Aspects of Athletic Training Management of the Fittest Lithuanian Skiers-Racers

DOI: 10.2478/v10131-009-0006-9

Algirdas Čepulėnas

Lithuanian Academy of Physical Education, Kaunas, Lithuania

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Key words: *skier-racer, skiing, physical loads, anaerobic alactic, glycolitic, critical intensity, anaerobic threshold*

Abstract

Background: *The aim of the research was to analyse the system of athletic training management of the fittest Lithuanian skiers - members of the Olympic national team and to establish the peculiarities of the changes in the skiers' sports performance in the perennial training process.*

Material/Methods: *The complex studies of Lithuanian skiers were carried out three times during an annual training cycle. The study analyses the indices of training loads, physical working capacity and the functional capacity of the organisms of Lithuanian Olympic national team skiers I. T (female), A. N (male) and M. S. (male). We present methods of control of functional powers and adaptation to physical loads of skiers' organisms, analyse indices of adaptation of skiers' organisms to physical loads and physical efficiency in the zones of different work intensity.*

Results: *Significant information about the adaptation of skiers' organisms during the two-year training cycle is gained by estimating the skiers' metabolism, the threshold limits of critical intensity and anaerobic effort.*

Conclusions: *Indices of oxygen consumption at the limit of anaerobic threshold and after reaching the limit of critical intensity often change during the annual cycle, and thus, we can judge the sports preparedness of athletes according to the parameters of those indices.*

Word count: 3518
Tables: 7
Figures: 1
References: 23

Received: December 2008
Accepted: June 2009
Published: September 2009

Address for correspondence:
Prof. Algirdas Čepulėnas
Lithuanian Academy of Physical Education, Sporto 6, LT-44221 Kaunas, Lithuania
Phone: +370 37 302 645 fax. + 370 37 204515 e-mail: a.cepulenas@lkka.lt

Introduction

The constant improvement of skiers-racers' results is achieved by perfecting the national systems of sports training and preparing individual technologies of training skiers [1, 2, 3]. Individual training programs are established according to individual motor abilities of athletes and adaptation possibilities of the organism to physical loads [4, 5].

Modern training of athletes means cooperation between the coach, the athlete and the scientist arranging advanced technologies of athletic training and striving for the perfect athletic shape during the most important competitions [6, 7].

The management of athletic training of elite skiers – racers relies on the appropriate planning of the training process, properly designed content of training, and the diagnostics of the impact of physical load on the athlete's organism [5, 8, 9].

During the last decade the programs of top level ski racing competitions (Olympic Games, World Championships, World Cup) have often changed. Now the program includes ski racing in classic and separate skiing ways, racing from a separate and common start, combined racing "Pursuit" (half of the distance is covered in classic ways, and the rest of it in skiing ways, when the skis and sticks are changed), individual and team skiing sprint races (1–1.5 km). Each skiing event requires specific adaptation of the skier's organism to the loads of competition activities [5, 8, 10, 11]. The indices of adaptation of the organisms of the same skiers to physical loads while skiing in different sliding ways is also different [12, 13].

Due to more masterly skiing equipment, new technologies of ski lubrication and ski route preparation, the competitive speed of skiers covering different distances has remarkably increased and the times have reduced. Modern skiing races demand great capacity of aerobic work, ability to work in a mixed aerobic-anaerobic zone of energy production, and muscle contraction power endurance [2, 5, 8]. Skiers who take part in sprint racing need high indices of working capacity and work endurance when the energy is produced in the anaerobic glycolytic way [5, 11].

Yearly training macrocycle of Lithuanian Olympic National Team skiers is distributed in three periods: preparatory (from 1 May to 10 November), competition (from 15 November to the end of March) and transition (April). The training load of ski racers is differentiated according to their general volume and specification and bioenergetic purposefulness of physical work, distributing into relative intensity zones.

Zone 1: aerobic work of low intensity. The pulse rate (HR) is 120–140 beats / min. Such a load is suitable for the development of long but non-intensive work.

