Control of speed-strength load in training of skiers-racers based on the application of tools

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Abstract

Objective of the study was to experimentally substantiate the use of feedback tools in the operational control of speed-strength loads in the training of highly qualified ski racers.

Methods and structure of the study. The experiment involved ski racers (n=4; MS; 24.5±3.8 years). During 15 training sessions, athletes performed interval exercises using a ski ergometer with regulation of the intensity of physical activity and monitoring of the bioelectric activity of the triceps brachii and latissimus dorsi muscles. The duration of the approaches was 30 seconds with rest pauses of 180 seconds. The intensity of the load was set within 80-85% of the maximum power shown in the test exercise on the ski ergometer. The number of approaches was determined based on muscle contractility. To assess the effectiveness of training, athletes were asked to undergo two tests with a stepwise increasing load on a roller ski treadmill. The test result was assessed by the number of load stages performed, the frequency of movements, the impulse of the driving force of pushing off with ski poles and the reactivity coefficient of the driving force.

Results and conclusions. The performance of athletes increased due to greater manifestation of speed-strength abilities, as indicated by an increase in impulse indicators and the reactivity coefficient of the driving force.

The proposed method of managing the training load using tools can be considered as recommendations for increasing the efficiency of the training process of highly qualified cross-country skiers. The basis of the load management technique using a ski ergometer is: the number of approaches is no more than 10; rest between sets 180 seconds; stopping criterion is a decrease in the power and magnitude of muscle bioelectric activity by more than 10% within 15 seconds.

Keywords: *cross-country skiing, speed-strength abilities, ski ergometer, electromyography, intensity control.*

Introduction. In cross-country skiing, successful performances are largely determined by the level of development of athletes' speed-strength abilities: the realization of power potential in short movements [7]. The effectiveness of speed-strength training depends on metabolic changes in the body, primarily achieved through pronounced degradation of creatine phosphate in the involved muscles and global activation of glycolysis [1, 5]. In this case, excessive accumulation of glycolytic metabolites inside the muscle fiber can lead to a significant decrease in contractility and further performance of the training task will be ineffective [8, 10]. Therefore, managing a speed-strength load is a complex task, since both conditions must be met: the load must lead to the degradation of creatine phosphate, but excessive accumulation of glycolytic metabolites in the active muscle must not be allowed. This task can be solved using simulators with feedback and control over the contractility of active muscles, performed using surface electromyography [4].

It has been suggested that controlling the load of cross-country skiers using tools based on control of muscle activity allows one to adequately and proportionately differentiate the main parameters of the load.

Objective of the study was to experimentally substantiate the use of feedback tools in the operational control of speed-strength loads in the training of highly qualified ski racers.

Methods and structure of the study. The experiment involved cross-country skiers who consistently took prizes in the cross-country skiing championships of the Republic of Belarus in the 2020-2022 seasons (n=4; 24.5±3.8 years). The research program consisted of three stages. At the first stage, initial testing of athletes was carried out in order to assess speed-strength abilities and the nature of their manifestation in the structure of ski locomotion. The second stage consisted of performing a block of training sessions, some of which contained exercises aimed at developing speed-strength abilities, performed in a ski ergometer with feedback and operational control of the bioelectrical activity of the muscles. At the third stage, repeated testing was carried out.

Testing procedure. Testing of athletes was carried out on a roller ski treadmill (POMA, Maschinen- und Anlagenbau GmbH; Germany) and consisted of performing a test with a stepwise increasing load until failure, during which the athletes moved on roller skis with a simultaneous stepless move. The initial angle of inclination of the treadmill track was 5°, and the speed of the belt was 3.0 m/s. Then the track speed increased every 15 seconds in increments of 0.25 m/s. During testing, the biomechanical parameters of the athletes' movement techniques were recorded using an information-measuring system of our own design in the form of KV+ TORNADO ski poles (KV+ SA, Switzerland), equipped with wireless strain gauge sensors, and Qualysis video motion capture cameras (Qualisys AB, Sweden). The assessment was carried out according to the following parameters:

- *movement frequency* (*f*, cycles/min*);*

- *impulse of the driving force of repulsion with ski poles (p,* N*s*),* defined as (1):

$$p=\int F_{mov}*dt, \qquad 1$$

where Fmov is the driving component of the force applied by the athlete to the ski pole (N); dt – time of action of the driving force component (s). Values were calculated in each cycle for the left and right limbs separately and then summed to obtain a total value for the cycle;

