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Sustainable Sport: Cardio-Differentiated Planning of Fitness Programs for High School Boys Engaged in Speed Skiing

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Abstract: In speed skiing, an athlete's functional readiness is tested by means of a bicycle ergometer (EGM). The purpose of this research is to make various mesocycle plans for high school boys, engaged in speed skiing, with due account for their cardio-functional indicators obtained by means of the EGM. The study was attended by the 16–17 years old, first-category and sub-master racing skiers, included in the junior regional teams of the Russian Federation (Republic of Tatarstan and Udmurtia). The total number of subjects included eight men. In training young racing skiers, a differentiated approach combined with leg muscle testing will allow an improvement in sports results more effectively at different stages, as well as monitoring the young athlete's response to the cardiovascular load. Low cardiac capacity indices have a negative impact on the racing skier's performance. EGM testing allows determining the maximum cardiac capacity by measuring the amount of oxygen delivered to the working muscles at the HR of 190 beats per minute. Therefore, case-specific aerobic load was planned for each mesocycle according to these data. Based on the cardiac capacity growth, such means of physical training as interval, high-speed, and tempo training were planned.

Keywords: racing skiers; high school student's fitness level assessment; cardiac capacity; instruction

1. Introduction

A racing skier's fitness planning defines a significant aspect of differential cardiovascular health study [1–3]. A competition success formula is formed during the training. The athlete's sports career directly depends on effective training activity and successful performance at competitions [4].

When it comes to ski races, heart performance is one of the endurance-limiting factors affecting performance [5,6]. It is well known that the main role of the heart is the ability to inject and push blood into the vessels. The more the heart pushes the blood out of the ventricles, the faster it is delivered to the contracting muscles [7,8]. Thus, heart capabilities predetermine the athlete's endurance in many ways [9,10]. Cardiac efficiency is higher than the ventilation efficiency; therefore, assessing heart rate thresholds as an alternative to ventilation thresholds is a popular and relatively new approach in speed skiing [11].

In most cases, any heart that is reaching its limit does not allow for increasing endurance. As the load increases, the cardiovascular system responds by increasing the ventricular stroke volume followed by a high increase in the heart rate [12,13]. The maximum heart rate growth that was recorded during the exercise indicates the muscle capability limit [14]. In modern studies [15–17], racing skiers are tested at the heart rate (HR) limit within the submaximal capacity range, where the maximal oxygen consumption (MOC) of muscles is recorded. This test turns the process of identifying cardiac capacity into a problem, since it determines the maximum aerobic capacity of leg muscles at the heart rate limit. Classical testing by means of an ergometer (EGM) with a stepwise increasing load gives more information about the cardiac response and muscle reactions. In speed racing, a bicycle ergometer test is a simple, short-term test, which can be used to determine the athlete's functional readiness as well as to monitor the progress and make case-specific training plans [18–20]. This differentiated approach towards fitness planning contributes to the best fitness level of the athlete because it is based on his/her personal needs and conditions [21]. Thus, the purpose of our research is to make various mesocycle plans for high school boys engaged in speed skiing with a due account for their cardio-functional indicators obtained by means of the EGM.

2. Methods

2.1. Research Subject

The study was attended by 16–17 years old, first-category and sub-master racing skiers, included in the junior regional teams of the Russian Federation (Republic of Tatarstan and Udmurtia). The total number of subjects included eight men.

The participating skiers were comparable in height and weight, not related, attending different sports schools, but familiar with each other for two years through participation in junior regional teams. Racing skiers classified as first-category and sub-master have good fitness, which allows for research with variation in load. Their medical records were examined to find contraindications to participate in the study, and the legal representatives gave their consent. A non-disclosure agreement was signed with the participants and their legal representatives, with the purpose of protecting personal data that are beyond the scope of this study.

2.2. Testing Procedure

The research was conducted for 16 weeks, from 8 May to 27 August 2017, at the basic stage of the preparatory period. At the first research stage, the test was conducted by means of a Kettler E3 upright ergometer (Ense, Germany) (the manufacturer claims a maximum deviation of ±2.9%). The initial load was 30 W. The test was carried out under the stepwise increasing load—the load was increased by 15 W each minute. The subjects had to maintain an even pace throughout the test at 70 cycles per a minute. At the end of each minute, the heart rate (HR) was recorded with a Polar RC3 GPS sports watch (manufacturers claim a maximum deviation of ±1.7%). The subjects were not allowed to change the position of their arms/body or to rise from the seat during the test. Students were allowed to push the pedal only with the thigh extensor muscles. The test was stopped when the maximum heart rate was reached (180 beats per minute), since this heart rate indicates the beginning of dangerous myocardial contraction.