Zone 2: a physical load that develops the aerobic capacity. Its intensity is close to the limit of the anaerobic threshold (4 mmol/l). The concentration of the lactate in blood may amount to 3–5 mmol/l. VO_2 reaches 60–80% VO_{2max}. HR is 141–160 beats / min.

Zone 3: a mixed anaerobic-aerobic load, the intensity of which is higher than the limit of the anaerobic threshold. The concentration of the lactate in blood may be 5–8 mmol/l, HR is 161–180 beats / min.

Zone 4: a load of high intensity is close to the limit of critical intensity or even higher. The concentration of the lactate in blood is higher than 8 mmol/l, HR is from 180 beats / min up to the maximum.

Zone 5: a load of maximum intensity (anaerobic-alactatic and mixed anaerobic alactatic-glycolytic).

The control of the adaptation of skiers' organisms to the physical loads and the analysis of its results are the prerequisite for a more rational management of the training process and the differentiation of the competitive activities [4, 5, 8, 9]. The process of athletic training is closely

linked to the modeling of the structural components of sports performance [7, 9]. The rates of adaptation of the functional systems of skiers-racers' organisms to physical loads are the precondition of planning sports results.

Thus, we suppose that performing a systematic complex control of skiers (evaluating the body composition, physical fitness, physical working capacity, muscle strength, functional capacity of the cardiovascular system, psychomotor functions) we can achieve results which correspond to the genetic abilities of skiers.

The aim of the research was to analyze the system of athletic training management of the fittest Lithuanian skiers and to establish the peculiarities of the changes in the skiers' sports performance in the perennial training process.

The object of the research was the training loads of Lithuanian Olympic national team skiers, the rates of physical efficiency and functional capacity of the organism, and the peculiarities of their changes.

Material and Methods

The complex studies of Lithuanian skiers were carried out three times during an annual training cycle. The study analyzes the indices of training loads, physical working capacity and the functional capacity of the organisms of Lithuanian Olympic national team skiers I. T (female), A. N (male) and M. S. (male).

Skier I. T. is the winner of the bronze medal in the World Youth Championship, participant in the Winter Olympic Games in Salt Lake City and Turin. Skier A. N. participated in Winter Olympic Games in Turin. Skier M. S. was the participant of Winter World University Games in Turin, World Cup skiing competitions and he is a member of Lithuanian Olympic National Team to participate in the Winter Olympic Games in 2010.

Research methods: scientific literature survey, analysis of athletic training programs of Lithuanian national team skiers, testing skiers in the laboratory and field settings. Tests were performed at Vilnius Sports Medicine Centre and Sports Science Institute of Vilnius Pedagogical University and Endurance Laboratory of the Lithuanian Academy of Physical Education.

While testing skiers in the laboratories we established the following rates: one-time muscle contraction capacity [14], maximal anaerobic alactic muscle capacity [15], maximal anaerobic alactic – glycolytic capacity (according to Wingate test), maximal anaerobic alactic capacity in 5–10 s exercising on the veloergometer with maximal efforts [16]. Determination of maximal anaerobic glycolytic potency completing 60 s work by veloergometer with maximal efforts [17].

When athletes were exercising on the veloergometer the gas analyzer was applied to determine their pulmonary ventilation, the frequency of their cardiac systole, oxygen uptake (VO_2), oxygen pulse and physical efficiency. We established the rates of oxygen consumption, pulmonary ventilation and physical efficiency when the limits of anaerobic threshold, aerobic threshold and critical intensity ($VO_{2\,max}$) were reached.

During the training sessions and competitions we registered the cardiac systole frequency applying the pulse meter "Polar AccuRex-Pluss". The blood lactate concentration of skiers was tested in the laboratory (after physical load) and in the field settings after the training session and skiing competition.

