



## THE EFFECT OF SYSTEMATIC PRACTICE OF SNOW SPORTS ON FUNDAMENTAL INDICATORS OF AEROBIC PERFORMANCE IN STUDENTS

### UTJECAJ SUSTAVNOG BAVLJENJA NA SNIJEGU SPORTOVIMA NA TEMELJNE POKAZATELJE AEROBNIH IZVEDBI KOD STUDENATA

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#### ABSTRACT

The snow sports course is a mandatory module at the Vasil Levski National Sports Academy, held in a high-altitude environment (2000 m above sea level). It combines technique training and intense aerobic training in real-world conditions, which stresses the cardiovascular, respiratory, and muscular systems. Winter sports such as alpine and cross-country skiing are highly aerobic and can improve cardiorespiratory fitness in students who do not engage in other sports. The present study aims to assess the effects of a 14-day winter snow sports course on cardiorespiratory fitness, energy expenditure, and aerobic adaptation in students without prior active sports participation. The study involved 52 students (23 men and 29 women) who underwent a maximal cardiopulmonary step test (CPET) before and after the course. Parameters such as maximal oxygen consumption ( $VO_{2max}$ ), metabolic equivalent (METS), maximal mechanical power, pulse rate, and body weight were measured. The course included daily alpine skiing training and one day of cross-country skiing with a total duration of up to 5 hours per day in altitude conditions.  $VO_{2max}$  and METS increased significantly in both sexes, with the effect stronger in men. A slight decrease in body weight was observed in men, which was associated with higher energy expenditure. Maximal mechanical power improved significantly in both women and men. Pulse rate remained stable, suggesting good adaptation without cardiac stress. The decrease in HRmax% in men, together with enhanced aerobic performance, indicates increased cardiovascular efficiency. The 14-day winter course leads to significant improvements in aerobic performance in men

#### SAŽETAK

Tečaj zimskih sportova obvezni je modul na Nacionalnoj sportskoj akademiji Vasil Levski, koji se održava na velikim nadmorskim visinama (2000 m nadmorske visine). Kombinira trening tehnike i intenzivni aerobni trening u stvarnim uvjetima, koji opterećuje kardiovaskularni, respiratorni i mišićni sustav. Zimski sportovi poput alpskog skijanja i skijaškog trčanja vrlo su aerobno zahtjevni i mogu poboljšati kardiorespiratornu kondiciju kod studenata bez sportske aktivnosti. Cilj ove studije je procijeniti učinak 14-dnevnog zimskog tečaja zimskih sportova na kardiorespiratornu kondiciju, potrošnju energije i aerobnu adaptaciju kod studenata bez aktivne sportske aktivnosti. U studiji je sudjelovalo 52 studenta (23 muškarca i 29 žena) koji su prije i nakon tečaja podvrgnuti testu maksimalnog kardiorpulmonalnog koraka (CPET). Mjereni su parametri poput maksimalne potrošnje kisika ( $VO_{2max}$ ), metaboličkog ekvivalenta (METS), maksimalne mehaničke snage, pulsa i tjelesne težine. Tečaj je uključivao dnevni trening alpskog skijanja i jedan dan skijaškog trčanja s ukupnim trajanjem do 5 sati dnevno u uvjetima na visini. Rezultati pokazuju statistički značajan porast  $VO_{2max}$  i METS u oba spola, s tim da je učinak bio jači kod muškaraca. Kod muškaraca je uočen blagi pad tjelesne težine, što je bilo povezano s većom potrošnjom energije. Maksimalna mehanička snaga značajno se poboljšala i kod žena i kod muškaraca. Puls je ostao stabilan, što sugerira dobru adaptaciju bez srčanog stresa. Smanjenje HRmax % u muškaraca, zajedno s poboljšanim aerobnim performansama, pokazatelj je povećane kardiovaskularne učinkovitosti. 14-dnevni zimski tečaj dovodi do značajnih poboljšanja aerobnih performansi

and women. Despite physiological differences between genders, the program proved effective in increasing students' cardiorespiratory endurance and functional training. The course serves as structured aerobic and adaptation training in a real high-altitude environment and supports the development of healthy motor habits and physical resilience. The results highlight the potential of short-term winter training programs to improve cardiorespiratory endurance and overall physical performance in young people. The study contributes to a deeper understanding of the physiological mechanisms underlying adaptation to moderate-altitude physical exertion.

*Keywords: Cardiopulmonary exercise test (CPET), Maximal oxygen consumption (VO<sub>2</sub>max), Metabolic equivalent (METS), High altitude adaptation, Non-athletic population, Physiological response to training*

kod muškaraca i žena. Unatoč fiziološkim razlikama među spolovima, program se pokazao učinkovitim u povećanju kardiorespiratorne izdržljivosti i funkcionalne kondicije studenata. Tečaj djeluje kao strukturirani aerobni i adaptacijski trening u stvarnom okruženju na velikoj nadmorskoj visini i podržava razvoj zdravih motoričkih navika i fizičke otpornosti. Rezultati ističu potencijal kratkoročnih zimskih programa treninga kao učinkovitog alata za poboljšanje kardiorespiratorne izdržljivosti i općih fizičkih performansi kod mladih. Studija doprinosi dubljem razumijevanju fizioloških mehanizama adaptacije na fizički napor u uvjetima umjerene nadmorske visine.