The initial test was carried out before the first mesocycle. Other tests were conducted at the end of every fourth week (three load weeks and one de-load week): Mesocycle I—From 8 May to 4 June; Mesocycle II—from 5 June to 2 July; Mesocycle III—From 3 July to 30 July; Mesocycle IV—From 31 July to 27 August. Testing was conducted after a week of training and a day of rest, in the first half of the day before training.

2.3. Methods for Measuring the Aerobic Threshold and the Cardiac Capacity

Based on the test data, we have drawn a heart rate curve graph at the increasing load of 15 W. A conditional straight line illustrating the cardiac capacity (in W) at the HR of 190 beats per minute was plotted following the first significant difference along the Y axis. In this case, cardiac capacity is the maximum amount of oxygen delivered to muscles at the HR of 190 beats/min.

The following indicators were additionally determined while testing the racing skiers by EGM: leg muscle capacity at the aerobic threshold (AeT) was indicated in W on the significant HR difference graph (the significance is identified and shown in Figure 1), as well as the relative aerobic capacity of the leg muscles (in W) with regard to body weight (BW); HR and leg muscle capacity at the AeT;

the maximum aerobic capacity (in W) of the leg muscles at a HR of 180 beats per minute; the relative maximum aerobic capacity of the leg muscles with regard to the BW; and the relative cardiac capacity with regard to BW (Figure 1).

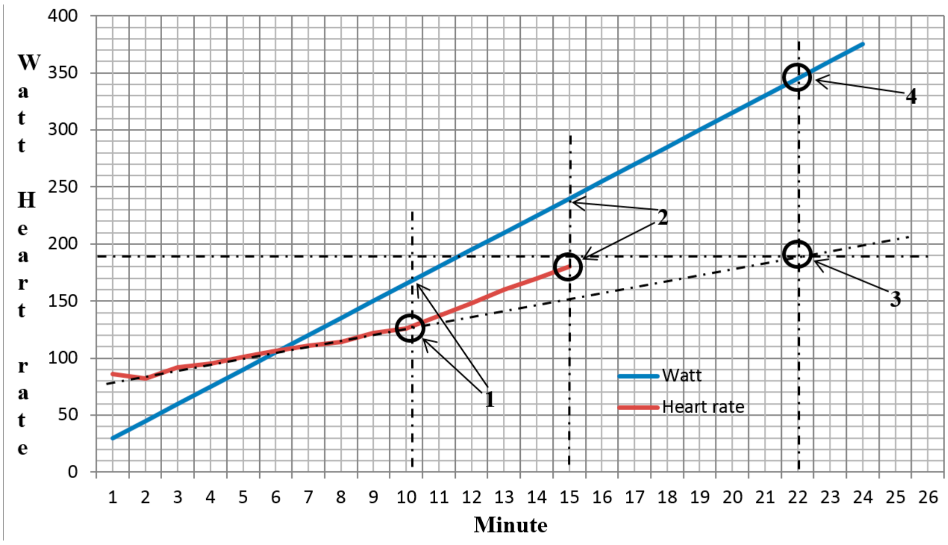

Figure 1. The AeT and cardiac capacity of high school boys engaged in speed skiing. Note: 1—HR at the AeT, muscle capacity at AeT, W; 2—capacity at a HR of 180 beats per minute; 3—HR of 190 beats per min at the conditional AeT line; 4—cardiac capacity, W.

2.4. Cardio-Functional Test Indices: Assessment

The working muscles consume a liter of oxygen in one minute of peddling at 75–78 W. In other words, 12.8–13.3 mL of oxygen is spent for 1 W/min [22]. Based on these data, relative cardiac capacity was measured with regard to the MOC (W/kg; at a HR of 190 beats per minute). Figures measured for high school boys engaged in speed skiing were matched with the sport categories (Table 1).

Table 1. Cardiac capacity and MOC figures matching with sport categories: fit assessment.

Relative Cardiac Capacity with Regard to BW in W/kg at the HR of 190 Beats per min	Correspondence to MOC, mL/kg/min	Correspondence to Sport Category	Assessment
>5.64 W/kg	>75 mL/kg/min	World class	High
5.26–5.63 W/kg	70–74.9 mL/kg/min	Master of sport, international class	Above average
4.89–5.25 W/kg	65–69.9 mL/kg/min	Master of sport	Average
4.51–4.88 W/kg	60–64.9 mL/kg/min	First category, sub-master	Below average
<4.14–4.50 W/kg	<55–59.9 mL/kg/min	First and second categories	Low

The study of leg muscle capacity on the EGM at a HR of 180 beats per minute gives information about the MOC level or about the maximum aerobic capacity. The higher this value is, the higher the AeT of the leg muscles.

In light of this information, we have developed a mechanism for measuring the relative maximum aerobic capacity of leg muscles in W with regard to the BW at a HR of 180 beats/min. Based on the calculation, 12.8–13.3 mL of oxygen is spent for 1 W/min (Table 2).