Results and Discussion

The indices of skiers' physical development and body composition are given in Table 1. They suggest that the indices of the skiers' body mass and body mass index are higher compared to model indices of long distance elite skiers. The body mass index of female skiers – medal winners of the Olympic Games is from 20.36±0.97kg/m^2 to 20.68±1.35kg/m^2, male skiers – medal winners is from 22.49±1.00 kg/m^2 to 22.80 kg/m^2 [18]. Lithuanian skiers for long distance races are too heavy.

Tab. 1. Changes of physical development and body composition of skiers in the training cycle of 2007–2008 (Lithuanian Olympic national team)

The skiers' initials	Testing date	Age, years	Height, cm	Body mass, kg	BMI, kg/m^2	LS, 1	Musc. mass, kg	Fat mass, kg	FMMI real. unit
I. T.	2007.08.29	23	168.0	59.5	21.0	4.1	33.4	5.4	6.18
(female)	2008.04.02	24	168.0	61.5	22.0	4.1	35.2	6.4	5.51
M. S.	2007.08.29	21	178.5	80.5	25.0	5.8	44.8	6.7	6.65
(male)	2008.04.02	22	178.0	78.5	24.5	5.5	44.9	5.9	7.66
A. N.	2007.08.29	22	188.0	82.2	23.0	6.4	43.6	4.8	8.93
(male)	2008.04.02	23	188.0	85.0	24.2	6.3	46.1	4.3	10.76

BMI – body mass index; LS – lung capacity; FMMI – muscle-fat mass index

The structure and the content of the skiers' training process are revealed through the parameters of training loads in one annual cycle of athletic training (Table 2, Fig. 1). The amount of skiing load makes 41–51% of the whole load of cycle exercising and corresponds to the recommended loads [19] for elite skiers. The load of roller skiing of I. T., A. N. and M. S. was 25.65%; 33.89%; 32.72%, respectively, of the whole annual cycle load of exercising.

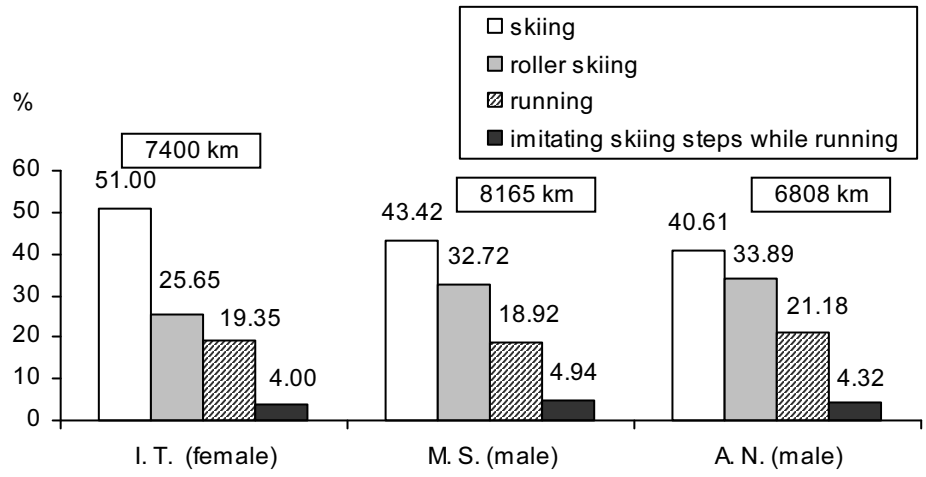

Fig. 1. Percentage distribution of cyclic exercises load of different specification of Lithuanian Olympic national team's skiers in the training cycle of 2007–2008

Tab. 2. Indices of training loads of Lithuanian Olympic national team's skiers during an annual macrocycle in the 2006–2008 period

The skiers' initials	Macrocycle	Running, km	Imitating skiing steps while running	Roller skiing, km		Skiing, km		General cyclic exercises load, km	Cycling, h
				C	F	C	F		
M. S. (male)	2006–2007	1389	584	943	1496	2004	2501	8917	17
	2007–2008	1545	403	1193	1479	1755	1790	8165	33
A. N. (male)	2006–2007	1485	271	597	1399	942	2629	7323	–
	2007–2008	1442	294	1071	1236	1146	1619	6808	–

C – classical style; F – free style

The load of intensive cycle (aerobic-anaerobic) work in the third zone of intensity is 10–12%. The skiers of the Lithuanian National Team are of a universal type. They participate in long distance, as well as sprint skiing races. The sports results in sprint skiing races largely depend on the muscle contraction power, anaerobic alactatic muscle strength, psychomotor reaction and movement frequency. Those indices greatly influence the maximal sliding speed in sprint races. The indices of the investigated participants' muscle contraction strength and psychomotor functions are given in Tables 3–5.

