3.94
Ground contact time	ms	117	130	129	123	117	123.20 ± 6.26
Flight time	ms	99	98	92	98	105	98.40 ± 4.62
STEP SEVEN							
Step length	cm	171	177	180	174	177	175.80 ± 3.42
Ground contact time	ms	129	117	117	123	117	120.60 ± 5.37
Flight time	ms	86	111	111	93	105	101.20 ± 11.23
STEP EIGHT							
Step length	cm	177	192	186	183	183	184.20 ± 5.45
Ground contact time	ms	117	111	105	117	110	112.00 ± 5.10
Flight time	ms	111	117	117	104	111	112.00 ± 0.09
STEP NINE							
Step length	cm	186	189	192	189	189	189.00 ± 2.12
Ground contact time	ms	99	98	104	111	105	103.40 ± 5.22
Flight time	ms	92	111	111	105	105	104.80 ± 7.76
STEP TEN							
Step length	cm	186	196	199	196	196	194.60 ± 4.98
Ground contact time	ms	117	105	111	110	110	110.60 ± 4.28
Flight time	ms	104	123	123	111	117	115.60 ± 8.17

Table 3. Ground contact and flight times in block acceleration

Variable	Unit	1	2	3	4	5	AS SD
20M SPRINT	**s**	**3.08**	**2.98**	**3.07**	**3.03**	**3.19**	3.07 ± 0.08
Flight time + ground contact time	ms	221	226	219	221	216	220.60 ± 3.65
Ground contact time in %	%	56.56	55.75	57.53	57.01	59.72	57.31 ± 1.50
STEP ONE							
Ground contact time + flight time	ms	234	215	248	222	228	229.40 ± 12.56
Ground contact time in %	%	73.50	82.79	74.19	75.22	81.14	77.37 ± 4.28
STEP TWO							
Ground contact time + flight time	ms	228	259	234	246	240	241.40 ± 11.91
Ground contact time in %	%	62.28	69.11	65.81	62.60	69.16	65.79 ± 3.35
STEP THREE							
Ground contact time + flight time	ms	221	221	221	209	221	218.60 ± 5.37
Ground contact time in %	%	63.80	58.37	61.08	61.72	66.96	62.39 ± 3.21
STEP FOUR							
Ground contact time + flight time	ms	240	222	234	228	228	230.40 ± 6.84
Ground contact time in %	%	54.16	58.55	55.55	59.64	67.01	58.98 ± 5.00
STEP FIVE							
Ground contact time + flight time	ms	197	215	216	210	209	209.40 ± 7.57
Ground contact time in %	%	56.34	60.00	56.94	58.57	55.98	57.57 ± 1.68
STEP SIX							
Ground contact time + flight time	ms	216	228	221	221	222	221.60 ± 4.28
Ground contact time in %	%	54.16	57.01	58.37	55.65	52.70	55.58 ± 2.24
STEP SEVEN							
Ground contact time + flight time	ms	215	228	228	216	222	221.80 ± 6.26
Ground contact time in %	%	60.00	51.31	51.31	56.94	52.70	54.45 ± 3.87
STEP EIGHT							
Ground contact time + flight time	ms	228	228	222	221	221	224.00 ± 3.67
Ground contact time in %	%	51.31	48.68	47.29	52.94	49.77	50.00 ± 2.21
STEP NINE							
Ground contact time + flight time	ms	191	209	215	216	210	208.20 ± 10.08
Ground contact time in %	%	51.83	46.88	48.37	51.38	50.00	49.69 ± 2.07
STEP TEN							
Ground contact time + flight time	ms	221	228	234	221	227	226.20 ± 5.45
Ground contact time in %	%	52.94	46.05	47.43	49.77	48.45	48.93 ± 2.62

The subject's best result of all five sprints was 2.98 sec. In this sprint he took 12 steps at an average frequency of 4.4 Hz and with a step length of 166 cm (Table 4). Compared to other sprints, the average step length was the highest, the flight phase the longest and the frequency the lowest. The activity index was 1.26. The contact phase time already equaled the flight phase time in the seventh step. From the eighth step onward the length of the step stabilized and the contact phase times were shorter than those of the flight phases. The transition from block acceleration to the maximal velocity of the athlete occurred in passing from the seventh to the eighth step. In his least successful attempt (3.19 sec.), this transition was only executed between the tenth and the eleventh steps.