Table 2. Relative maximum aerobic capacity of leg muscles (high school boys engaged in speed skiing).

Relative Maximum Aerobic Capacity, W/kg	MOC, mL/kg/min	Assessment
>4.51 W/kg	>60 mL/kg/min	High
4.13–4.50 W/kg	55–59.9 mL/kg/min	Above average
3.76–4.12 W/kg	50–54.9 mL/kg/min	Average
3.39–3.75 W/kg	45–49.9 mL/kg/min	Below average
<3.38 W/kg	<44.9 mL/kg/min	Low

The in load by 15 W each minute allows recruiting muscular fibers gradually during the test and, thus, finding the aerobic threshold (in W) or the strength indices of slow muscle fibers on the HR graph, as well as the pulse zone of the aerobic threshold.

Based on these indicators, we have developed a mechanism for measuring the relative aerobic capacity of leg muscles in W with regard to BW. Based on the calculation, 12.8–13.3 mL of oxygen is spent for 1 W/min (Table 3).

Table 3. Relative aerobic capacity of leg muscles (high school boys engaged in speed skiing).

Relative Aerobic Capacity, W/kg	MOC, mL/kg/min	Assessment
>3.01 W/kg	>40 mL/kg/min	High
2.63–3.00 W/kg	35–39.9 mL/kg/min	Above Average
2.26–2.62 W/kg	30–34.9 mL/kg/min	Average
1.88–2.25 W/kg	25–29.9 mL/kg/min	Below Average
<1.87 W/kg	<24.9 mL/kg/min	Low

2.5. Physical Training Methods

The program of physical training designed for high school students is based on the 5th year curriculum used in the Children and Youth Sports School (CYSS) and the Specialized Children and Youth School of the Olympic Reserve (SCYSOR). According to the 5th year program, there are 248 training hours provided for physical training from 1 May to 31 August. Based on the programs used in the CYSS and SCYSOR, experimental training program for young high school students will contain 230 training hours for the period from 8 May to 27 August. The decrease in hours is based on the fact that our experiment did not begin on 1 May and ended not on 31 August. In the first mesocycle, 20 training sessions were planned for the period of four weeks (46 h). This mesocycle was as follows: *3 training days + 1 rest day + 2 training days + 1 rest day*. The first three weeks were planned as load mesocycles while the fourth week was planned as a de-load mesocycle. In the second mesocycle, 26 training sessions were planned for the period of four weeks (56 h). The first three weeks were planned as the wave-like load mesocycles while the fourth week was planned as a de-load mesocycle. The load mesocycle was as follows: *3 training days with 2 sessions at the second day + 1 rest day + 2 training days with 2 sessions at the second day + 1 rest day*. The de-load mesocycle was as follows: *3 training days + 1 rest day + 2 training days + 1 rest day*. In the third and fourth mesocycles, 29 training sessions were planned for the period of four weeks (64 h). The first three weeks were planned as the wave-like load mesocycles while the fourth week was planned as a de-load mesocycle. The load mesocycle was as follows: *3 training days of training with 2 sessions at the first and the third days + 1 rest day + 2 days training with 2 sessions at the second day + 1 rest day*. The de-load mesocycle was as follows: 3 *training days + 1 rest day + 2 training days + 1 rest day* (Table 4).

Table 4. Training means distribution by mesocycles designed for the high school boys engaged in speed skiing.

Physical Training from 8 May to 27 August (230 h)															
Mesocycle I (from 8 May to 4 June)				Mesocycle II (from 5 June to 2 July)				Mesocycle III (from 3 July to 30 July)				Mesocycle IV (from 31 July to 27 August)			
46 h				56 h				64 h				64 h			
1 week, hours (h)	2 week, hours (h)	3 week, hours (h)	4 week, hours (h)	1 week, hours (h)	2 week, hours (h)	3 week, hours (h)	4 week, hours (h)	1 week, hours (h)	2 week, hours (h)	3 week, hours (h)	4 week, hours (h)	1 week, hours (h)	2 week, hours (h)	3 week, hours (h)	4 week, hours (h)
13h	11h	14h	8h	16h	14h	18h	8h	19h	16h	21h	8h	19h	16h	21h	8h
230 h															

The fitness program designed for high school boys engaged in speed skiing involves the following training tools:

(1) Aerobic distance—an endurance training technique [23] that allows increasing the aerobic capabilities of racing skier's muscles and affects the cardiac capacity growth by increasing the stroke volume. Cardiac capacity of each racing skier was increased individually by means of the cyclical activity at the HR recorded at the AeT. The HR at the AeT figure is available from the EGM test. The aerobic capacity of muscles was increased by means of a cyclical activity at the HR of no more than 150 beats per minute.

