

Strategies for enhancing general and special endurance in 15–16-year-old skiers during the preparatory period

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Abstract:

Enhancing endurance motor skills is a key focus of training sessions for skiers. **Purpose:** The aim of this study is to develop and evaluate a methodology for enhancing general and specific endurance in 15–16-year-old cross-country skiers during the preparatory phase of the macrocycle. **Materials and methods:** The research project involved 24 skiers aged 15–16 years, evenly divided into a control group (CG) and an experimental group (EG), with 12 participants in each. The athletes held 1–2 sports categories and were members of a sports specialization group at the Children's and Youth School of the Olympic Reserve in the Siberian region of Russia. In the EG, the progression of physical activity during the preparatory period was marked by a gradual increase in both volume and intensity, with a primary emphasis on expanding the volume of training work. The increase in the impact of the applied training loads was achieved by emphasizing their speed-oriented focus while maintaining intensity levels appropriate to the specific stage of preparation. The highest intensity of physical activity was observed during the third stage of the preparatory mesocycle. To improve aerobic capacity, various activities were incorporated, including alternating running with simulated inclines, roller skiing, cross-country skiing, sports games, cyclocross, step simulation with poles, swimming, strength training, and exercises for technique and movement coordination. At each stage of the preparatory period, milestone tests were performed to assess the motor skills and physical performance of all athletes. **Results:** The effectiveness of the proposed method for improving general and special endurance was validated at the end of the research project through significantly higher test results in motor qualities and physical performance among skiers in the EG compared to those in the CG. After the preparatory stage, the EG athletes demonstrated a 7.9% improvement in their 5 km ski race performance compared to the CG, highlighting the superior effectiveness of the proposed method. **Conclusions:** The developed methodology for enhancing general and special endurance in 15–16-year-old cross-country skiers during the preparatory stage of training is recommended for practical use by coaches in children's and youth sports schools.

Key Words: physical activity, physical training, cross-country skiers, endurance, sports technique

Introduction

Cross-country skiing is not only a winter sport but also a valuable means of physical education for young people and an active recreational activity (Kropta et al., 2020; Romanova et al., 2024).

Modern sports performance in cross-country skiing is closely related to the high physical fitness requirements of athletes (Wang et al., 2021). A key factor in an athlete's ability to perform on skis is the development of special endurance, which is essential for managing frequent high-intensity physical loads alongside periods of moderate or low exertion (Talsnes et al., 2024). This requirement arises from the unique features of the course, including both descent and ascent sections. As a result, cross-country skiing is referred to as "intermittent endurance competition" (Falk Neto et al., 2024). The motor quality of endurance has considerably improved in recent years, and sports results are increasingly dependent on its level (Castañeda-Babarro et al., 2022). According to observations by J.O. Osborne et al. (2023), the total annual volume of

physical training for cross-country skiers consisted of approximately 90% endurance training, focusing on the development of maximum aerobic power.

In the annual training macrocycle of a skier, the preparatory stage plays a crucial role because it forms the foundation for the athlete's future performance. During this period, the groundwork for subsequent sports achievements is established (Wang et al., 2021; Osborne et al., 2023). According to A.S. Bakhareva et al. (2017), the preparatory period involves further improvement in the skier's special endurance, achieved by increasing the aerobic power of the muscles in both the limbs and the trunk.

The manifestation of special endurance in various sports can be associated with an athlete's genotype (Johansen et al., 2020), as well as their biochemical and functional indicators (Hébert-Losier et al., 2017; Mishica et al., 2023; Bocharin et al., 2023), personal and psychological qualities, and gender characteristics (Solli et al., 2024). However, the key factor driving the improvement of sports performance is the effective structure and content of the training process in cross-country skiing (Vandbakk et al., 2017; Talsnes et al., 2022). To achieve this, sports experts recommend using various training tools and methods that consider age and gender characteristics (Andersson et al., 2021; Vahtra et al., 2022). Additionally, it is essential to account for the sensitive periods of development for both special and general endurance, which occur between the ages of 14 and 20. Sports scientists emphasize the importance of maintaining proportionality between the development of endurance and strength. During certain age periods, the application of excessive strength training can result in a decrease in endurance. An opposite effect may occur when endurance training predominates, potentially hindering the development of strength qualities. The results indicate that parallel training, which combines endurance and maximum strength, is more effective in enhancing the performance of skiers (Castañeda-Babarro et al., 2022). Additionally, it has been observed that highly qualified athletes exhibit additional adaptive mechanisms for metabolic regulation compared to less qualified skiers (Parshukova et al., 2021; Bocharin et al., 2021). The literature highlights the importance of improving skiing tactics for cross-country sprint performance, particularly in taking the lead approaching the final section of the climb while also maintaining the ability to ski quickly on that section (Haugnes et al., 2022). As a result, skiers adjust their pacing strategies, transitioning from a low oxygen deficit in the endurance section to a higher deficit in the sprint section (Gloersen et al., 2024). Skiing technique also plays a crucial role in achieving optimal athletic performance (Løkkeborg & Ettema, 2020; Andersson et al., 2021; Therell et al., 2022). The incorporation of roller skis into the training process, which closely mimics cross-country skiing, has proven effective in enhancing running skills and special endurance in athletes during the off-season (Løkkeborg & Ettema, 2020; Andersson et al., 2021; Yanaka et al., 2024). According to the authors, this improvement is attributed to the increased contribution of the anaerobic energy system, which improves skiing efficiency during submaximal loads in preparation for the competitive season.