Now the skiers pay much attention to increasing anaerobic alactatic and anaerobic powers because the route conformation is hard – much rough country, and the intensity of work in the races is high. The research findings show that skiers' M. S. and A. N. powers of anaerobic capacity in the last skiing seasons increased (Table 3, 4). The indices of anaerobic alactatic-glycolytic and anaerobic glycolytic efficiency are especially significant in sprint skiing races (1–1.5 km). In the last season of 2007/2008 Lithuanian skiers achieved better results in sprint races.

Tab. 3. Indices of single muscle contraction power, anaerobic muscle strength of Lithuanian Olympic national team skiers in the training cycle of 2006–2008

The skiers' initials	Testing date	Standing high jump		SMCP			AAMP		
		cm	mls	kGm/s/kg	W	W/kg	kGm/s/kg	W	W/kg
I. T. (female)	2006.09.27	32	171	1.87	1137.00	18.39	1.26	766.00	12.35
	2007.04.16	34	175	1.94	1169.12	19.01	1.21	724.00	11.86
	2007.08.29	28	168	1.66	968.30	16.20	1.03	600.80	10.10
	2007.10.08	34	205	1.66	1001.00	16.30	1.14	689.00	11.20
	2008.04.02	31	194	1.60	956.00	15.69	1.24	741.00	12.16
M. S. (male)	2006.09.27	47	178	2.64	2029.00	25.88	1.80	1384.00	17.65
	2007.02.14	43	162	2.65	2065.00	25.98	1.78	1387.00	17.45
	2007.04.16	44	153	3.12	2416.00	30.59	1.98	1533.00	19.41
	2007.08.29	46	163	2.82	2225.00	27.60	1.75	1410.00	17.10
	2007.10.08	44	225	1.96	1518.00	19.20	1.98	15.34.00	19.40
	2007.12.05	41	155	2.65	2052.00	25.98	1.72	1332.00	16.86
	2008.04.02	42	147	2.86	2199.00	28.01	1.81	1392.00	17.75
A. N. (male)	2006.09.27	39	177	2.20	1812.00	21.57	1.62	1334.00	15.88
	2007.02.14	45	195	2.31	1857.00	22.65	1.73	1391.00	16.96
	2007.04.16	39	186	2.10	1708.00	20.59	1.84	1497.00	18.04
	2007.08.29	36	167	2.15	1732.00	21.00	1.65	1329.70	16.10
	2007.12.05	40	187	2.14	1752.00	20.98	1.69	1384.00	16.57
	2008.04.02	41	182	2.25	1877.00	22.09	1.77	1475.00	17.35

SMCP– single muscular contraction power; AAMP– anaerobic alactatic muscular power

In sprint racing 50% of energy is produced by aerobic reactions, and 50% – by anaerobic reactions [5].

In the ski racing competition the distances covered are different, so the bioenergetics of competitive activities covering different distances is different too [8]: in 5–10 km races 80–90% of energy is produced in aerobic ways, and 20-10% in anaerobic ways, and the blood lactate concentration is 12-14 mmol/L; in 15 km races 90–95% of energy is produced in aerobic, and 10-15%- in anaerobic ways. The blood lactate concentration is 12–10 mmol/L; in 30 km races 95–98% of energy is gained in aerobic ways, and 5-2% – in anaerobic, and the blood lactate concentration is 4–8 mmol/L.