(2) Weight routine—muscle contractility training that allows increasing the aerobic capacity of muscles by means of isometric, eccentric, and concentric strength exercises with different kinds of weights. In this case, there was an effect on the main working muscles, as well as on the stabilizer muscles. Strength training was held by means of the circular training method [24].

(3) Interval training was performed on various mountain hills and slopes. Such training affects both slow and fast muscle fibers. This type of training allows increasing the anaerobic metabolism threshold and maximizing the aerobic capacity of the muscles [25]. In this case, intervals were in the range from 20 s to five minutes at a HR no higher than 180 beats/min.

(4) High-speed interval training, in which the intensity is above the competitive speed. In this case, speed intervals were in the range from 10 s to one minute [26]. At this point, HR restoration (up to up to 110–120 beats/min) between intervals was taken into account. These exercises allow recruiting a great number of fast muscle fibers, thereby increasing the anaerobic metabolism threshold and maximizing the aerobic capacity of muscles.

(5) Tempo training, in which intensity is of competitive speed. Tempo intervals were in the range from 10 to 30 min. These exercises allow recruiting a certain part of the fast muscle fibers for a long time, thereby increasing the anaerobic metabolism threshold and maximizing the aerobic capacity of the muscles [27].

Based on the EGM test data, these means of physical training were distributed by mesocycles for each specific case in percentages (Table 5).

Table 5. Case-specific distribution of training means selected for the fitness program designed for 16–17 years old racing skiers.

	Aerobic Distance (%)				Weight Routine (%)				Interval Training (%)				High-Speed Interval Training (%)				Tempo Training (%)			
Sportsman number	1 mesocycle	2 mesocycle	3 mesocycle	4 mesocycle	1 mesocycle	2 mesocycle	3 mesocycle	4 mesocycle	1 mesocycle	2 mesocycle	3 mesocycle	4 mesocycle	1 mesocycle	2 mesocycle	3 mesocycle	4 mesocycle	1 mesocycle	2 mesocycle	3 mesocycle	4 mesocycle
1	70	50	70	40	20	25	20	10	10	15	10	30	-	8	-	15	-	2	-	5
2	70	60	80	40	20	30	20	15	10	10	-	30	-	-	-	15	-	-	-	-
3	70	60	80	90	20	30	20	10	10	10	-	-	-	-	-	-	-	-	-	-
4	70	50	70	40	20	25	20	10	10	15	10	30	-	8	-	15	-	2	-	5
5	70	60	80	40	20	30	20	15	10	10	-	30	-	-	-	15	-	-	-	-
6	70	50	80	40	20	30	20	10	10	15	-	30	-	5	-	15	-	-	-	5
7	70	50	70	40	20	25	20	10	10	15	10	30	-	8	-	15	-	2	-	5
8	70	60	80	40	20	30	20	10	10	10	-	30	-	-	-	15	-	-	-	5

3. Results

The initial test conducted before the experiment showed that four subjects had average cardiac capacity, three subjects had below average cardiac capacity, and one subject had low cardiac capacity. According to data on aerobic capacity and muscle capacity at the HR of 180 beats/min, there were two subjects with below average indices and six subjects with low ones. Test results show that all athletes had low functional and physical fitness before the preparatory training period. Therefore, in all sports where endurance is the basis, cardiac capacity is one of the main limiting factors where endurance is a key success factor. Hence, low cardiac capacity indicates a low cardiac output, which entails a high increase in HR under small and medium loads. Since all the athletes had an average or low cardiac capacity, it was suggested to change the mesocysle I plan by increasing the share of aerobic distance training by 70% of the total training time (Tables 5 and 6).

Table 6. The EGM test results before the experiment.

Sportsman Number	BW (kg)	Aerobic Capacity of Leg Muscles (W)	Relative Aerobic Capacity (W/kg)	HR at the AeT (beats/min)	Muscle Capacity at the HR of 180 beats/min (W)	Relative Muscle Capacity at the HR of 180 beats/min (W/kg)	Potential Capacity (W)	Relative Potential Capacity (W/kg)
1	64	135	2.11 (2)	135	240	3.75 (2)	330	5.16 (3)
2	65	105	1.62 (1)	138	210	3.23 (1)	300	4.62 (2)
3	76.5	115	1.5 (1)	145	215	2.81 (1)	323	4.22 (1)
4	64.5	130	2.02 (2)	141	230	3.57 (2)	325	5.04 (3)
5	70	125	1.79 (1)	139	225	3.21 (1)	320	4.57 (2)
6	71.5	120	1.68 (1)	142	210	2.94 (1)	350	4.89 (3)
7	72	130	1.80 (1)	138	220	3.06 (1)	370	5.14 (3)
8	64	110	1.72 (1)	137	195	3.05 (1)	300	4.70 (2)
Standard Deviation			0.1171893			0.106066		0.5047772
Arithmetic Mean			1.6333333			3.135		4.8
Coefficient of Variation, %			7.1748554			3.383286		10.516191

Note: (1) low estimate; (2) below average estimate; (3) average estimate; (4) above average estimate; (5) high estimate.