By monitoring heart rate and blood lactate levels (Talsnes et al., 2024), the dynamics of these indicators were tracked in relation to individual loads during speed races. As a result, these physiological markers are effectively used in managing the training process (Lee et al., 2024). Despite the existing scientific literature devoted to the issues of improving the speed-strength qualities of skiers, this area still remains relevant in the theory and practice of sports. The materials on improving special endurance in young, promising skiers at the preparatory stage of their training are not presented in sufficient detail. Detailing the issues and making adjustments to the process of improving the speed-strength qualities of young men will improve the effectiveness of training sessions and the effectiveness of their sports performances.

Research aim. The objective of this study is to develop and evaluate a methodology for enhancing general and special endurance in 15–16-year-old cross-country skiers during the preparatory phase of the macrocycle.

Materials and methods

The research project was performed at the Children's and Youth Olympic Reserve School in Taishet (Siberian Federal District, Russia), with 24 skiers aged 15–16 years (15.7 ± 1.6 years) participating in this study. All athletes held 1–2 sports categories and trained in a sports specialization group, following the federal standard program for cross-country skiing (Federal Standard of Sports Training in the Sport of "Cross-Country Skiing," 2022). The participants were randomly assigned to either the control group (CG, $n = 12$) or the experimental group (EG, $n = 12$). The study was carried out jointly by scientists from the departments of physical education and pedagogy at various universities in Russia, Kyrgyzstan, and Kazakhstan. The study adhered to the principles outlined in the 2008 Helsinki Declaration for research involving human participants.

The preparatory period for cross-country skiers was divided into three stages: Stage I - spring–summer, Stage II - summer–autumn, and Stage III - winter. Stage I training focused on general preparation, incorporating activities such as cross-country running, cyclocross, walking simulation with poles, roller skiing, swimming, sports games, strength exercises, and drills for technique and movement coordination. Cyclic aerobic work was performed at low (120–140 beats per minute) and moderate (140–160 beats per minute) heart rates. Training sessions were performed on circles with low and medium complexity. The volume of cyclic work completed by athletes in both the CG and the EG was approximately the same (Table 1).

Table 1. Cyclic work volume during Stage I of the preparatory period

Means of preparation	Months				Total for stage I	
	May		June			
	CG	EG	CG	EG	CG	EG
Cross-country running, km	50	65	110	120	160	185
Cyclocross, km	65	60	170	150	235	210
Stepping simulation, km	30	25	75	80	105	105
Roller skis, km	20	25	30	30	50	55
Volume of cyclic work, km	165	175	385	380	550	555

The analysis of the distribution of various training methods during Stage I revealed that in the CG, the uniform method was predominant, accounting for 60%, followed by the game method (18%), the variable method (10%), the repeated method (7%), and the competitive method (5%). For cyclic training methods, the uniform method was predominant, comprising 87%, while the variable method accounted for 13%. In the EG, 42% of the training was based on the uniform method, 28% on the variable method, 20% on the game method, and 5% each on the repeated and competitive methods. In terms of cyclic training, the uniform and variable methods were used in approximately equal proportions.

Stage II of the preparatory period focused on special preparation. This stage began in July and continued until the onset of snow. During July and August, athletes attended a training camp where they participated in two daily training sessions. Training activities included cross-country running (heart rate of 140–180 beats/min), alternating running with simulated climbs ranging from 6° to 20° and distances of 50–200 m (heart rate of 155–185 beats/min), and serial jumping simulations with poles during climbs (heart rate of 150–195 beats/min). At Stage II, athletes in the experimental group had different volumes of specialized training, as shown in Table 2.