- *driving force reactivity coefficient (RC,* N/s*kg), calculated using the following formula (2) [8]:

$$\mathrm{RC} = \frac{Fmove\_max}{\mathrm{T}_{move\_max} * \mathrm{m_c}}, \qquad 2$$

where Fmove_max is the maximum value of the driving force of repulsion with a ski pole, recorded in one cycle (N); Tmove_max – time to achieve the maximum driving force of repulsion from the moment of contact of the ski pole with the support (s); mc – mass of the "athlete-equipment" system (kg). The final indicator for the cycle was determined as the average value between the indicators of the right and left limbs.

The calculation of the driving force component (Fmov, N) was carried out taking into account the angle of inclination of the ski poles relative to the horizontal plane and the inclination angle of the treadmill according to formula (3):

$$\mathrm{F}_{move} = \sqrt{((F * \sin \mathrm{a}) * \sin \varphi)^2 + ((\mathrm{F} * \cos \mathrm{a})\ * \cos \varphi)^2}, \qquad 3$$

where F is the force applied by the athlete to the ski pole (N); α – angle of inclination of ski poles relative to the horizontal plane (degrees); φ – angle of inclination of the treadmill track (degrees).

Training program. During the 15-week preparatory period (from early May to mid-August), athletes performed 1 workout per week using a SkiErg ski ergometer (Concept2 Inc., USA). A special feature of this device is the presence of a monitor that displays in real time the values of a number of parameters for performing an exercise, which allows it to be used as a means of feedback and operational control over the actions of an athlete.

Training on an ergometer was carried out using the interval method with regulation and control of the intensity of physical activity, expressed in the power developed by the athlete and the frequency of movements. The frequency of movements was set in the most optimal range for simultaneous stepless movement – 60±5 cycles per minute [9]. The target range of movement power was set in the range of 80-85% of the maximum power recorded in the test exercise, which was performed on the 1st, 5th and 10th training sessions using an ergometer. This test consisted of performing a short exercise (10–15 s), during which the athlete first needs to smoothly "spin" the ergometer and then try to develop maximum power [2]. Also, when performing exercises, the athletes were given the task of focusing their efforts on the second half of the active phase of movement, since it is in this interval while moving on skis that the best conditions are created for converting the applied force on ski poles into driving force, and visualization of the force-time curve of the active phase of movement on the ergometer monitor allowed athletes to independently control their actions.

During the exercises, the contractility of the triceps brachii and latissimus dorsi muscles was operatively monitored according to bioelectrical activity data using a Trigno multichannel wireless electromyograph (Delsys Inc., USA). The real-time electromyogram signal was compared to a preset target value of 80-85%

of the maximum recorded during the ski ergometer test exercise described above.

The duration of the exercises was 30 seconds with rest pauses of 180 seconds between each approach. The number of approaches was determined based on monitoring the parameters of movement power and bioelectrical activity of muscles. During one training session, athletes were asked to perform up to 10 approaches, however, if within 15 seconds the athlete could not maintain the target power of movements, and the amount of muscle bioelectrical activity decreased by more than 10%, the task was stopped and the remaining approaches were not performed.

Results of the study and discussion. During the initial testing, the speed of 4.75 m/s was the last step fully completed by all athletes. The average frequency of movement cycles consistently increased from 45.13 ± 2.51 to 69.30 ± 1.86 cycles per minute in the first and last stages, respectively. The maximum values of the impulse of the repulsive driving force were observed at steps with a speed of 4.00-4.25 m/s and amounted to 234.64±27.37 N*s and 234.53±25.50 N*s, respectively. Further, with an increase in speed to maximum, the force impulse values decreased to 203.66±17.03 N*s. The dynamics of the reactivity coefficient indicators were similar: the maximum values were recorded when moving at a speed of 4.00-4.25 m/s (33.69±5.76 N/s*kg and 35.14±4.53 N/s*kg) with a further decrease in values (26.67±4.31 N/s*kg at the last stage) (Table 1). Such dynamics of indicators with an increase in speed from submaximal to maximum probably indicated the inability of athletes to demonstrate strength when performing movements with high frequency, which, at the same time, is of paramount importance for high speed skiing.