The coefficient of variation was calculated as the percentage ratio of standard deviation to the mean. The result characterizes sample uniformity and, therefore, uniformity in the status of the athletes.

Based on the data in Table 1, we can observe that pre-experiment values differ within the sample: the relative aerobic capacity by 7.17%; the relative muscle capacity at a HR of 180 beats/min by 3.3%; and the relative potential capacity by 10.5%. These data indicate that participating athletes are comparable in fitness level. Hence, further research is feasible and data concerning the variation coefficients alongside mesocycles will be of value.

Test results obtained after mesocycle I have shown that the cardiac capacity increased in all the subjects due to high aerobic load. There were three young men with below average relative cardiac capacity, two subjects with average cardiac capacity, two subjects with below average cardiac capacity, and one subject with indices that remained low. The No. 3 athlete experienced an increase, but his relative cardiac capacity remained low, since he has the highest body weight. Therefore, cardiac output increase is a challenge that requires more preparation time. In light of the low cardiac capacity indices recorded in Nos. 2, 3, 5, and 8 subjects, the share of their aerobic load was planned to be 60% for the next mesocycle. At the same time, the share of aerobic load planned for the rest of subjects was 50%.

The relative aerobic capacity and the relative leg muscle capacity at the HR of 180 beats/min also increased during this mesocycle. There were three sportsmen with below average relative aerobic capacity while the remaining ones had low indices. Since the aerobic capacity resulted in not being high in all the subjects, the share of weight routine was increased by 25% and 30%. In the next mesocycle, the share of strength training of athletes, whose indices were low (below average), was planned to be 30% (25%) of the total training time. Higher cardiac capacity indices were recorded in Nos. 1, 4, 6, and 7 subjects. This allowed including the high-speed (8% of training time for Nos. 1, 4, and 7, and 5% for No. 6) and tempo (2% of training time for Nos. 1, 4, and 7) training into their programs (Tables 6 and 7).

Table 7. The EGM test results after the mesocycle I.

Sportsman Number	BW (kg)	Aerobic Capacity of Leg Muscles (W)	Relative Aerobic Capacity (W/kg)	HR at the AeT (beats/min)	Muscle Capacity at the HR of 180 beats/min (W)	Relative Muscle Capacity at the HR of 180 beats/min (W/kg)	Potential Capacity (W)	Relative Potential Capacity (W/kg)
1	63.5	140	2.20 (2)	130	245	3.85 (3)	345	5.42 (4)
2	64.5	110	1.71 (1)	134	220	3.41 (2)	310	4.81 (2)
3	76.2	115	1.51 (1)	141	220	2.89 (1)	330	4.33 (1)
4	64.1	140	2.18 (2)	138	240	3.74 (2)	340	5.30 (4)
5	69.7	130	1.86 (1)	137	230	3.30 (1)	335	4.81 (2)
6	71	130	1.83 (1)	140	215	3.03 (1)	365	5.14 (3)
7	71.5	135	1.89 (2)	133	230	3.22 (1)	380	5.31 (4)
8	63.5	115	1.81 (1)	135	200	3.15 (1)	315	4.96 (3)
Standard Deviation			0.228594307			0.332434204		0.359364518
Arithmetic Mean			1.87375			3.32375		5.01
Coefficient of Variation, %			12.19982959			10.00178124		7.172944481

Note: (1) low estimate; (2) below average estimate; (3) average estimate; (4) above average estimate; (5) high estimate.

The coefficients of variation for relative aerobic capacity and relative muscle capacity at a HR of 180 beats/min increased compared with the pre-experiment values, reaching the point above 10%. This affected the homogeneity of the sample but does not make it unsuitable for comparison. The said raise that took place against the background of a decrease in potential capacity may be a result of different exercise styles that vary between sports schools and between individuals, depending on the time when they engaged in sports.

Test results obtained after the mesocycle I have shown that the relative cardiac capacity has increased in all subjects. However, this increase is not enough for deeper high-speed and tempo training, since the low relative cardiac capacity will be compensated by a high HR under these loads.

This will have a negative effect on the recovery. Therefore, aerobic load was increased once again in the next three mesocycle. Boys with above average relative cardiac capacity spent 70% of training time performing the aerobic exercises, while the students with lower indices spent 80%.

The relative aerobic capacity has noticeably increased during the second mesocycle. According to the test results, there were three subjects with average indices, four subjects with the below average indices, and one subject with a low aerobic capacity. High load has positively affected the aerobic capacity growth in all the subjects. The next mesocycle contains only 20% of strength training due to low relative aerobic capacity indices and a positive combination of strength and long-term aerobic training.