Table 2. Volume of aerobic work at Stage II of the preparatory period

Means of preparation	Means						Total for Stage II	
	July		August		September			
	CG	EG	CG	EG	CG	EG	CG	EG
Cross-country distance	150	150	180	200	130	150	460	500
Jump imitation	70	100	110	120	105	120	285	340
Speed work	20	25	40	60	65	70	125	155
Roller skis	50	55	80	80	70	70	200	205
Volume of special work	290	330	410	460	370	410	1070	1200

The distribution of training methods at Stage II in the CG showed a preference for the uniform method (54%), followed by the variable method (25%) and the repeated method (21%). In cross-country running and jump simulation, the ratio was 75%–25%. Speed work primarily used the repeated method (70%), with the variable method accounting for 30%. In the EG, the method distribution was as follows: uniform method (27%), variable method (54%), and repeated method (19%). Special work in the EG was largely performed using the variable method, which facilitated a greater volume of speed and simulation exercises.

Stage III of the preparatory period focused on improving special endurance. This stage began with the establishment of snow cover in the second half of October and ended in early December. During this period, skiing was the primary training method, with a predominant use of the uniform method and, to a lesser extent, the variable and tempo methods. At Stage III, the volume of skiing at medium and high intensity was increased, as shown in Table 3.

Table 3. Volume of ski training at the third stage of the preparatory period, km

Zones of skiing intensity by heart rate (bpm)	Months						Total for Stage III	
	October		November		December			
	CG	EG	CG	EG	CG	EG	CG	EG
1. 120-140	100	60	200	120	80	60	380	240
2. 140-160	50	80	150	180	150	120	350	380
3. 160-180			30	60	50	100	80	160
4. 180-200				10	10	30	10	40
Total km	150	140	380	370	290	310	820	820

Table 3 shows that while the total volume of skiing performed by athletes in both groups during Stage III is similar, the intensity of skiing differs. The percentage distribution of intensity zones by heart rate (first, second, third, and fourth zones) during skiing is as follows: in the CG - 46.3%, 42.7%, 9.8%, and 1.2%, respectively, and in the EG - 29.2%, 46.3%, 19.6%, and 4.9%, respectively. These data suggest that the athletes in the EG completed the planned training volume with higher intensity compared to the CG.

A milestone assessment of the development of motor qualities and physical performance in the skiers from both the CG and EG was performed. The following control tests were used to evaluate their progress: 100 m run (s), 5 × 10 m shuttle run (s), 6 km cross-country skiing (m/s), pull-ups from a high bar (number of repetitions), 30-s torso lift (number of repetitions), standing long jump (cm), standing forward bend (cm), and 5 km cross-country skiing in snowy weather (m/s).

The results of the control tests were analyzed using mathematical statistics, where the arithmetic mean, its error, and sigma were calculated. The reliability of the differences between groups was determined using Student's t-test. Differences were considered statistically significant at $p < 0.05$.

Results

At the beginning of the research project, no statistically significant differences were found between the values of general and special physical fitness and physical performance indicators in skiers from both observation groups ($p > 0.05$), indicating that the participants were correctly distributed into the groups. The results of the testing of athletes in both observation groups at different stages of the research project are presented in Table 4.

Table 4. Limit values of indicators of testing motor qualities and physical performance of skiers in both observation groups, $M \pm m$

