Milan Čoh[1] and Nusret Smajlović[2]

DIFFERENCES BETWEEN THE ELITE AND SUB-ELITE SPRINTERS IN KINEMATIC AND KINETIC VARIABLES OF DROP JUMP

[1]*Faculty of Sport, University of Ljubljana, Slovenia*
[2]*Faculty of Sports and Physical Education, University of Sarajevo, Bosnia and Herzegovina*

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Abstract
The aim of the study was to examine differences in an area of take-off strength between the elite and sub-elite sprinters. Drop jump – 45 cm tests were used as criteria of take-off strength. Sample of measured subjects included 12 best sprinters. They divided in two subgroups with the official 100-metre sprint running result being used as a grouping criterion. Biomechanical parameters of both jumps were measured with the use of bipedal tensiometric platform and a system of 9 infraspectral CCD cameras with a 200 Hz frequency. Differences between the groups of sprinters were examined with the use of ANOVA variance analysis. Statistically significant ($p<0.05$) differences between the sprinters of both groups were revealed in three kinematic and kinetic parameters. In drop jump, elite and sub-elite sprinters differentiated in the realisation of movement velocity in the eccentric and concentric phases (a difference between the groups is statistically significant $p<0.05$). Elite sprinters better utilise the stretch reflex, which allows them to more efficiently transfer elastic energy from first into second phase of take-off action.

Key words: **muscular activity, take-off strength, stretch reflex, bipedal tensiometric platform**

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. Therefore the increase in stride length must be directly proportionally with the decrease of stride frequency especially at the beginning of the race – the initial acceleration phase (Mackala, 2007). 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; Harland &Steele, 1997; Novacheck, 1998; 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; Mero et al., 1992) the stride of sprinters is defined with the optimal execution of contact phase, which consists of two connected subphases: braking phase and propulsion phase. Basic criterion of rational sprinting technique is the smallest possible impulse of force in braking phase and the largest possible impulse in propulsion phase (Man & Sprauge,1980).

The second parameter of sprinting speed is a frequency of strides, which to the greatest extent depends on the regulation of functioning of central neural system, particularly conductivity of neuromuscular synapses in the conditions of maximum excitation (De Luca, 1997). High frequency of strides requires precise and regulated alternating work of agonists and antagonists (muscular groups) of lower extremities. Frequency of strides is a sum of support and flight phases. In elite sprinters, the ratio between the support and flight phase is between 1: 1.3 and 1: 1.7 (Mero et al., 1992, Glize & Laurent, 1997; Novacheck, 1998).

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 (Mann & Sprague, 1980; Mero et al., 1992; Mero et al., 2006). 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).

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. The purpose of the present study is to find differences in the test drop jump - 45 cm between the elite and sub-elite sprinters with a hypothesis that better sprinters also have better results in vertical and drop jumps. Findings in biomechanical parameters of drop jumps and their differences according to the quality of sprinters can provide better planning and control of training process in sprinters. Fallowed this assumption the present paper was mainly intended to examine differences in an area of take-off strength between the elite and sub-elite sprinters.

Methods

Experiment included 12 best 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 100-metre sprint was 10.82 ± 0.25 s (best result 10.39 s). All the measured subjects were notified about the purpose of experiment and measuring procedures and they have all signed a declaration of participation in accordance with the Helsinki-Tokyo declaration, stating that their participation is voluntary and that they can end the participation at any time. Selected measured subjects had to train track and fields at least five years and were specialised in either 60-, 100- or 200-metre sprint running. According to the goal of the study, sprinters were divided in two groups. Criterion for grouping of elite and sub-elite sprinters was a result at an official competition in 100-metre sprint event. Basic characteristics of the two groups are shown in Table 1.

Measuring procedure protocol (data collection and data analysis methods)

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 (Figure 1). 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.

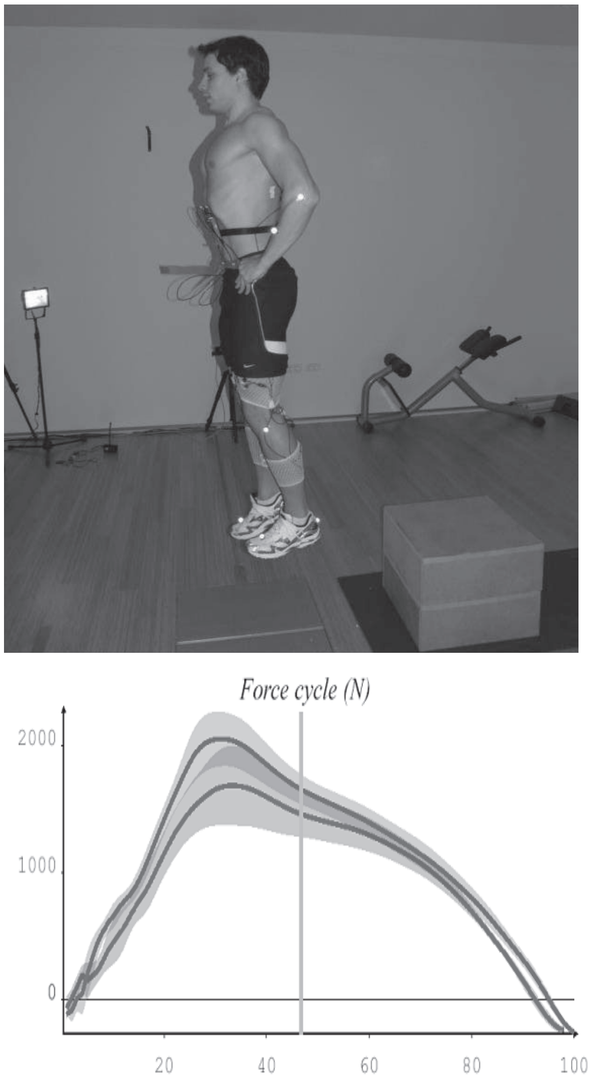

Figure 1. Measurement protocol for kinematic and kinetic parameters of the drop jump - 45 cm