The relative muscle capacity at the HR of 180 beats/min also increased in all the subjects at the end of the second mesocycle. In light of the high aerobic load, no high-speed or tempo training was planned to be included into the mesocysle III plan. The interval training was planned to be included (10% of the total training time) only into the programs designed for Nos. 1, 4, and 7 athletes with higher relative cardiac capacity (Tables 5 and 8).

Table 8. The EGM test results after mesocycle II.

Sportsman Number	BW (kg)	Aerobic Capacity of Leg Muscles (W)	Relative Aerobic Capacity (W/kg)	HR at the AeT (beats/min)	Muscle Capacity at the HR of 180 beats/min (W)	Relative Muscle Capacity at the HR of 180 beats/min (W/kg)	Potential Capacity (W)	Relative Potential Capacity (W/kg)
1	63.4	150	2.37 (3)	128	260	4.10 (3)	353	5.57 (4)
2	64.6	125	1.93 (2)	133	230	3.56 (2)	320	4.95 (3)
3	76	130	1.71 (1)	140	225	2.96 (1)	335	4.41 (1)
4	63.9	165	2.58 (3)	136	255	3.99 (3)	355	5.55 (4)
5	69.6	150	2.15 (2)	135	240	3.45 (2)	345	4.96 (3)
6	70.8	160	2.26 (3)	139	230	3.25 (1)	365	5.15 (3)
7	71.3	155	2.17 (2)	132	250	3.51 (2)	380	5.33 (4)
8	63.5	135	2.13 (2)	133	210	3.31 (1)	323	5.09 (3)
Standard Deviation			0.2637504			0.3769023		0.3763713
Arithmetic Mean			2.1625			3.51625		5.12625
Coefficient of Variation,%			12.196551			10.718871		7.3420395

Note: (1) low estimate; (2) below average estimate; (3) average estimate; (4) above average estimate; (5) high estimate.

Data in Table 8 (variation coefficients) show a progression of phenomena from the first mesocycle, which confirms the hypothesis that, with similar fitness level, differences in the training program between schools provoke sample heterogeneity and variation within the group.

Test results obtained after mesocycle I have shown that the cardiac capacity has increased in all the subjects. There were two students with the high relative cardiac capacity, five students with the above average indices, and one subject with the below average relative cardiac capacity. In general, all the high school boys, except for the No. 3 athlete, have reached a significant fitness level. Therefore, we have reduced their aerobic load in the next mesocycle—40% of the total training time. Since the No. 3 athlete had below average cardiac capacity, his aerobic load was increased by 90% of the total training time.

The relative aerobic capacity has increased in all the subjects, except for the No. 2 athlete, whose dynamics were rather negative due to high aerobic load. In the fourth mesocycle, the share of strength training was reduced to 10% for students with above average and average indices, and to 15% for two athletes with below average ones. The share of strength training for the No. 3 athlete was planned to also be 10% due to a large amount of aerobic load.

As for the relative leg muscle capacity at a HR of 180 beats/min recorded after the third mesocycle, positive dynamics were recorded only in those athletes who had less aerobic exercise and were included in the interval training program.

In light of a significant increase in the relative cardiac capacity in all the subjects, except for the No. 3 athlete, the mesocycle IV plan involved a share of interval (30%), high-speed (15%), and tempo (5%) training. Tempo training was included only into the programs designed for Nos. 1, 4, 6, 7, and 8 subjects. The No. 2 and 5 athletes spent more time on the weight routine (Tables 5 and 9).

Table 9. The EGM test results after mesocycle III.

Sportsman Number	BW (kg)	Aerobic Capacity of Leg Muscles (W)	Relative Aerobic Capacity (W/kg)	HR at the AeT (beats/min)	Muscle Capacity at the HR of 180 beats/min (W)	Relative Muscle Capacity at the HR of 180 beats/min (W/kg)	Potential Capacity (W)	Relative Potential Capacity (W/kg)
1	62.7	160	2.55 [3]	123	265	4.23 [4]	363	5.79 [5]
2	63.7	120	1.88 [2]	128	225	3.53 [2]	340	5.34 [4]
3	75	135	1.8 [1]	135	220	2.93 [1]	355	4.73 [2]
4	63.2	175	2.77 [4]	129	265	4.20 [4]	363	5.74 [5]
5	69	150	2.17 [2]	131	230	3.33 [1]	375	5.43 [4]
6	69.7	165	2.37 [3]	130	225	3.23 [1]	390	5.59 [4]
7	70.5	160	2.27 [3]	126	250	3.55 [2]	390	5.53 [4]
8	62	140	2.26 [3]	127	205	3.31 [1]	345	5.56 [4]
Standard Deviation			0.320822			0.459360969		0.33105621
Arithmetic Mean			2.25875			3.53875		5.46375
Coefficient of Variation,%			14.20352172			12.98088221		6.059139056

Note: [1] low estimate; [2] below average estimate; [3] average estimate; [4] above average estimate; [5] high estimate.