No	Test	Project start		Stage I		Stage II		Stage III	
		CG	EG	CG	EG	CG	EG	CG	EG
1.	100 m run, s	14.23± 0.12	14.25± 0.14	14.21± 0.13	14.20± 0.12	14.19± 0.13	13.35± 0.11*#	14.15± 0.14	13.23± 0.14*#
2.	5 × 10 m shuttle run, s	8.22± 0.22	8.24± 0.23	8.13± 0.22	8.10± 0.23	8.10± 0.22	8.03± 0.21	8.05± 0.23	6.25± 0.16*#
3.	6 km cross-country skiing, m/s	23:22± 1:18	23:25± 1:23	22:41± 1:14	22:15± 1:34	22:05± 1:56	21:45± 1:15	-	-
4.	Pull-ups on the horizontal bar, number of repetitions	10.3± 0.39	10.5± 0.25	11.7± 0.49*	12.5± 0.25*	12.3± 0.29*	13.5± 0.25*#	12.7± 0.39*	13.8± 0.25*#
5.	Torso lifting in 30 s, repetitions	47.5± 1.42	46.55± 1.16	48.25± 1.66	49.45± 1.96	52.45± 2.16*	55.35± 2.76*	54.75± 2.93*	62.12± 3.03*#
6.	Standing long jump, cm	190.0± 4.12	190.4± 4.04	193.8± 4.27	196.5± 4.65	195.4± 4.68	199.5± 5.24	199.8± 5.25*	204.4± 7.57*
7.	Forward bend from standing position, cm	10.65± 1.15	10.42± 1.06	11.65± 1.87	12.35± 1.86	12.05± 2.15	12.55± 2.64	12.25± 2.87	12.35± 2.67
8.	5 km cross-country skiing, m/s	-	-	-	-	-	-	17:48± 0:56	16:09± 0:43#
9.	Harvard step test index, arbitrary units	102.5± 3.44	104.5± 3.58	110.5± 4.12	115.0± 4.23*	117.5± 4.67*	123.5± 4.22*	124.4± 4.87*	137.7± 4.90*#

Note. * significant difference in indicator values compared to the beginning of the project, $p < 0.05$;

significant difference in indicator values between athletes in the CG and EG, $p < 0.05$

During the boundary testing of skiers in both groups at the end of each preparatory stage, improvements were observed in all athletes. At the end of Stage I, a significant increase in the indicator values was recorded for CG athletes only in the pull-up test. In EG skiers, a significant increase was observed in the pull-up test and the Harvard step test index, $p < 0.05$, compared to the beginning of the research project.

At the end of Stage II, further improvements in the results of the boundary testing were observed in both observation groups. In the CG, a significant improvement was recorded in three tests: "pull-up," "torso lifting in 30 s," and the Harvard step test index. In the EG, a significant increase was observed in four tests: "100 m run," "pull-up," "torso lifting in 30 s," and the Harvard step test index, compared to the beginning of the project, $p < 0.05$.

At the end of Stage III, significant improvements were observed in the results of CG athletes in four tests and in six tests for EG skiers, compared to the beginning of the research project, $p < 0.05$. The indicator values in these tests were substantially higher for EG athletes than those of the CG. Additionally, at the end of Stage I of the preparatory period, the increase in the values of indicators for all physical fitness and physical performance tests was greater in the EG compared to the CG, as shown in Figure 1.

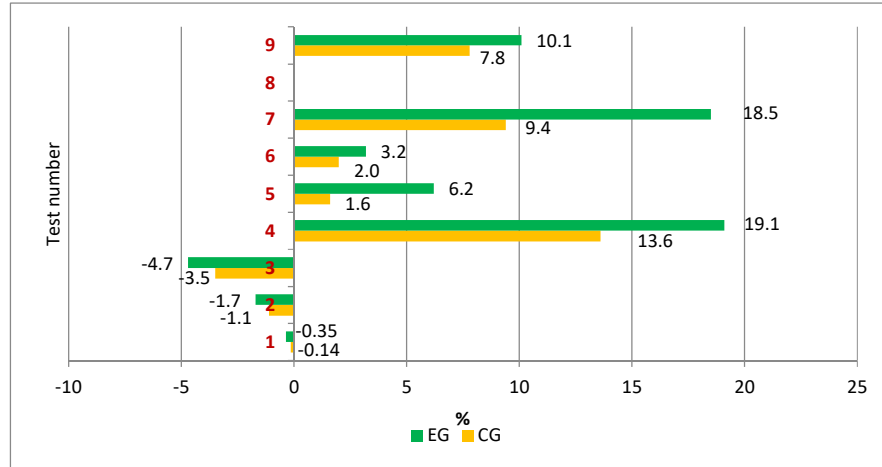


Fig. 1. Changes in physical fitness and physical performance indicators in CG and EG skiers at the end of Stage I of the preparatory period

The most significant improvement in EG skiers was observed in the strength test ("Pull-ups on the bar"), with a 19.1% increase, followed by the flexibility test with an 18.5% increase.

The changes in the values of general, special fitness, and physical performance indicators at the end of Stage II are shown in Figure 2.