According to the findings of [2], in the skiing races on the ski routes which correspond to the requirements of International Skiing Federation (FIS), in 5 and 10 km races for women and 10-15 km races for men, anaerobic alactatic – glycolytic work takes on average 7.2% of the race time, anaerobic glycolytic work – 35.8%, and combined anaerobic–aerobic work – 36.5%, aerobic work – 20.5% of the time to cover the distance. In the 30 km races the energy production by aerobic reactions amounts to 58.8% of the time to cover the distance, combined aerobic-anaerobic work – 5.7%. In the 50 km distance aerobic work amounts to 62.1%, and combined aerobic-anaerobic work – 37.9%.

However, in the skiing races the most important thing is skiers' aerobic capacity. The indices of aerobic power and aerobic capacity are especially significant [4, 5, 8]. If we want to know the organism's ability to adapt to physical loads, it is important to establish the parameters of aerobic efficiency at the thresholds of aerobic, anaerobic limits and after reaching the limit of critical intensity. While evaluating the skier's aerobic efficiency, it is important to estimate the limits of critical intensity and the changes in the anaerobic threshold in the multi-year training period [20, 21].

Tab. 4. Data of anaerobic alactatic capacity, anaerobic alactatic-glycolytic capacity and anaerobic glycolytic capacity of Lithuanian Olympic national team skiers in the training cycle of 2006–2008

The skiers' initials	Testing date	Mean power capacity during 10 s, 30 s, 60 s						
		W	W/kg	W	W/kg	W	W/kg	La, mmol/l
I. T. (female)	2006.09.27	529	8.50	–	–	380	6.10	9.6
	2007.04.16	621	10.20	466	7.70	402	6.60	14.1
	2007.08.29	544	9.07	453	7.55	397	6.73	15.6
	2007.10.08	538	9.00	468	8.00	390	6.80	13.1
	2008.04.02	516	8.05	502	8.20	390	6.40	14.3
M. S. (male)	2006.09.27	921	11.80	–	–	560	7.20	11.9
	2007.02.14	1037	13.30	722	9.30	576	7.40	16.7
	2007.04.16	1080	13.70	727	9.20	574	7.30	14.8
	2007.08.29	1036	12.95	713	8.92	568	7.12	15.1
	2007.10.08	1114	14.10	720	9.10	590	7.80	15.4
	2007.12.05	1042	13.20	735	9.30	587	7.40	15.4
	2008.04.02	1140	14.60	745	9.60	584	7.50	16.1
A. N. (male)	2006.09.27	941	11.20	–	–	568	6.80	11.0
	2007.02.14	1101	13.40	732	8.90	596	7.30	14.3
	2007.04.16	1162	14.20	736	8.90	587	7.10	13.9
	2007.08.29	833	10.16	646	7.88	522	6.37	12.8
	2007.12.05	990	12.10	660	7.90	571	7.00	13.9
	2008.04.02	1257	14.80	748	8.80	577	6.80	13.0

The two-year changes in aerobic capacity indices of Lithuanian Olympic national team are given in Tables 6 and 7. Indices of oxygen consumption (VO_2 max) and VO_2 at the anaerobic threshold limit are impermanent and they often change in the annual cycle. Our research indicated that the highest indices of VO_2 max of skiers A. N. and M. S. were achieved in the season of 2007/2008. As many authors suggest [20, 22], the threshold of anaerobic circulation of elite skiers who develop their endurance can come close to the limit of maximal intensity and amount to 80–95% of VO_2 max. Three levels of VO_2 are recommended [23] to evaluate the threshold of anaerobic circulation: low level, when VO_2 =43–50 ml/kg/min, moderate level, when VO_2 is 50–58 ml/kg/min, and high, when VO_2 is 59–68 ml/kg/min [20]. Oxygen consumption (VO_2) of the researched skiers in per cent from VO_2 max at the threshold of anaerobic circulation is high: I. T. 76.9–90.3%, A. N 87.61–95.9%, and M. S 79.7–92.5%.

