Differences between the Elite and Sub-Elite Athletes in Kinematic and Dynamic Variables of Sprint - Start

UDC: 796.422.12.054.2(497.4)

(Original scientific paper)

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Abstract
The purpose of the study was to determine differences between the elite and sub-elite athletes in some kinematic and dynamic parameters of sprint start, which represents the first segment of sprinting velocity. The study included 12 athletes, who were divided in two groups according to the 60 and 100-metre time criterion. System with 9 Smart-e 600 cameras was used for 3-D kinematic analysis. Dynamic parameters were determined with the help of bipedal tensiometric force plates with starting blocks installed on them. Differences between the athletes were calculated with the use of t-test for independent samples. The results revealed statistically significant differences between the measured subjects in seven kinematic and seven dynamic parameters of sprint start. The most important noticed kinematic generators of differences between the elite and sub-elite athletes were: pre-motor reaction time, total reaction time, block velocity, duration of leaving the rear starting block, duration of leaving the front starting block, length of first step and length of second step. In the dimension of sprint start dynamics, the athletes differentiated in the absolute force on the rear starting block, maximum vertical force on the rear starting block, time needed to generate the maximum force on the front starting block, the impulse of force on the front starting block and the absolute impulse on the front and rear starting blocks.

Key words: sprinters, technique, kinematic, sprint start, biomechanics.

Introduction
In sprint events, the sprint start is one of the crucial factors of competition success. According to the studies (Guissard and Hainaut, 1992; Harland and Steele, 1997; Hunter et al., 2004), the efficiency of realisation of sprint start depends mainly on the block positioning, position of body centre of gravity (BCG) in “set” position, block time, impulse of force on the front and rear starting blocks and block velocity, which continues into block acceleration. All these factors depend on specific motor abilities, energetic processes, morphological characteristics and central processes of motor regulation. Mero, Luhtanen and Komi (1983) have in their study found that block velocity is strongly correlated with horizontal and vertical force created on the front and rear starting blocks. Block positioning of both blocks, position of the body in “set” position has to ensure that the body centre of gravity (BCG) is at a height between 54 cm – 75 cm, whereas the horizontal projection of BCG has to be at the distance between 28 cm - 30 cm from starting line (Harland & Steele, 1997). Optimal correlation of start and block acceleration represents a specific motor problem, where an athlete has to integrate time and spatial acyclic movement into a cyclic one (Harland and Steele 1997; Oszu, 2014). The purpose of the study was to determine the differences in kinematic and dynamic parameters of sprint start between the elite and sub-elite athletes. Hypothesis was set that the quality of athletes in kinematic and dynamic variables of start represents the generators of differences. The results of the study will help the understanding of biophysical starting mechanisms, which will then lead to the development of suitable training methods and tools for improvement of the quality of sprint start in athletes.

Methods
The experiment included 12 best Slovenian sprinters (average age 22.4 ± 3.4 years, average body height 177.6 ± 6.9 cm, average body weight 74.9 ± 5.2 kg) with the average personal best results in 60-metre sprint at 6.93 ± 0.12 s (with the best result 6.65 s) and in 100-metre sprint at 10.82 ± 0.25 s (the best result 10.39 s). Concurring to the aims of the study, the athletes were divided in two groups, where the criterion for selection into either elite or sub-elite group was the result at an official competition in a 60 or 100-metre
sprint event. Measurements of sprint starts were carried out in a biomechanical laboratory of Polyclinic for physical medicine and rehabilitation »Peharec« in Pula, Croatia. The positioning of starting blocks was left individually to every athlete. System of 8 CCD cameras (SMART-e 600, BTS Bioengineering) with a 200 Hz frequency. Dynamic sprint start parameters were determined with the help of two independent force plates (Kistler Type 9286A), frequency 800 Hz, where two starting blocks were installed (see Figure 1). Data were statistically analysed with the use of SPSS for Windows 15.0 programme. In addition to basic statistical parameters of variables, the differences between the two groups of athletes were calculated with the use of t-test for independent samples. Differences were accepted at a 5% risk level (p<0.05).

Results

In relation to the 100-metre sprint event results, the athletes significantly differentiated in eight kinematic parameters of sprint start (see Table 1): reaction time – premotor time, total reaction time (time from starting signal to the last contact with starting blocks), block velocity, time of the last contact of feet in front and rear starting blocks, the length of first step and block acceleration. According to the group of dynamic parameters of sprint start (see Table 2), the elite and sub-elite athletes differentiate in nine parameters: maximal horizontal and vertical force on the front starting block, maximal vertical force on the rear starting block, time of force acting on the front starting block, the impulse of force on the front starting block and in total impulse of force on both starting blocks.

Table 1. Kinematic parameters of sprint-start

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>ELITE ATHLETES (6)</th>
<th>Mean</th>
<th>SD</th>
<th>SUB-ELITE ATHLETES(6)</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time – premotor time</td>
<td>ms</td>
<td>121 **</td>
<td>11.33</td>
<td></td>
<td>131</td>
<td>16.53</td>
<td></td>
</tr>
<tr>
<td>Block velocity</td>
<td>ms$^{-1}$</td>
<td>3.83 **</td>
<td>0.17</td>
<td></td>
<td>3.16</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Total block reaction time</td>
<td>ms</td>
<td>453 *</td>
<td>24.62</td>
<td></td>
<td>436</td>
<td>18.83</td>
<td></td>
</tr>
<tr>
<td>Reaction time - front block</td>
<td>ms</td>
<td>332 *</td>
<td>28.73</td>
<td></td>
<td>305</td>
<td>24.35</td>
<td></td>
</tr>
<tr>
<td>Reaction time – rear block</td>
<td>ms</td>
<td>162 *</td>
<td>9.47</td>
<td></td>
<td>149</td>
<td>12.40</td>
<td></td>
</tr>
<tr>
<td>Step one / length</td>
<td>m</td>
<td>1.30 *</td>
<td>0.51</td>
<td></td>
<td>1.06</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Step two / length</td>
<td>m</td>
<td>1.03 *</td>
<td>0.12</td>
<td></td>
<td>0.98</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>