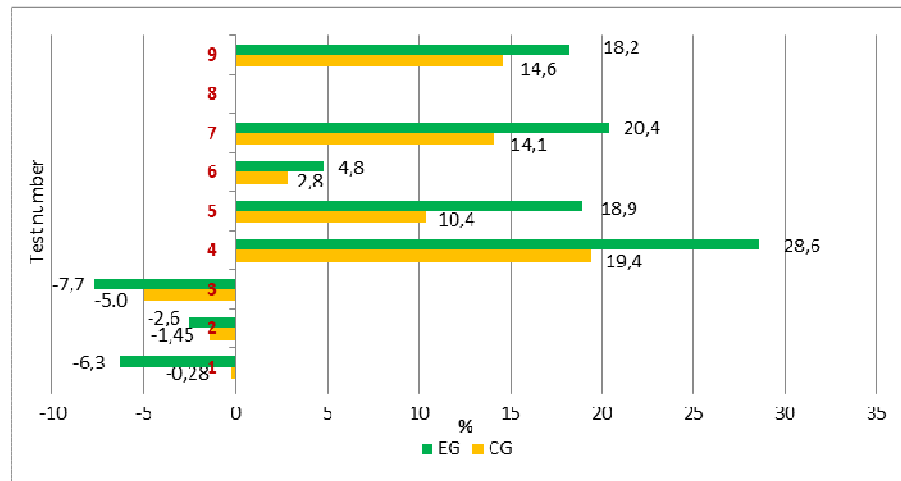


Fig. 2. Changes in the values of physical fitness and physical performance indicators in the experimental group skiers at the end of Stage II

At the end of Stage II of the preparatory period, a further increase in all indicators of general, special fitness, and physical performance was observed in skiers from both groups compared to the beginning of the research project.

The most significant improvements were observed in the EG skiers, with a 28.6% increase in strength test No. 4, 18.9% in strength test No. 5, 20.4% in the flexibility test, and 18.2% in the Harvard step test index compared to the project's start.

The increase in the values of general, special fitness, and physical performance indicators at the end of Stage III is shown in Figure 3.

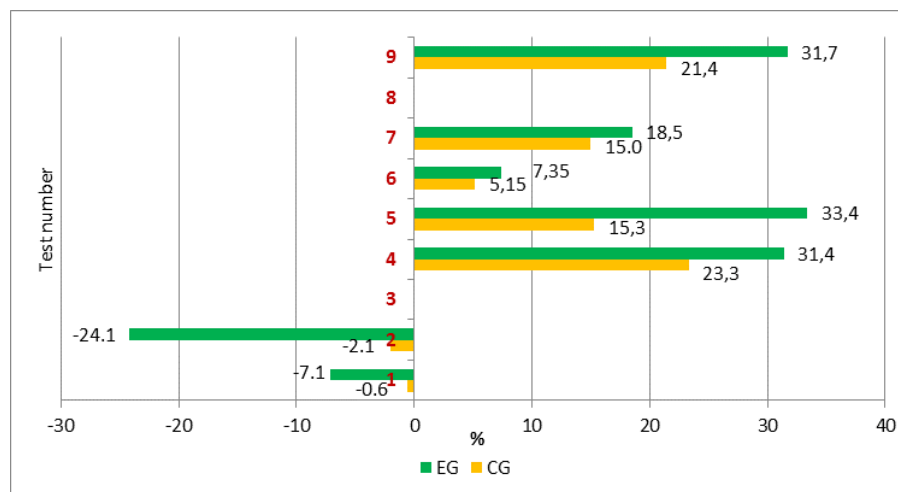


Fig. 3. Changes in the values of physical fitness and physical performance indicators in skiers at the end of Stage III

At the end of Stage III of the preparatory period, further improvements in the motor test results and physical performance indicators were observed in both groups of skiers. The most significant increases, exceeding 30%, were recorded for EG athletes in tests No. 4, 5, and 9 compared to the beginning of the project. Overall, the EG demonstrated greater improvements in motor test indicators compared to the CG athletes.

The use of the proposed method for improving general and special physical fitness, as well as physical performance at the preparatory stage of training skiers made it possible to obtain significantly better results for athletes in the experimental group, compared to the control group of athletes. The result of improving general and special fitness is a reliably better result for EG athletes in the 5 km ski race at the end of stage III. The EG athletes' result was 1:39 sec (7.9%) better than the CG result. These data indicate the significant effectiveness of the proposed method for improving general and special endurance.

Discussion

The steady growth of athletic performance in cross-country skiing requires continuous improvement of existing methods for training athletes (Wang et al., 2021). It is known that the key role in the training of a skier is given to the preparatory stage of the annual macrocycle. During this period, the general and special physical fitness of the skier, his tactical training are improved, and the athlete's physical performance increases (Wang et al., 2021; Osborne et al., 2023).