At the third mesocycle, the previously described trends progress, while the coefficient of variation for the relative potential capacity shows a significant decrease. Hence, with an increase in load, the relative potential capacity aligns between athletes in the series despite the difference in the exercise styles, which means that when interacting as a team in ski races, they all have chances to show similar, potentially best, results.

The EGM test conducted after the fourth mesocycle showed the following results: The relative aerobic capacity and the relative leg muscle capacity at a HR of 180 beats/min have increased markedly in all the subjects (except for the No. 3 athlete) due to high aerobic load (90%). This, in turn, had a negative effect on the maximum aerobic capacity of the leg muscles.

The relative cardiac capacity indices recorded after the fourth mesocycle turned to be lower in all the subjects, except for the No. 3 athlete. This decline is associated with deeper intervals, high-speed, and tempo training, followed by a high HR. Such training has led to a decrease in cardiac capacity through the cardiac output reduction, but affected the increase in cardiac muscle contraction. The latter indicates an increase in the HR at the AeT in all the subjects (Table 10).

The fourth mesocycle saw further improvement in the uniformity of the sample (i.e., in terms of potential capacity), which proves that each individual athlete thrived to reach one's own full potential during the exercise. Given that participating athletes are members of the same team, the proposed differentiated approach to training program creation will boost the efficiency of both individual skiers and the team without excessive loads, injuries, and potential diseases. Hence, a differentiated approach ensures the compliance of physical development programs for athletes with the principles of sustainability and lays the groundwork for the sustainable development of youth sports in general, with safety, healthcare, and long-term targets at the core.

Table 10. The EGM test results after mesocycle IV.

Sportsman Number	BW (kg)	Aerobic Capacity of Leg Muscles (W)	Relative Aerobic Capacity (W/kg))	HR at the AeT (beats/min)	Muscle Capacity at the HR of 180 beats/min (W)	Relative Muscle Capacity at the HR of 180 beats/min (W/kg)	Potential Capacity (W)	Relative Potential Capacity (W/kg)
1	63	165	2.62 (3)	127	280	4.44 (4)	355	5.63 (4)
2	64.2	130	2.02 (2)	130	240	3.74 (2)	333	5.19 (3)
3	74.8	135	1.8 (1)	131	215	2.87 (1)	373	4.99 (3)
4	63.5	180	2.83 (4)	135	275	4.33 (4)	355	5.59 (4)
5	69.3	165	2.38 (3)	136	245	3.54 (2)	365	5.27 (4)
6	70	170	2.43 (3)	133	245	3.50 (2)	380	5.43 (4)
7	70.7	170	2.40 (3)	129	265	3.75 (2)	380	5.37 (4)
8	62.3	150	2.41 (3)	130	220	3.53 (2)	340	5.45 (4)
Standard Deviation			0.322288136			0.497242396		0.211322367
Arithmetic Mean			2.36125			3.7125		5.365
Coefficient of Variation,%			13.6490476			13.39373456		3.938907123

Note: (1) low estimate; (2) below average estimate; (3) average estimate; (4) above average estimate; (5) high estimate.

4. Discussion

This research method allows assessing various functional capabilities of young male students without special difficulties and applying the results for making case-specific training programs. This research is relevant, as we have tested the cardiovascular system (muscle) capacity directly under the load. This allowed obtaining accurate information about each subject before the next mesocycle [28].

In speed skiing, legs make a gradual contribution to the racing skier's movement as the speed increases in a double poling manner in order to maintain the ability of the upper body muscles to react [29]. The aerobic energy contribution of leg muscles is higher than aerobic energy contribution of the upper limb girdle [30]. Hence, leg muscle testing is of considerable interest when it comes to speed skiing. This test provides more information about the cardiac capacity, since the MOC is limited by the ability of the cardiovascular system to deliver oxygen to the muscles [31].

The initial study has shown that the majority of subjects have low and average cardiac capacity indices, since the load was reduced during the recovery stage of training (six weeks) before testing. Accordingly, the cardiac capacity decreased. Low estimates can also indicate poor cardiac development. The most favorable and intensive cardiac output growth was recorded earlier in 16–18-years-old skiers [32]. Based on these indicators and test data, we have increased the aerobic load for each specific case. This allowed us to increase the cardiac capacity in 16 training weeks. Large studies have revealed that athletes participating in long-distance races have a low risk of heart ischemia [33], since they are racing if their HR is low. The latter factor contributes to a cardiac output increase. High cardiac output is compensated by the stroke volume. This has a less negative effect on the cardiac muscle under intensive loads. Therefore, cardiac capacity increase will allow for gradually increasing the high-speed and tempo load without much harm to the cardiac muscle.