Table 1. Basic characteristics of the samples of elite and sub-elite sprinters

		ELITE (6)		SUB-ELITE (6)	
Parameter	Unit	Mean	SD	Mean	SD
Age	yrs	23.67	3.26	22.67	3.55
Height	cm	179.17	7.65	176.17	6.58
Body mass	kg	77.50	5.32	72.33	3.98
100m	s	10.66*	0.18	10.96	0.16

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

Kinetic 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 800 Hz. Analysis included the following kinetic variables: maximal ground reaction force, impulse of force, impulse of force in eccentric and concentric phases. Ground reaction force (GRF) was measured unilaterally and bilaterally. Force has further been normalised according to the body weight of measured subjects (N/kg).

Data were statistically analysed with the use of SPSS for Windows 15.0 programme (Chicago, IL, USA). In both types of jumps three best (highest) jumps were considered. In addition to basic statistical parameters of variables the differences between the two categories of sprinters in tests 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

Results in the Table 2 reveal that the elite sprinters are slightly older with higher body weight and height and with statistically significantly better results in 60- and 100-metre sprint running. Tables 2 present mean values and standard deviations of variables for 45-cm drop jump - 45 cm . In drop jump the difference in the height of jump between the two groups amounted to 8.7 cm. Important differences between the groups have also been noticed in the vertical take-off velocity for both countermovement and drop jumps. Furthermore, the velocity of body centre of gravity (BCG) in the eccentric phase of drop jump importantly discriminated elite sprinters from sub-elite sprinters.

Table 2. Kinematic and kinetic variables of drop jump – 45 cm

		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 ($p<0.05$).*

Discussion

In drop jump - 45 cm 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. Previous studies indicated a high correlation between the drop jump and sprinting speed (Saraslanidis, 2000; Young, 1995; Marković, 2004). 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. According to some studies (Gollhofer & Kyrolainen, 1991; Komi, 2000), the key mechanism to short contact time in conditions of eccentric-concentric cycle (stretch-shortening cycle – Komi & Nicol, 2000) is an efficient pre-activation of agonists and synergists of ankle joint (*m. gastrocnemius latera-*

lis, *m. gastrocnemius medialis*, *m. soleus* and *m. tibialis*). Pre-activation starts 100 ms prior to the contact of foot with the ground (Gollhofer & Kyrolainen 1991). Agonists and synergists provide increased stiffness of ankle joint, regulated by the central motor programme (joint stiffness regulation), which controls and synchronises the work of flexors and extensors in ankle prior to the contact with the ground (Gollhofer & Kyrolainen, 1991, Nicol et al., 2006). 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 (Zatsiorsky, 1995).

There is one significant difference between the sprint running and drop jump test evaluating elastic strength. From the biomechanical point of view, sprinting represents alternate activity of left and right leg, i.e. a unilateral activity. According to Mero et al. (1992), realisation of strength in sprint running considerably depends on intra- and inter-muscular coordination. Vertical jumps are a typical example of bilateral activity. Nevertheless, similarity between these two activities exists particularly from the aspect of ground reaction force. In the phase of maximal sprinting velocity the vertical ground reaction force amounts to 1300 to 1600 N (Mero et al., 1992) on each leg. The sum of ground reaction force on both legs is thus between 2600 N and 3200 N. In drop jump elite sprinters achieve in average a bilateral ground reaction force 2984 N and sub-elite even 3132 N. Unilateral ground reaction force amounts in elite sprinters to 1492 N and in sub-elite sprinters to 1566 N. Similarly, the impulse of force in eccentric phase of jump is in average higher in the group of sub-elite sprinters, compared to the group of elite sprinters (elite 149.18 Ns, sub-elite 156.03 Ns).

Apparently, sub-elite sprinters are despite higher ground reaction force not capable of realising higher jumps than the elite sprinters. Elite sprinters in average achieved 8.7 cm higher vertical jumps after 45-cm drop jump than the sub-elite sprinters.

According to the kinematic parameters (duration of take-off, duration of eccentric and concentric phase) and kinetic 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 (Komi & Nicol, 2000). 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.

Conclusion

Drop jumps are important training tools in plyometric training of sprinters. They can be used to improve functioning of eccentric-concentric muscular work in lower extremities. In drop jump, elite and sub-elite sprinters differentiated in the realisation of movement velocity in the eccentric and concentric phases (a difference between the groups is statistically significant $p<0.05$). Elite sprinters better utilise the stretch reflex, which allows them to more efficiently transfer elastic energy from first into second phase of take-off action. Furthermore, these jumps are reliable and objective measuring instrument for diagnosing and planning of training process of athletes in the area of strength.

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Corresponding author:
Ph.D. Nusret Smajlović, full professor
Faculty of sport and physical education,
University of Sarajevo
Bosnia and Herzegovina
Tel: ++387 33 668-768
email: nsmajlovic@fasto.unsa.ba