A particularly important role in cross-country skiing is given to the motor quality of endurance (Castañeda-Babarro et al., 2022). According to J.O. Osborne et al. (2023), approximately 90% of the annual training volume of XC skiers is devoted to physical activity associated with endurance. At the same time, the key point in cross-country skiing is a high level of development of aerobic performance (Talsnes et al., 2024). In order to develop and improve general physical fitness with an emphasis on increasing the level of special endurance, we proposed a technique aimed at improving these parameters of the body. A feature of the proposed technique is the use of different ratios of methods for performing training loads and their intensity in the preparatory period, especially at stage III of preparation. In particular, at stage I of the preparatory mesocycle, both experimental groups had approximately the same volume of loads performed, and a uniform training method prevailed in the control group. The experimental group had a greater volume of the alternating and competitive methods than the control group. At stage II of training of skiers of the experimental group, the alternating method was predominantly used, which developed special endurance in athletes. In EG, the alternating method accounted for 54% of the total structure of special work in training sessions. In the control group, training sessions were conducted mainly using the repeated (70%) and alternating (30%) methods. At stage III, both experimental groups mainly used the uniform and, to a lesser extent, the alternating and tempo methods. In the skiers of the experimental group, we increased the volume of cross-country skiing at medium and high intensity, which contributed to their achieving high test results compared to the control group. These data are consistent with the opinion of Talsnes et al. (2024) that the use of high-intensity interval training in the training of skiers in preparation for the competitive season allows to increase the maximum oxygen consumption of athletes, which ultimately improves athletic performance. According to Yanaka et al. (2024) in the preparatory period, the improvement of skiing results in athletes is mainly associated with an increase in the contribution of the anaerobic energy system due to the use of maximal loads. In our opinion, the use of maximal and submaximal intensity physical loads in the preparatory stage of training skiers is justified by the fact that

cross-country skiing is characterized by variable loads of different intensity, which is explained by the ascents and descents of the competition track. Therefore, skiers must have a high resistance to such bursts of loads. We agree with the opinion of other researchers (Falk Neto et al., 2024; Romashov & Posazhennikov, 2024), who express the opinion that such repeated high loads can affect the formation of a training strategy for achieving success in cross-country skiing.

The results of our studies confirmed the opinion of other researchers (Vandbakk et al., 2017; Talsnes et al., 2022; Solli et al., 2024) about the leading means of improving special endurance. Such means are alternating running with imitation of an incline, the use of roller skis, serial imitation of inclines and skiing, sports games, cyclocross, step imitation with poles, swimming, strength exercises, exercises for technique and coordination of movements. When performing these exercises in the preparatory period, skeletal muscles are strengthened and all motor qualities and elements of skiing technique are improved. This is confirmed by an increase in the values of motor test indicators in athletes who participated in the experiment we conducted.

The testing of the proposed method for improving general and special endurance is confirmed not only by significant positive results of testing these motor qualities, but also by a higher level of physical performance of skiers in the experimental group at the end of the research project compared to the results in the control group. At the end of the preparatory mesocycle, athletes in the experimental group showed a reliably high result in the 5 km ski race compared to the control group. The results of the experimental group athletes in the 5 km cross-country skiing race were 7.9% better than the results in the CG, which indicates the greater effectiveness of the proposed method compared to the traditional training program.

Conclusion

A method for enhancing the general and special endurance of 15–16-year-old cross-country skiers during the preparatory phase of their annual training cycle has been developed and tested.

In the EG, the physical activity dynamics during the preparatory period showed a gradual increase in both volume and intensity, with a predominant focus on volume. The increase in load intensity was achieved by emphasizing speed-oriented exercises in the intensity limits appropriate for each training stage. The highest intensity of physical activity was observed at the end of the third stage of the preparatory period. During this period, the increased volume of medium- and high-intensity skiing among the EG athletes contributed to superior results in motor qualities compared to the CG. The most significant result of applying the proposed method was observed in the 5 km cross-country ski race, where the EG athletes achieved a performance of 7.9% better than their CG counterparts. This indicates the greater effectiveness of the proposed method compared to the traditional approach.

The proposed method for enhancing the general and special endurance of 15–16-year-old cross-country skiers during the preparatory stage of their training can be recommended for practical use by coaches at children's and youth sports schools.

Conflicts of interest. The authors declare no conflict of interest.

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