Determinants of a simulated cross-country skiing sprint competition using skating technique on roller skis by junior XC skier

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Abstract

The present study analyses the main factors determining the performance in simulated sprint race on roller skis for junior XC skiers. At the same time it is trying to check a hypothesis whether the performance in simulated freestyle sprint race and the time spending in each section of racetrack have close continuity with performance in maximum muscle performance test on ski simulator.

Eight czech male junior XC skiers performed a simulated freestyle sprint race (4x1600 metres and 20 minutes rest) on the racetrack of the World Championship in Liberec – Vesec. We looked into their performance in simulated freestyle sprint race and the performance in each section of the racetrack. We measured the total time and the time measured in five different sections of the racetrack. The total time, time and speed measured in different sections were taken by using sport tester Polar RS800CX with GPS navigation and Google Earth. In addition, the athletes underwent the laboratory test of spiroergometry on the treadmill and maximum power performance test on Skierg. The test on the treadmill was performed with increasing load until athletes' exhaustion and during this we measured the maximal aerobic capacity ($VO_{2max)}$, blood lactate concentrations (LA) and maximum heart rate (HR_{max}). In the examination of the maximum power performance by using ski simulator -Skierg we investigated the maximal power performance and blood lactate concentrations.

We discovered that the final time in simulated race correlates with two measured sections in the ascent and one measured section in flat terrain ($r_{uphill1}$= 0,89; r_{flat}= 0,73; $r_{uphill2}$= 0,70, p<0,05). A correlation has been shown in dependence of measured section of downhill and total time (r= 0,54; p<0,05) and between both measured sections in the ascent (r= 0,69; p<0,05) .The correlation has been found also between the maximal aerobic capacity VO_2 and final time in simulated race (r= -0,79, p<0,05). When we were analysing a connection among the performance in simulated freestyle sprint race, time spent in each sections of the racetrack and results from maximum power performance test on Skierg we found out a correlation between results from the maximum power performance test and the final time in race (r= - 0,91, p<0,05) and contemporaneously the correlation has been also established between results from maximum power performance test and the time of the first measured section in the ascent ($r_{uphill1}$= -0,69).

Key words
performance, roller ski, cross country skiing

Introduction

Sprint cross-country skiing is a physiologically and technically complex discipline, performed as a time-trial qualification race and three subsequent knock-out heats. The racing time in a single heat is 2-4 min and is comparable to other middle-distance sports. However, sprint skiing is performed in varied terrain at constantly changing intensities using multiple techniques involving the arms and the legs to various degrees (Sandbakk, 2011). Sprint skiing was increasingly accepted as a discipline in cross-country skiing and included in the World Cup in the late 1990s. The first World Championship in sprint skiing was performed in Lahti, Finland in 2001 and the first Olympic event in Salt Lake City, USA in 2002 (FIS, 2012).

Since then the ski sprint has changed a lot. The performances are better and better. The speed of skate ski sprint has been increasing in last 10 years from 6,5-8,8 to 7,0-10,05 m/s (23,4-36,1 km/h (Stöggl,Stöggl, & Müller,2009). It is caused by many reasons. One of the reasons is using new materials and technical elements as are ski wax, ski, poles, but also ski bindings. The skating technique develops thank these factors. Of course, the performance is influenced by other factors. Many studies tried to find an answer to the question which other factors are participating in increasing speed and performance in ski sprint.

Zory, Millet, Schena, Bortolan & Rouard (2006) investigated a classical sprint simulation on snow for the effects of fatigue on kinematic parameters (cycle, phases, and joints angles) in the double poling technique. This study showed that the mean heat speed remained the same over the heats. However, the final sprint speed ("spurt") was significantly lower in the third heat compared to the first.

Stöggl, Lindinger & Müller (2007) showed peak values of 90-95% of VO2max and 95-100% of maximal heart rate (HRmax) during a simulated classical sprint race on the treadmill. This study demonstrated that sprint performance strongly correlated to maximal speed, and that the fastest skiers produced longer cykle lenght in all techniques at equal cycle rate.