* Significantly different at p ≤ 0.05
** Significantly different at p ≤ 0.01

Figure 1: Measuring procedure of dynamic and kinematic variables in sprint start
The reaction - premotor time (RT), which is defined with a time interval between the starting signal and the activation of muscles applying the horizontal (pressure) force on the starting block, exceeding the 10% of maximal force (Mero and Komi, 1990; Mero, Komi end Gregor 1992). Premotor reaction time is statistically significantly shorter in elite athletes (121±11 ms) in comparison with the sub-elite athletes (131±16 ms) - see Table 1. The same could not be found for the total block reaction time, which is defined with premotor reaction time and the time of leaving the front and rear starting blocks. Elite athletes have significantly longer total block reaction time. The difference between the elite and sub-elite groups was revealed at 17 ms. Time spent in front-rear starting block, which is defined with the start of production force on the starting block (10% of maximal horizontal force) to the moment the foot leaves the front-rear starting blocks (force = 0 N). The time of action in the front block is statistically significantly shorter in the sub-elite group of athletes (sub-elite = 305±24, elite = 332±29 ms). Similarly, the sub-elite group of athletes had significantly shorter time of force action on the rear starting block

Longer reaction time allows the elite athletes to develop larger total block force on the front and rear starting blocks (see Table 2). The difference in the total force on the front starting block was noticed at 31 N. Yet, it does not carry statistical significance. In contrast, the total force on the rear starting block is statistically significant; in the group of the elite athletes the difference between the total block force on the front and rear starting block is 17.3%, whereas the difference in the same parameter in the group of sub-elite athletes was measured at 28.1%. It can be concluded that better athletes develop more even force on both starting blocks. The impulse of force - block force (Impulse $N_s = F \times t$), which is mathematically equal to the total area under the force - time curve, is one of the most significant criterion of the efficient start (Harland end Steele, 1997; Gutierrez- Davila et al., 2006; Slawinski et al., 2010). The impulse of force is larger on the front than rear block, understandable as the front leg spends twice as much time on the block as the rear leg. Elite athletes develop statistically significantly larger impulse of force on the front block, compared to the group of sub-elite athletes (recorded difference = 24.8 N.s). Total impulse on both starting blocks thus significantly differentiates two groups of athletes. In the group of elite athletes the total impulse was measured at 294.3±21.1 Ns, whereas in the group of sub-elite athletes it was 269.5±17.9 Ns. Larger impulse of force on the front starting block generates larger block velocity (Harland end Steele, 1997). In order to generate the impulse of force, the largest part is down to the agonists and antagonists of ankle joint, which ensure the necessary stiffness of this segment. The key role in this process is in the motor programme joint stiffness regulation, which controls and synchronises the work of flexors and extensors of the foot in take-off action from the starting block (Mero end Komi 1990; Guissard end Hainaut, 1992).

Start velocity is a product of optimal set position, production of force on front and rear starting block and high degree of automatism of start motor pattern (Mero end Komi, 1990; Slawinski et al., 2010). Start velocity is defined with the speed of leaving the front starting block; this parameter significantly differentiates elite and sub-elite athletes. The values of start velocity in the group of elite athletes were measured at 3.83±0.17 m.s\(^{-1}\) and in sub-elite at 3.16±0.19 m.s\(^{-1}\). The important criteria of start acceleration are the lengths of first two steps and their contact times. From the biomechanical aspect, the relationship between the length of step and ground contact time is changing. With the progressive increase in the length...
of step, the ground contact times are getting shorter. The speed is generated mainly by these two parameters (Mero end Komi, 1990; Guissard end Hainaut, Slawinski et al., 2010). In the group of elite athletes, ground contact times vary between 160 ms and 184 ms (Mero end Komi, 1990; Mero, Komi end Gregor 1992; Hunter et al., 2005). No significant differences were found in the ground contact times of first two steps in the athletes from the chosen sample. Elite athletes have generally shorter contact times in the first two steps, yet they are statistically not significant

Sprint-start is a very important element of sprinting dynamics. Its contribution to the final result in a 100-metre run is somewhere between 8 to 10%. The present study revealed that better athletes possess better quality of start in some kinematic and dynamic parameters. The differences were shown mostly in reaction times, block velocity, the magnitude of force production on the front and rear starting blocks, in larger total and partial impulse of force on starting blocks, in the time interval needed for the realisation of maximal force on the front block and in better transition from start into starting acceleration. Study was carried out on the best Slovenian athletes and with the use of latest diagnostic technology. On the basis of acquired information, the training process of sprinters will be easier to monitor and plan. A prerequisite for a good result in a 100-metre sprint event is a stable and efficient motor pattern of sprint start. Insufficient starting technique is often a cause of disqualification of the athlete in accordance with the latest rules. Optimisation of motor pattern is a long-term process, which can be successful only when its key biomechanical parameters and mechanisms are understood.

References

*This paper was presented in 5th International Scientific Conference „Contemporary Kinesiology“, Faculty of Kinesiology, University of Split, Croatia, August, 28-30, 2015.*