Analyzing the skiers' data of two-year research [20, 21] we found that indices of muscle contraction strength and anaerobic alactatic capacity do not change much in the annual training cycle.

After the competition season of 2007–2008 the Lithuanian national team skiers' rates of onetime muscle contraction capacity, anaerobic glycolytic capacity (exercising on the veloergometer for 60 s) and aerobic capacity (according to VO_{2max}) were as follows:

Male skier M. S.: 2199 W – 28.01 W / kg; 584 W – 7.5 W / kg; 76.2 ml / min / kg;
Male skier A. N.: 1877 W – 22.09 W / kg; 577 W – 6.8 W / kg; 72.6 ml / min / kg;
Female skier I. T.: 956 W – 15.69 W / kg; 390 W – 6.4 W / kg; 59.6 ml / min / kg.

Tab. 5. Indices of time psychomotor reaction and frequency of Lithuanian Olympic national team skiers in the training cycle of 2006–2008

The skiers' initials	Testing date	Psychomotoric reaction, ms	Tapping test, cycles/10 s
I. T. (female)	2006.09.27	220	73
	2007.04.16	170	74
	2007.08.29	168	76
	2007.10.08	167	73
	2008.04.02	180	68
M. S. (male)	2006.09.27	188	79
	2007.02.14	174	92
	2007.04.16	165	98
	2007.08.29	195	70
	2007.10.08	152	76
	2007.12.05	156	74
	2008.04.02	159	75
A. N. (male)	2006.09.27	195	74
	2007.02.14	156	74
	2007.04.16	165	79
	2007.08.29	151	78
	2007.12.05	174	92
	2008.04.02	157	79

Table 6. Functional indices at the limit of anaerobic threshold of Lithuanian Olympic national team skiers in the training cycle of 2006–2008

The skiers' initials	Testing date	Anaerobic threshold							
		PR, b/min	LV, l/min	VO_2, l/min	VO_2, ml/min/kg	VO_2 % from VO_2 max	OP, mb/b	Work capacity	
								W	km/h
I. T. (female)	2006.09.27	164	94.2	2.63	42.5	76.9	16.0	230	–
	2007.04.16	164	78.0	2.47	40.6	84.0	15.0	240	–
	2007.08.29	176	96.7	3.72	62.1	90.3	21.1	–	13
	2007.10.08	166	80.1	3.31	54.3	85.7	19.9	225	–
	2008.04.02	166	76.9	3.22	52.8	88.4	19.4	–	13.4
M. S. (male)	2006.09.27	167	144.5	3.74	48.1	88.6	22.4	320	–
	2007.02.14	170	144.5	4.56	58.6	85.7	26.8	360	–
	2007.04.16	164	104.6	2.89	36.1	83.5	17.6	300	–
	2007.08.29	169	151.4	5.47	68.4	91.3	32.3	–	13
	2007.10.08	167	148.3	4.81	60.9	79.7	28.8	300	–
	2007.12.05	161	163.9	5.51	70.7	88.9	34.2	–	13
	2008.04.02	170	169.4	5.57	70.5	92.5	32.7	–	13
A. N. (male)	2006.09.27	159	123.3	3.99	47.1	95.5	25.0	350	–
	2007.02.14	160	125.8	4.46	55.1	95.9	27.8	370	–
	2007.04.16	146	126.6	3.96	47.3	90.9	26.9	360	–
	2007.08.29	165	124.9	5.19	63.4	88.5	31.4	–	12
	2007.12.05	161	125.5	5.69	68.6	87.61	35.3	–	12
	2008.04.02	172	135.8	5.90	69.4	95.60	34.3	–	13

PR– pulse rate; LV – lung ventilation;VO_2– oxygen uptake; OP– oxygen pulse

Tab. 7. Indices of aerobic capacity at the limit of critical intensity of Lithuanian Olympic national team skiers in the training cycle of 2006–2008