The determinants, which influence the performance in simulated cross-country skiing sprint competition, were recognized by Mikkola, Laaksonen, Holmberg, Vesterinen, & Nummela (2010). Sixteen elite male XC skiers performed a simulated sprint competition (4 x 850 m heat with a 20-minute recovery) using V2 skating technique on an indoor tartan track. Heat velocities, oxygen consumption, and peak lactate were measured during or after the heats. Maximal skiing velocity was measured by performing a 30-m speed test. Explosive and maximal force production in the upper body was determined by bench press. Subjects also performed maximal anaerobic skiing test and the 2 x 2 km double poling test. The results show that faster skiers in sprint simulation had a higher absolute VO2 during sprint heats, and higher anaerobic skiing power and better anaerobic skiing economy than slower skiers. Faster skiers were also stronger in bench press, with regard to both absolute and relative values.

The last research, which deals with this problem is work Sandbakk, Ettema, Leirdal, & Jakobsen (2011), which found out the physiological and biomechanical aspects of sprint skiing. They worked with 33 men and 8 women in their research. All subjects were categorized as world-class or national level skiers. The world-class skiers were all national team skiers in Norway and Sweden and included five World Champions and three Olympic Champions. All of the national level skiers ranked among the 10-30 best in the Norwegian or Swedish Cup Series. The results show, that maximal aerobic capacity, gross efficiency and high speed capacity differentiate world-class from national level sprint skiers, and these variables seem to determine sprint skiing performance. World-class skiers include more low and moderate-intensity endurance training and maximal speed training in their conditioning, which indicates that these training methods are important to achieve an international level in sprint skiing. Performance on uphill and flat terrain has the greatest impact on sprint time-trial performance, and the last part of a sprint race contains the greatest differential among skiers. Performance on the uphill sections correlates to overall sprint time-trial performance, particular because the better skiers used the V2 skating and double dance technique to a greater extent and the slower skiers used V2 skating. The maximal speed tests in double poling and V2 skating and double dance technique correlated to the percentage of racing time using V2 skating and double dance technique, indicating the significance of the upper body and movement specific power in uphill terrain. VO2max correlates to the ability to maintain uphill racing speed from the first lap to the second lap.

From these letters it is clear that performance improvement is associated with changes in the development of physiological conditions and important physical abilities. The recent studies (Holmberg, Lindinger, Stöggl, Eitzlmair, & Müller, 2005; Smith & Holmberg, 2010; Stöggl, Müller, Ainegren, & Holmberg, 2011; Stöggl, Lindinger, & Müller,2007; Zory, Vuillerme, Pellegrini, Schena, & Rouard, 2009) show that the level of power abilities and their development is a major cause of performance improvement, especially for athletes in sprint disciplines. This is exactly the reason why our article is specialized in analyses of the determinants, which influence the performance in ski sprint. It tries to find the relationship between performance in simulated cross-country skiing sprint and the time spent in different sections of the racetrack. In the same time we try to find a correlation between performance in a simulated race in sprint and in the test of maximum muscle performance on the ski simulator.

Subjects and methods

Eight czech male junior XC skiers performed a simulated freestyle sprint race (4x1600 metres and 20 minutes rest) on the racetrack of the World Championship in Liberec – Vesec. We looked into their performance in simulated freestyle sprint race and the performance in each section of the racetrack. We measured the sprint time-trial (STT) and the time measured in five different sections of the racetrack (S1-S5). The total time, time and speed measured in different sections were taken by using sport tester Polar RS800CX with GPS navigation and Google Earth (Fig. 1). In addition, the athletes underwent the laboratory test of spiroergometry on the treadmill and maximum power performance test on Skierg. The test on the treadmill was performed with increasing load until athletes' exhaustion and during this we measured the maximal aerobic capacity (VO2max), blood lactate concentrations (LA) and maximum heart rate (HR max). In the examination of the maximum power performance by using ski simulator -Skierg we investigated the maximal power performance (Watt) and blood lactate concentrations. Table 1 shows the basic parameters.