Table 4. Dynamics of the contact-flight phases, the frequency and the length of steps and velocity in block acceleration in a 20m run (2.98 sec.)

Step	Ground contact time [s]	Flight time [s]	(Step) frequency [Hz]	Step length [cm]	TBCG velocity [m/s]
1	---	---		103	---
2	0.178	0.037	4.7	105	4.88
3	0.179	0.080	3.9	136	5.25
4	0.129	0.092	4.5	140	6.33
5	0.13	0.092	4.5	155	6.98
6	0.129	0.086	4.7	164	7.63
7	0.13	0.098	4.4	177	7.76
8	0.117	0.111	4.4	192	8.42
9	0.111	0.117	4.4	189	8.29
10	0.098	0.111	4.8	196	9.38
11	0.105	0.123	4.4	208	9.12
12	0.104	0.111	4.7	214	9.95
13	0.105	---	---	---	---
A	0.126	0.100	4.4	166	7.62
SD	0.024	0.021	0.16	39.09	1.64

4. CONCLUSION

The sprint start and block acceleration are indisputably the two most important phases of a 60m and 100m sprint which is why the training for these two components deserves special attention. To maximize the efficiency of training, the structure of these two phases has to be examined in detail. Both phases are strongly dependent on genetic, motor and biomechanical factors. The aim of this study is to explain the most important biomechanical parameters generating an efficient performance of the start and block acceleration. So far, such studies have usually been performed on samples of sprinters of medium quality, in some cases even with inadequate accuracy of the measurement procedures. What we have here is a biomechanical analysis of one of the current top world class sprinters, which was conducted on the basis of the technology which meets the highest standards of biomechanical research. The study pointed to the indisputable correlation between the start and block acceleration. The basis is an optimally set position guaranteeing the maximal block velocity of the sprinter. The transition from block velocity to block acceleration depends on the execution of the first step, particularly the length of the step and positioning of the foot in the braking phase. The efficiency of block acceleration generates the time aspect of the contact/flight index in the first ten steps. Step length and frequency have to be coordinated to such an extent as to enable ground contact times to equal those of the flight phases within the shortest time possible. In the first three steps, the total body's centre of gravity has to rise gradually in a vertical direction so as to enable the maximization of the horizontal component of block velocity. The results of the study cannot be generalized; however, they may be a valuable contribution to explaining the sprint phenomenon at the highest level of competitive performance.

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BIOMEHANIČKI MODEL SPRINTERSKOG STARTA I BLOK UBRZANJA

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Ovo istraživanje analizira i indentifikuje glavne kinematičke parametre faza sprinterskog starta i bloka ubrzanja koji utiču na rezultate u sprinterskom trčanju. Biomehanička merenja i kinematička analiza su urađeni na najboljem svetskom sprinteru tokom njegovih priprema za Evropsko atletsko prvenstvo u Geteborgu 2006. godine. U ovom takmičenju Matic Osovnikar

je osvojio bronzanu medalju u trci na 100 metara i postavio slovenački rekord od 10,14s. Kinematički parametri sprinterskog starta su ustanovljeni putem 2-D kinematičke analize. Kinematički parametri sprinterskog starta su upoređivani pomoću 2-D kinematičke analize i visokobrzinske kamere frekvencije 200 F/s. Merenja ubrzanja na blokovima su urađena pomoću opto Track tehnologije i infracrvenim fotoćelijskim sistemom. Takmičar je izveo pet niskostartnih sprinteva na 20 metara u konstantnim i kontrolisanim uslovima merenja. Cilj istraživanja je startna pozicija uzimajući u obzir visinu celog tela u središtu gravitacije (TBCG), vreme na prednjem i zadnjem bloku, brzinu na bloku, ugao na bloku, brzinu TBCG u prva tri metra na bloku, indeks faze kontakta/trčanja u prvih deset koraka i optimalni odnos dužine i frekvencije koraka.

Ključne reči: *sprinterski start, ubrzanje na bloku, tehnika, kinematika, vrhunski sprinter*