The skiers' initials	Testing date	Critical intensity limit						
		PR, b/min	LV, l/min	VO_2, l/min	VO_2, ml/min/kg	OP, mb/b	Work capacity	
							W	km/h
I. T. (female)	2006.09.27	175	119.4	2.86	46.3	16.3	260	–
	2007.04.16	176	118.0	2.94	48.2	16.7	280	–
	2007.08.29	194	123.0	4.12	68.7	21.2	–	14.4
	2007.10.08	181	107.0	3.86	63.3	21.3	–	14.0
	2008.04.02	168	91.6	3.64	59.6	21.6	–	14.0
M. S. (male)	2006.09.27	178	189.3	4.22	54.3	23.7	370	–
	2007.02.14	190	227.0	5.32	68.3	28.0	420	–
	2007.04.16	189	214.0	3.46	43.3	18.3	400	–
	2007.08.29	186	190.8	5.99	74.9	32.2	–	13.8
	2007.10.08	188	192.0	6.03	70.7	32.1	–	14.0
	2007.12.05	180	201.0	6.20	79.5	34.4	–	15.0
	2008.04.02	183	209.6	6.02	76.2	32.9	–	14.4
A. N. (male)	2006.09.27	170	141.2	4.18	49.8	24.5	390	–
	2007.02.14	169	148.0	4.65	57.4	27.5	390	–
	2007.04.16	154	141.0	4.32	52.0	28.0	380	–
	2007.08.29	172	151.3	5.86	71.5	34.0	–	13.0
	2007.12.05	176	169.0	6.49	78.3	36.8	–	13.0
	2008.04.02	182	154.0	6.17	72.6	33.9	–	13.4

PR – pulse rate; LV – lung ventilation;VO_2 – oxygen uptake; OP – oxygen pulse

Indices of oxygen consumption at the limit of anaerobic threshold and after reaching the limit of critical intensity often change during the annual cycle, and thus, we can judge the sports preparedness of athletes according to the parameters of those indices.

The rates of maximal oxygen consumption of Lithuanian skiers were lower compared to the model rates of elite skiers. Thus, it would be appropriate to apply more training means and physical loads, stimulating the increase of maximal oxygen consumption, during the whole training process.

Conclusions

1. Significant information about the adaptation of skiers' organisms during the multi-year training cycle is gained by estimating the skiers' metabolism, the threshold limits of critical intensity and anaerobic circulation.
2. Oxygen consumption at the threshold limit of anaerobic circulation is a very informative index of the adaptation of the organism. In many cases this index is moderate among Lithuanian skiers. We would like this index to be higher than 60 ml/min/kg, when athletes are in good athletic form.
3. Skiers of the Lithuanian National Olympic Team have to increase their training loads which improve the indices of maximal oxygen consumption (VO_2 max). It is desirable that VO_2 max of male skiers would be 80 ml/min/kg and higher, and 70 ml/min/kg and higher for female skiers.