Statistical analyses

All data were shown to be normaly distributed and are presented as means and standard deviation (SD). Correlations between the various parameters were analyzed using Pearson's product–moment correlation coefficient test and simple linear regression was used to draw trend lines. Repeated measurements of the physiological and kinematic parameters on the treadmill demonstrated intraclass correlation coefficients of >0,60. The corresponding coefficients for repeated determinations of STT performance and the relative contribution of section times during pilot testing were 0,90 - 0,95. Statistical significance was set at α value of $p<0,05$.

Table 1 Antropometric, physiological and performance characteristic of the 8 male XC skiers

Parameter	Mean ± SD
Age (years)	17,3 ±0,4
Body weight (kg)	68,2 ±3,5
Body height (cm)	178,7 ±4,7
Body fat (%)	9,5 ±3,0
VO^2 max (ml min^{-1} kg^{-1})	65,3 ±3,5
HR max (min)	195 ±5,5
SKIERG (watt)	275,0 ±8,8
LA (mmol l^{-1})	10,8 ±2,5

Fig. 1 The lenghts and inclines of the track sections (with Google Earth)

Results

In the first result part we compare speed in every single section of the racetrack in relationship with time achieved in sprint section (Table 2).

Table 2 The time spent in the 5 different section of the track during the sprint time trial

Terrain	Track section	Section lenght (m)	Time in section (s)	Correlation (r) of the section time to STT*
Flat	S1	807	102,5 ± 3,8	0,73
	S5	102	11,0 ± 1,3	0,38
Uphill	S2	259	61,0 ± 3,2	0,89
	S4	204	42,2 ± 3,1	0,70
Downhill	S3	258	20 ± 1,1	0,54
STT		1600	236,5± 5,9	-

*$p<0,05$

We found out that total racing time strongly correlates with two measured uphill sections and with one flat section ($rS2= 0,89$; $rS4= 0,70$; $rS1= 0,73$; $p<0,05$). The strong correlation was also identified by downhill section and total racing time ($rS3= 0,54$, $p<0,05$). But we didn't discover the correlation between total racing time (STT) and time in the last flat section (S5) ($rS5= 0,38$, $p<0,05$) (Fig.2).

