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DIFFERENCES IN THE REACTIVE FORCE OF ELITE AND SUB-ELITE SPRINTERS

INTRODUCTION

Sprinting speed is defined with the frequency of strides and the length of stride. Parameters are mutually dependant with their optimal ratio enabling a realisation of maximal sprinting speed. Increase of speed can be achieved with the increased length of stride or increased frequency of strides. Increase of both parameters simultaneously is not possible due to mutual dependency. Increased frequency results in shorter stride length and vice versa. This relationship is individually conditioned with the processes of neuro-muscular regulation of movement, morphological characteristics, bio-motor abilities and biochemical energetic resources (Mann, Sprague, 1980; Prampero et al., 2005). The length of stride depends on the length of lower extremities and the impulse of ground reaction force. According to the biomechanical studies of some authors (Bruggemann, Glad, 1990), the stride of sprinters is defined with the optimal execution of contact phase, which consists of two connected subphases: braking phase and propulsion phase.

Sprinting is a natural movement of people, its movement structure comprises of the series of jumps from one leg to another. According to biomechanical characteristics, jumps can be divided into vertical and horizontal jumps. Vertical jumps are important training tools as well as a diagnostic method for examining the take-off strength of lower extremities in sprinters. Basic criterion of efficient sprinting velocity is developing highest possible ground reaction force in the shortest time possible during the contact phase of sprinting stride (Cavagna, 1977; Mann, Sprague, 1980; Mero et al., 1992; Mero et al., 2006; Čoh, 2008). Contact time in the elite sprinters equals 80 to 95 milliseconds with ground reaction force exceeding three- to four-times body weight of the athletes. Movement structures in jumps and sprint running are very similar in relation to the muscular contractions. Development of force is a result of connection between eccentric and concentric muscular contractions. Majority of natural movements comprises of active stretching of muscles in the amortisation phase (eccentric contraction) followed by an extension (concentric contraction). Vertical and drop jumps are important tools in the training of sprinters. They can be used to improve a function of eccentric-concentric muscular action of lower extremities. In addition, these jumps represent one of the most important diagnostic methods of take-off strength in athletes.

METHODS

Experiment included 12 best Slovenian sprinters (age 22.4 ± 3.4 years, body height 177.6 ± 6.9 cm, body weight 74.9 ± 5.2 kg. Average of best results in 60-metre sprint was 6.93 ± 0.12 seconds (best result 6.65 s); average of best results in 100-metre sprint was 10.82 ± 0.25 s (best result 10.39 s). Criterion for grouping of elite and sub-elite sprinters was a result at an official competition in 60- and 100-metre sprint event. Drop jumps were executed from a 45 centimetre high bench, landing was performed on a surface – tensiometric plate – followed by an immediate vertical take-off. Drop jump was also executed without the arm movement. A system of 9 CCD cameras (BTS Smart-D, BTS Bioengineering, Padua, Italy) with a 200 Hz frequency of 200 and resolution 768 x 576 pixels was used in order to carry out a 3-D kinematic analysis of vertical jumps. A programme BTS SMART Suite was used to analyse kinematic parameters. Kinematic model was defined with a system of 17 markers, sensitive to the infrared light (head, shoulders, forearm, upper arm, torso, hips, thigh, calf and foot – Vaughan, Davis in O'Connor, 1992). Dynamic variables of vertical jumps were examined with the use of two separate force platforms (600x400, Type 9286A, Kistler Instrumente AG, Winterthur, Switzerland) at a sampling rate of 1000 Hz. Analysis included the following dynamic variables: maximal ground reaction force, impulse of force, impulse of force in eccentric and concentric phases **(Figure 1**).

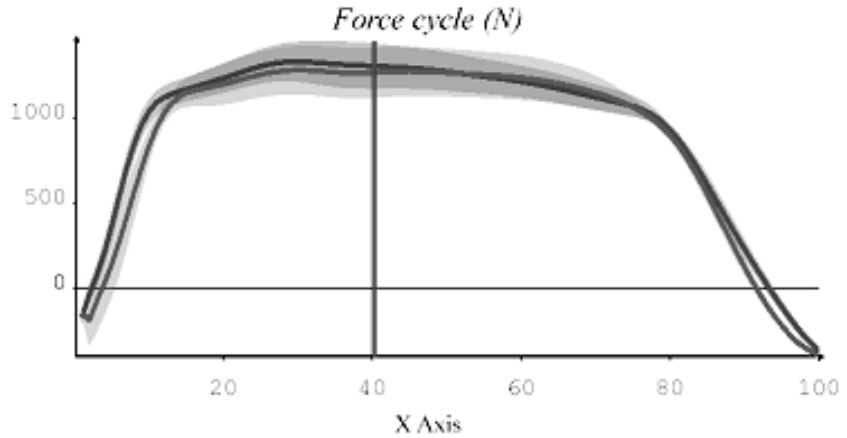

Figure 1: *Measurement protocol for dynamic parameters of the drop jump - 45 cm*

Data were statistically analysed with the use of SPSS for Windows 15.0 programme (Chicago, IL, USA). In addition to basic statistical parameters of variables the differences between the two categories of sprinters in test drop jump were also examined with a repeated measures ANOVA variance analysis. Significance of differences was assessed at 5% risk level ($p<0.05$).