References

1. Batalov AG. Modelno-celovoy sposob postroenijasportivnoj podgotovki vysokokvalificirovanych sportsmenov v zimnich ciklicheskich vidach sporta [in Russian] [Model training of top-qualified sportspersons regarding winter sport disciplines]. *Teorija i Praktika Fizicheskoj Kultury* 2000;11:46-52.
2. Ramenskaya TI. Bioenergetitcheskoje modelirovanije sorevnovatelnoj dejatelnosti silnejshih lyshnikov-gonshchikov na XVIII Zimnich olimpijskich igrach (Nagano, 1998) [in Russian] [Bio-energetic modelling the top-panchenists actions during Winter Olympic Games Nagano 1998]. *Teorija i Praktika Fizicheskoj Kultury* 2000;2:6-12.
3. Kindinger W, Spitz L, Nittel R. Top Team Turin – die Konzeption Vorbereitung des Deutschen Wintersports auf die XX Olympischen Winterspiele 2006 Turin [in German] [Idea of preparation of German winter sport disciplines for 20th Winter Olympic Games 2006 Turin]. *Leistungssport* 2004;34(3): 28-30.
4. Gaskill SE, Serfass RS, Bacharch DW, Kelly JM. Responses to training in cross-country skiers. *Med Sci Sport Exerc* 1999;31(8):1211-1217.
5. Rusko H. Physiology of cross country skiing. In: Rusko H, editor. *Handbook of Sports Medicine and Science Cross Country Skiing.* Oxford: Blackwell Science; 2003, 1-31.
6. Bompa TO. Periodization: Theory and methodology of training. 4th ed. Champaign, IL.: Human Kinetics; 1999.
7. Mester J, Perl J. Grenzen der Anpassungs-Zeitreihenanalyse und ein informatisches Metamodell zur Untersuchung physiologischer Adaptationprozesse [in German] [The IT metamodell for physiologigal adptation porecess research]. *Leistungssport* 2000;1(30):43-51.
8. Neumann G. Leistunggstruktur. In: Hottenrott K, Urban V, editors. *Handbuch für Skilanglauf*. Aachen: Meyer & Meyer; 1998, 260–271.
9. Čepulėnas A. Achievable model of physical and functional abilities of high performance skiers. *Sport Science* 2001;23(1):38-42.
10. Viitasalo J, Norvapalo K, Laakso J, Leppävuore A, Salo A. Effects of 50 km racing on ski skating kinematics in the Falun World Championships in 1993. In: Müller E, Schrameder H, Kornexi E, Rashner C, editors. *Science and Skiing.* Cambridge; 1997, 88-96.
11. Stöggl T, Lindinger S, Müller E. Testing concepts for the cross-country skiing sprint. In: Linamo V, Komi PV, Müller E. *Science and Nordic Skiing.* Aachen: Meyer & Meyer; 2007, 159-170.
12. Hoffman MD. Psychological comparisons of cross-country skiing techniques. *Med Sci Sport Exerc* 1992;24(9):1023-1032.
13. Holmberg H-C, Lindinger S, Stögl T, Björklung G, Müller E. Contribution of the legs to double-poling performance in elite cross-country skiers. *Med Sci Sport Exerc* 2006;38(10):1853-1860.
14. Bosco C. Strength assessment with the Bosco's Test. Rome: Italian Society of Sport Science; 1999.

15. Margaria R, Aghemo P, Rovelli E, Measurement of muscular power (anaerobic) in man. *J Appl Physiol* 1966;21(5):1662-1664.
16. Inbar O, Bar-Or O. Anaerobic characteristics in male children and adolescents. *Med Sci Sport Exerc* 1986;18:264-269.
17. Szögy A, Cherebetin G. Minuten test auf dem Fahradergometer zur Bestimmung der anaeroben Kapazitat. *Eur J Appl Physiol* 1979;33:171-176.
18. Čepulėnas A. Interaction peculiarities of age somatic indices and sport results of ski-racers, participants of Olympic winter games. *Biol Sport* 2006;23(1):55-72.
19. Czepulenas A. Wskaźniki modelowe obciążenia w rocznym cyklu treningowym narciarzy-biegaczy najwyższej klasy [in Polish] [Model indices of loads in a yearly trainig cycle in top class ski racers]. *Sport Wyczynowy* 1999;3-4:31-41.
20. Milašius K. The dynamics of bodily adaptation indices in the Lithuanian national skiing team members over an annual cycle of training. In: Szopa J, Gabryś T, editors. *Sport training in interdisciplinary scientific researches.* Czestochowa: University of Czestochowa; 2004.
21. Čepulėnas A, Stasiulis A, Poderys J. Physical loads applied to the candidates for Lithuanian Olympic skiing team, the fluctuation of physical efficiency, functional power and psychoemotional state during the third Olympic cycle year. *Education. Physical Training. Sport* 2005;5(59):3-12.
22. Wisloff U, Helgerud J. Methods for evaluating peak oxygen uptake and anaerobic threshold in upper body of cross-country skiers. *Med Science Sport Exerc* 1998;30(6):963–970.
23. Mishchenko V. Physiology del deportista. 2nd ed. Barcelona: Ed. Paedotribo; 1997