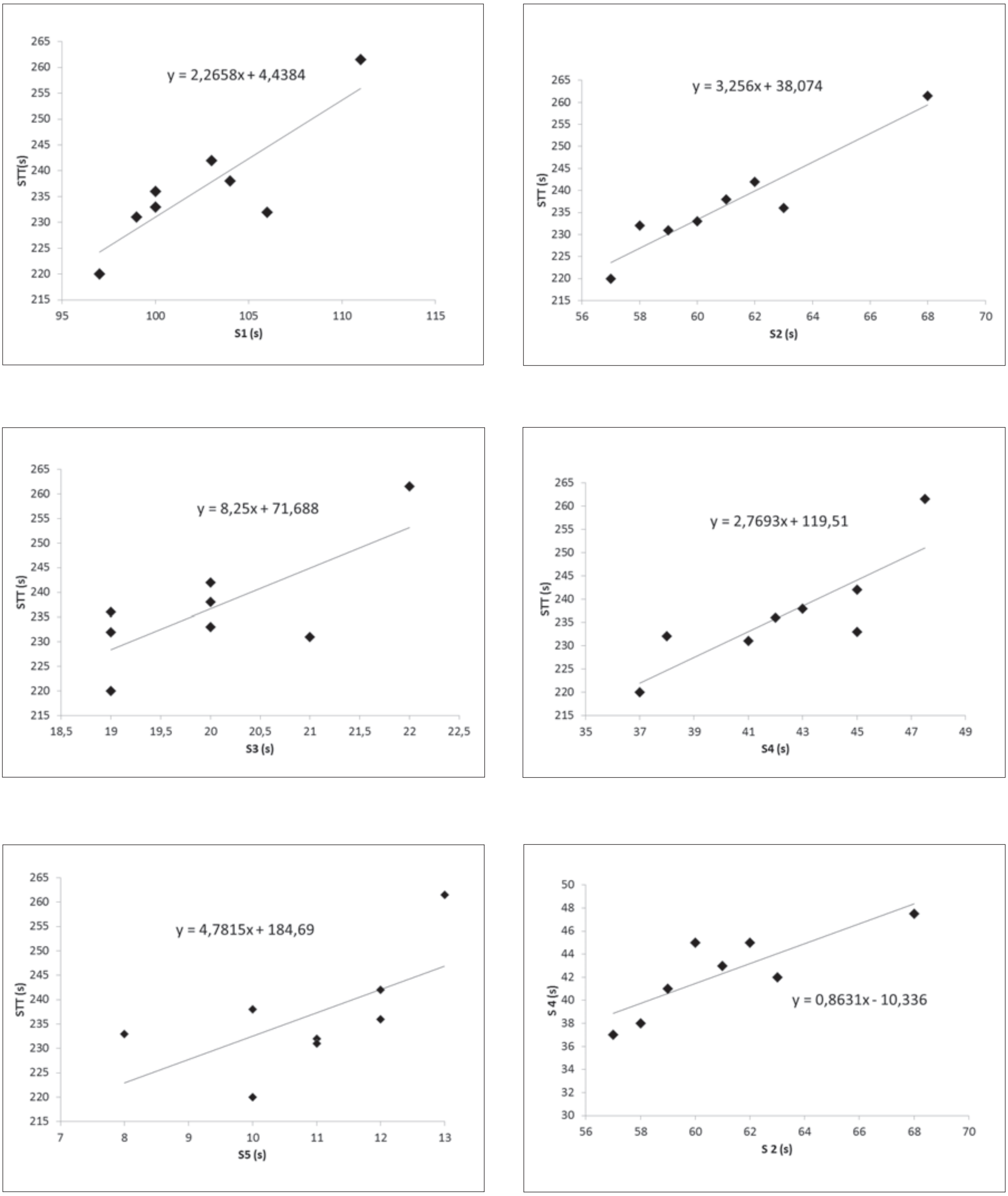
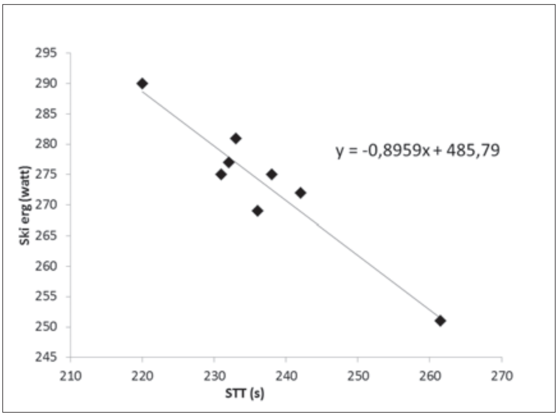
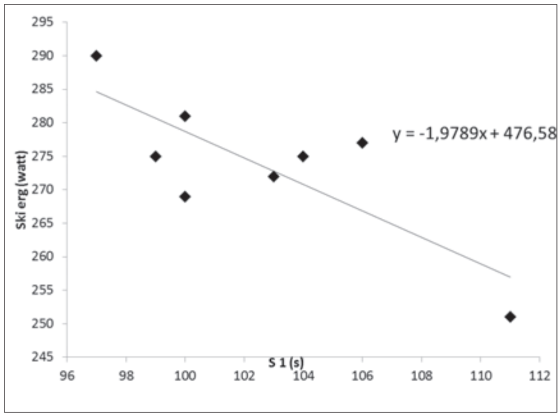