Some researchers note that endurance training divided into block periods has an excellent effect on several endurance and performance indicators compared to the traditional one [34,35]. Such block-like division is associated with a high concentration of training means and methods applied while developing particular physical quality at a certain stage of training. Our research is also partly based on a block training system. In our case, however, it is combined with a differentiated approach and test estimates obtained for each mesocycle. This allowed increasing the cardiac capacity in each specific case.

Traditional high-intensity training provides a limited performance improvement among highly skilled racers, and often leads to overload [36]. The high-intensity loads of racing skiers were planned starting from their specific results. The problem was approached carefully.

A significant amount of high-intensity load improves the neuromuscular status and anaerobic muscle strength, and increases the cardiac muscle contraction power without much harm to the body only in highly qualified and enduring athletes [37]. Test results obtained after the fourth mesocycle has shown that leg muscle capacity has increased significantly at the HR of 180 beats/min as the load increased. This indicates a complex increase in the cardiac capacity and the anaerobic metabolism threshold of the leg muscles. However, a higher amount of high-speed and tempo intervals applicable at this stage has led to a slight decrease in relative potential capacity and to an increase in the cardiac muscle activity at the aerobic metabolism threshold. This also reflects the cardiovascular system capacity.

To assess and distribute the intensity load in the training of trained young skiers, we measured the HR at the anaerobic metabolism threshold and the MOC at the maximum HR to assess and distribute the load while training the racing skiers that had an appropriate fitness level. We have also used the HR at the AeT figure to control the fixed load during the training.

In the course of examining the 16–18 years old skiers, the cardiovascular system response to the highly-intensive block interval training within the framework of a polarized microcycle was analyzed. The study showed that well-trained racing skiers can complete nine workouts with high intensity during a week without harming one's health [38]. In our case, a small amount of high-speed interval load was applied in specific cases during mesocycle 2, since not all of the subjects had suitable cardiac capacity for high-intensity loads. In the fourth mesocycle, high-speed, interval, and tempo training time was significantly increased for all the subjects, except for one skier, since his functional capabilities were low at that time. At these stages, high-intensity training loads were alternated in a wave manner to exclude over-training.

In the case of 17–18 years old skiers, studies have shown that prolonged intensive (5–10 min) aerobic training courses taken twice a week (40–45 min in total) improve the endurance and oxygen uptake at the anaerobic metabolism threshold, but not the short intervals with greater intensity [39]. This can be explained by the fact that a prolonged intense aerobic load allows putting the high-threshold muscle fibers to work, as well as increasing their oxygen consumption.

The anaerobic capacity often changes at the critical intensity limit during the cycle. Thus, we can assess the athlete's fitness level [40].

In block training studies, there is also a strong increase in the athlete's strength [41,42]. In the case of 16–18-year-old skiers, the study has showed that strength training, whose share has been increased during these 10 weeks, increases the strength of the upper body girdle [43]. In our study, we have determined the aerobic capacity of the leg muscles, which indicates the power development of slow muscle fibers. The case-specific combination of weight routine and aerobic distance training has allowed a significant increase in the aerobic strength of the leg muscles in high school boys, engaged in speed skiing.

A further differentiated approach toward the physical training of young racing skiers, based on the leg muscle test data, will allow for improving their performance more effectively at different stages, as well as monitoring the response of their cardiovascular systems to the load. This research should also start from the upper body strength test conducted by means of the EGM for the purpose of designing a fitness program.

4.1. Limitations

This research has some limitations. The overall assessment of an athlete's functional readiness requires a randomized controlled study with long-term follow-up. Many modern studies are based on an individual approach with a small number of subjects [44–47]. In our case, the fitness level should be controlled with regard to the received test data on a daily basis.

4.2. Ethical Approval

This research has been approved by the ethical review board of the authors' affiliated institutions. Participants and their legal representatives gave informed written consent to participate in the study.

5. Conclusions

Physical training means were introduced into the fitness programs according to the cardiac capacity indices, since the cardiovascular system is under great loads in speed skiing due to upper body (leg and back) muscle recruitment. Low cardiac capacity indices have a negative impact on the racing skier's performance. EGM testing allows determining the maximum cardiac capacity by measuring the amount of oxygen delivered to the working muscles at a HR of 190 beats per minute. Therefore, case-specific aerobic load was planned for each mesocycle according to these data. Based on the cardiac capacity growth, such means of physical training were planned as the interval, high-speed, and tempo training. This allowed designing the fitness programs for the high school male students engaged in speed skiing before mesocycles with regard to the cardio-functional indicators. The differentiated approach proposed here ensures the compliance of physical development programs for athletes with the principles of sustainability and lays the groundwork for the sustainable development of youth sports in general, with safety, healthcare, and long-term targets at the core.

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