During repeated testing, an increase in the athletes' performance was recorded: the step with a movement speed of 5.00 m/s was the last one fully completed for all subjects. The frequency of movements with increasing speed increased from 40.27±3.47 to 72.75±3.74 cycles per minute at the first and last stages. The values of the driving force impulse and the reactivity coefficient consistently increased with increasing speed up to 4.25 m/s, and then a kind of "plateau" was observed - stabilization of the values at approximately the same level with a slight decrease at the last stage (Table 2). The resulting dynamics of the indicators reflected, in comparison with the initial testing, changes in the mechanisms by which athletes increased their speed of movement: an increase in speed to a submaximal level (4.25 m/s step) was achieved by increasing the frequency of movements and power characteristics of repulsion, and a further increase in speed to maximum (step 5.00 m/s) was performed by increasing the frequency while maintaining the achieved level of manifestation of strength qualities. This strategy for increasing speed is considered the most optimal for highly skilled ski racers [6]. In addition, performing more powerful and "explosive" push-offs allowed athletes to move with a lower frequency of movements than in the initial testing, which is also a significant performance characteristic [3].

Thus, high-intensity interval training on a ski ergometer with feedback and operational control of muscle contractility can presumably contribute to the development of speed-strength qualities and increase the performance of highly qualified cross-country skiers. The positive effect achieved was generally expected, given previously published studies that showed that high-intensity training on ski ergometers leads to an increase in power and improvement in the mecha-

Table 1. Results of primary testing (data for the last 4 stages are indicated)

Athlete	Parameters	Movement speed, m/s			
		4,0	4,25	4,5	4,75
V-v	*f, cycles/min*	0,84	0,88	0,94	1,16
	p, N*s	224,2	214,24	203,75	180,96
	RC, N/s*kg	30,31	33,7	28,43	26,94
Sh-v	*f, cycles/min*	0,91	1,01	1,08	1,17
	p, N*s	260,38	268,6	264,5	222,02
	RC, N/s*kg	32,08	30,75	28,71	27,09
B-v	*f, cycles/min*	0,99	1,09	1,2	1,18
	p, N*s	200,98	215,74	208,88	203,81
	RC, N/s*kg	30,14	34,62	29,87	21,07
K-v	*f, cycles/min*	0,86	0,87	1,09	1,11
	p, N*s	253,17	239,54	228,76	207,86
	RC, N/s*kg	42,23	41,47	34,39	31,59

Table 2. Results of repeated testing (data for the last 5 steps are indicated)

Athlete	Parameters	Movement speed, m/s				
		4,0	4,25	4,5	4,75	5,00
V-v	*f, cycles/min*	0,82	0,87	0,89	1,09	1,13
	p, N*s	326,22	317,2	336,14	329,44	326,44
	RC, N/s*kg	62,61	76,06	92,14	101,56	91,72
Sh-v	*f, cycles/min*	0,87	0,97	1,02	1,16	1,28
	p, H*c	232,88	273,08	268,5	263,56	216,72
	RC, N/s*kg	44,95	59,16	56,04	56	49,04
B-v	*f, cycles/min*	0,85	0,93	0,99	1,14	1,21
	p, N*s	269,45	304,16	287,46	298,15	307,76
	RC, N/s*kg	62,96	69,72	71,35	67,95	51,50
K-v	*f, cycles/min*	0,85	0,95	1,05	1,16	1,23
	p, N*s	245,38	298,94	285,61	322,73	274,64
	RC, N/s*kg	48,46	60,74	73,81	79,03	71,87

nisms of anaerobic energy supply to muscle work. At the same time, operational control over the bioelectrical activity of muscles helps the coach to objectively judge the results of the athlete's activity and creates conditions for more effective management of the intensity and volume of the training load.

Conclusions. This study showed that racing skiers performing high-intensity interval training on a ski ergometer contributes to the growth of sports performance by improving speed and strength qualities. At the same time, the use of tools that provide feedback on the parameters of the exercise and operational control over muscle contractility helps to increase the effectiveness of training. Further research is needed to assess the sustainability of the achieved effects over a longer period and to study the potential impact of this type of training on the performance of athletes during the competitive period, involving a larger sample of subjects.

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