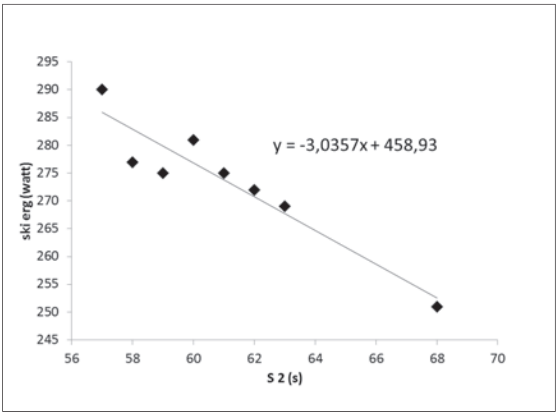
Fig. 2. Sprint time-trial performance in relationship to the time spent in different section of terrain

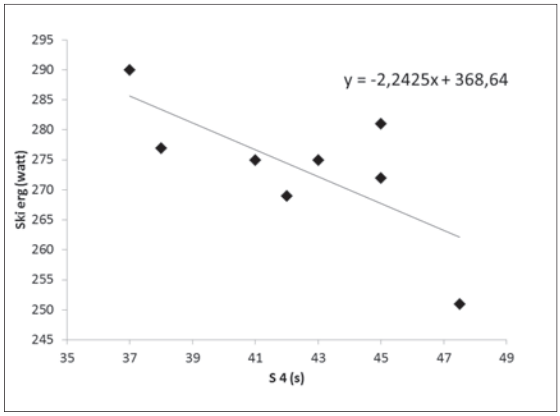
We figured out that measured (uphill) sections S2 and S4 are also strongly correlated (r= 0,69, p<0,05) (Fig. 2).

In the same time we tried to confirm if performance in simulated sprint race has connection with results in test of maximum muscle performance on the ski simulator. We found out that total time STT, results in test of maximum muscle performance (Skierg) (r= -0,91; p<0,05) and first uphill section S2 (r= - 0,88; p<0,05) have strong correlation. The level of muscle strength was approved in other sections of the racetrack. We discovered good correlation between first flat section (S1) (r= - 0,63; p<0,05) , second uphill section (S4) (r= - 0,52; p<0,05) and also final flat section (S5) (r= - 0,56; p<0,05) (Fig. 3 and Table 3).









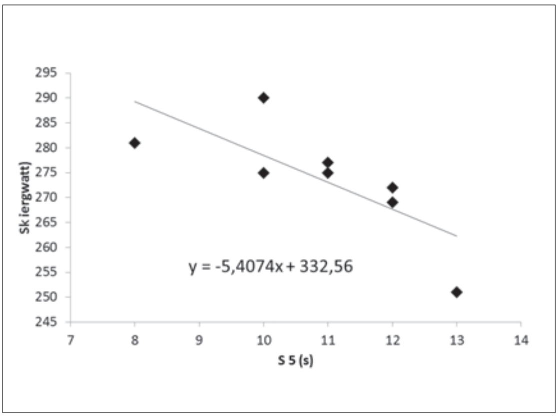


Fig. 3 Sprint time-trial performance and time the section in relationship to the maximum power performance test SKIERG

At comparison of the results which were ascertained by functional investigation we can submit that we find a significant dependence among pursued parameters (Table 3).

Table 3 The correlations (r-values) between physiological and kinematical parameters versus sprint time-trial (STT) performance and time spent in the different sections of terrain and Skiergometry (Ski-erg) for the 8 male cross-country skiers

Correlations (r)*						
Section	STT	Flat		Uphill		Downhill
Parameters	S1-S5	S1	S5	S2	S4	S3
Skierg (watt max)	-0,91	-0,63	-0,56	-0,88	-0,52	-0,49
VO_2max (ml min^{-1} kg^{-1})	-0,79	-0,69	-0,64	-0,85	-0,81	-0,56
Peak BLa (mmol l^{-1})	0,04	0,05	0,05	0,03	0,03	0,06

*p<0,05

Treadmill performance (VO_2max) was strongly negatively correlated to overall STT performance ($r = -0,79$, $p<0,05$), as well as to the time spent on the uphill ($r = -0,85$ and $-0,81$; $p<0,05$) and flat sections of the STT ($r = -0,69$ and $-0,64$; $p<0,05$). Significant dependence, but not such in case as other sections of the racetrack, is also found between treadmill performance (VO_2max) and downhill section ($r = -0,56$; $p<0,05$). At comparison with level of Peak BLa and time in every single section of the racetrack, we figured out very small correlation ($r= -0,03$ to $- 0,06$, $p<0,05$).