RESULTS AND DISCUSSION

In 45-cm drop jump statistically significant differences between the groups of elite and sub-elite sprinters were revealed in three parameters: height of jump, velocity of body centre of gravity in eccentric and concentric phases **(Table 1**). Previous studies indicated a high correlation between the drop jump and sprinting speed (Saraslanidis, 2000; Young, 2001). High correlation between drop jumps and starting acceleration over 10 metres have been found by Mero et al., (1992), Rimmer and Sleivert (2000), Marković (2004) and Maulder et al., (2006). Neuro-muscular mechanisms in the execution of drop jump and sprinting strides are very similar. Faster stretching of muscular-tendon complex, shorter time and the amplitude of movement all result in higher amount of elastic energy. It is known that muscular-tendon complex (Achilles tendon, *m. gastrocnemius medialis*, *gastrocnemius lateralis, m. soleus*) can in conditions of higher velocity of eccentric-concentric cycle store higher amount of kinetic energy in a form of elastic energy (Bobbert, van Soest, 2000; Komi, 2000). Generation of elastic energy also means shorter contact times, which is a decisive factor in sprinting. If the time of contact with the surface is longer, a part of absorbed kinetic energy is transformed into chemical energy – heat (Komi, 2000). In comparison with the group of sub-elite sprinters, sprinters from elite group have shorter cumulative duration of contact phase (elites=160.4 ms, sub-elites=171.2 ms) as well as shorter duration of eccentric phase in 45- cm drop jump; however, the difference is statistically not significant. Young et al. (1999) have found that in sprinters the training of drop jumps significantly shortens contact times and improves the height of jumps. Short contact phase is one of the most important factors in sprint running, both from the point of view of higher frequency and the velocity of take-off in sprinting stride. In powerful motor structures, such as sprint running, the time available for generation of force is one of the most important limiting factors. Speed of generation of muscular force (gradient of force) is in sprint more important factor than the maximal muscular force.

Table 1: *Kinematic and dynamic parameters of 45-cm drop jump*

		ELITE (6)		**SUB-ELITE (6)**	
Parameter	**Unit**	**Mean**	**SD**	**Mean**	**SD**
Height	cm	54.76 *	5.34	46.02	5.95
Concentric time	ms	90.00	5.42	93.55	5.75
Eccentric time	ms	70.43	8.38	77.70	7.51
Contact time	ms	160.43	10.68	171.25	16.11
Peak Force /Right	N	1551.20	286.07	1516.32	309.12
Peak Force /Left	N	1433.21	170.58	1616.02	229.74
Eccentric Impulse /Right	Ns	78.33	16.35	76.03	12.77
Eccentric Impulse/Left	Ns	70.85	7.50	80.00	13.14
Concentric Impulse/Right	Ns	87.61	12.30	85.18	19.00
Concentric Impulse/Left	Ns	82.55	12.32	88.48	13.71
Take - off velocity	$m.s^{-1}$	3.18 *	0.15	2.87	0.24
Eccentric velocity	$m.s^{-1}$	3.05 *	0.11	2.81	0.07

* A difference between the groups is statistically significant ($p<0.05$).

According to the kinematic parameters (duration of take-off, duration of eccentric and concentric phase) and dynamic parameters (maximal force reaction, impulse of force in eccentric and concentric phase), it can be concluded that the elite sprinters use a strategy of jumping with a fast eccentric-concentric cycle, whereas the sub-elite sprinters use a strategy of slow eccentric-concentric cycle. Only a quick transformation of eccentric contraction into concentric one whilst utilizing a stretch reflex enables an efficient transfer of elastic energy from first into second phase of take-off action. In the pre-stretch phase of elongation of muscles and tendons the larger part of elastic energy is stored in serial elastic muscle elements (aponeurosis, tendon, cross-bridges) and smaller part in parallel elastic elements (muscular fascia, connective tissue, sarcolemma). This energy is released in concentric phase together with a chemical energy of a muscle. A part of elastic energy is available only for 15-120 ms, which is a lifetime of cross-bridges. The speed of eccentric-concentric cycle in elite sprinters is mostly a result of statistically significantly higher speed of body centre of gravity in the amortisation of jump phase and the extension of jump phase. At a time of leaving the ground the average vertical velocity of elite sprinters is 0.31 ms^{-1} higher in comparison to sub-elite sprinters. Drop jump as a complex multi-joint movement, where inter-muscular coordination particularly of agonists and synergists is of high importance, has been revealed as an important diagnostic instrument of result prediction for sprint running.

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DIFFERENCES IN THE REACTIVE FORCE OF ELITE AND SUB-ELITE SPRINTERS

The study aimed at establishing the differences between the kinematic and dynamic parameters of reactive force which is one of the most important biomotor ability of sprinters. Reactive force was assessed during a drop jump from 45 cm. The basic kinematic and dynamic parameters were registered using the Smart 600E bipedal force platform which had been synchronised with a 3D infra-red kinematic system. The sample of subjects consisted of 12 elite sprinters. Based on the analysis of variance (Anova) the main generators of reactive force which differentiate between elite and sub-elite sprinters were established. The statistically significant differences between the sprinters were found in the following: jump height, eccentric phase time, take-off velocity, eccentric velocity and force impulse in the eccentric phase.

***Key words**: diagnostics, dynamics, kinematics, sprinters, reactive force, drop jump*