Discussion

According to an analysis of the sprint competition on roller ski we tried to make conditions as with competition on cross-country ski. We chose the racetrack where was the world cup in cross – country skiing in 2009 and also where is organized the world cup in sprint every year (Liberec). During the simulated race we were measuring total time but also we were finding times in every single section of the racetrack. We ascertained that total time of simulated race (STT) is strongly correlated with two measured uphill sections and one flat section of the racetrack ($r_{S2}= 0,89$; $r_{S4}= 0,70$; $r_{S1}= 0,73$; $p<0,05$). It's acknowledged by many authors (Mikkola, Laaksonen, Holmberg, Vesterinen, & Nummela, 2010; Sandbakk, Ettema, Leirdal, & Jakobsen, 2011) that speed, achieved in uphill, participates in final overall race in ski sprint. It's interesting that higher dependence in STT was shown in the first uphill section, but not in final uphill section, where we expected final acceleration of skiers (follow Sandbakk, Ettema, Leirdal, & Jakobsen, 2011). Perhaps it was caused by lenght and height profile of these sections. First uphill was 55 meters longer than second uphill, but the second uphill had higher absolute slope, which reached to 14%.

During the analysis we found out very strong correlation between the performance in simulated sprint race and results from test of maximum muscle performance on Skierg ($r= - 0,91$; $p<0,05$). Also negative correlative dependence was established between first uphill section (S2) ($r= - 0,88$; $p<0,05$) and result in test of maximum muscle performance on Skierg. A good correlation was discovered between Skierg test and first flat section (S1) of the racetrack (S1) ($r= - 0,63$; $p<0,05$) (Fig. 3). It's confirmed that level of muscle strength participates in total result of performance in sprint on roller ski, which is followed by many authors (Mikkola, Laaksonen, Holmberg, Vesterinen, & Nummela, 2010; Zory, Millet, Schena, Bortolan, & Rouard, 2006). The results show that faster skiers in STT were also stronger (f.e. bench--press).

By many studies, the level of VO_2max is the most important factor of the performance in ski sprint (Hoffman & Clifford, 1992; Holmberg, Lindinger, Stöggl, Eitzlmair, & Müller, 2005; Mahood, Kenefick, Kertzer, & Quinn, 2001; Mikkola, Laaksonen, Holmberg, Vesterinen, & Nummela, 2010; Sandbakk, Ettema, Leirdal, & Jakobsen, 2011; Stöggl, Lindinger, & Müller, 2007). But also in our study were established significant dependence between VO_2max and performance in simulated sprint race on roller ski ($r = -0,79$, $p<0,05$). We discovered a strong correlation between VO2max and performance in uphill sections (S2 and S4) ($r=0,85$ and $r=0,81$, $p<0,05$). The strong negative correlation between VO_2max and STT performance, which is reported here, illustrates the general importance of high-speed ability for sprint time-trial performance.

Conclusions

The results show that the time spent in the ascent, in the flat terrain and especially during the second part of the racetrack correlate with total output in the race. It means that the crucial factor of performance is an ability to keep the average speed for the entire length of the race. Other important factors of skiers' performance are physiological conditions which are correlated both the final time at the finish line and measured sections in the ascent. At the same time we discovered that the strength abilities of athletes are participating for total output in run on roller skis. It follows that the modern cross country skiing is increasing demands on strength-endurance capability for the classical technique cross country skiing and skating.

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