*Ključne riječi: Kardiopulmonalni test vježbanja (CPET), Maksimalna potrošnja kisika (VO<sub>2</sub>max), Metabolički ekvivalent (METS), Adaptacija na veliku nadmorsku visinu, Nesportska populacija, Fiziološki odgovor na trening*

## INTRODUCTION

The “Snow Sports” course is one of the mandatory training modules at the “Vasil Levski” National Ski Academy - Sofia, conducted in a real high-mountain environment (~2000 m above sea level), which places students in conditions of increased physical and mental stress. Within the course, they acquire practical skills and knowledge in alpine skiing and cross-country skiing, as the motor activity is characterized by high intensity and duration.

The so-called “systematic practice” in this context represents a purposeful, daily physical activity with a pre-planned workload and gradually increasing intensity, which stimulates aerobic adaptation and improves the functional indicators of the cardiorespiratory system. In addition to specific technical skills, the course develops students' endurance, coordination, and resilience in cold and high-altitude conditions, as well as habits for safe and responsible behavior in a mountain environment (20, 21).

Winter sports are gaining increasing popularity as a form of active recreation and sports training, especially among young people. The study of physiological parameters in students who are not professional athletes is of key importance for optimizing educational programs and improving their health.

Aerobic exercise is physical activity of prolonged duration and moderate intensity, in which the primary energy source is aerobic metabolism - the process of oxidation of glucose and fats with the participation of oxygen. They engage large muscle groups, are maintained at a constant pace, and lead to increased heart rate and ventilation without reaching peak fatigue (1, 13, 15).

The leading indicators of aerobic capacity are oxygen consumption (VO<sub>2</sub>), heart rate (HR), and energy expenditure, which reflect the efficiency of the cardiorespiratory system and metabolic processes during physical exertion (1, 13, 15)

Skiing sports, especially cross-country (cross-country skiing) and alpine disciplines, are characterized by a high degree of aerobic load due to the need for prolonged work of large muscle groups (lower and upper limbs), performed in a natural mountain environment with often reduced partial pressure of oxygen (e.g., at 2000 m above sea level).

Research shows that cross-country skiing, for example, is among the most aerobically demanding sports, with VO<sub>2</sub>max exceeding 80–90 mL/kg/min in elite athletes and 50–65 mL/kg/min in well-trained amateurs (14, 8). VO<sub>2</sub>max is determined by the capacity of the systems to transport oxygen to the working muscles (hemoglobin level, blood pH, HR, cardiac stroke volume, peripheral blood flow redistribution, oxygen utilization in muscle cells, mitochondrial density and function, cellular diffusion), which is a product of cardiac output (cardiac output) (10). Even when practiced recreationally, skiing results in:

- significant increase in heart rate (HR) to 70–85% of maximum,
- high energy expenditure – between 400 and 700 kcal / hour in alpine skiing and over 900 kcal /hour in cross-country skiing (18)
- activation of aerobic metabolic pathways, especially during long-term activity at low to moderate intensity.

Practical skiing activities, especially within organized courses with a daily workload (4–5 hours), can be considered a structured form of aerobic training, making them suitable for improving cardiorespiratory fitness in untrained or moderately active individuals.

This study aims to track the dynamics of oxygen consumption, pulse rate, energy expenditure, and overall performance in students participating in a 14-day snow sports course, including alpine skiing and cross-country skiing. The analysis will reveal the impact of practicing skiing on physiological adaptations in a high-altitude environment.

## METHODOLOGY

### Participants

The study involved students from all faculties of the Vasil Levski National University of Sport and Fitness who were not currently actively competing at a high level. The group included 23 men and 29 women, with an average age of 21 years (range: 19–25 years). The volunteers were selected at random, without prior screening for physical fitness.

### Anthropometric characteristics

The average age of the participants was  $21.9 \pm 1.3$  years. The average height of the sample was  $173.6 \pm 7.8$  cm, and the average body weight before the course was  $69.2 \pm 8.4$  kg. After completing the course, the average weight was  $68.1 \pm 8.2$  kg, which indicates a minimal but significant decrease associated with increased energy expenditure during daily activities. The calculated basal metabolic rate (BMR) before the course was  $1579.8 \pm 120.5$  kcal/day, and after the course,  $1568.9 \pm 115.3$  kcal/day, confirming the stability of metabolic indicators in the participants.

The participants' initial level of physical activity was not quantitatively measured, as the study focused on changes in aerobic performance after the 14-day snow sports course. Regardless of the individual sports preparation of the students, laboratory tests conducted before and after the course allow for the assessment of differences in indicators such as  $VO_2\max$ , METS, and HRmax, which are due to the systematic load within the training.

### Experimental conditions

The study is conducted at the training base of the Vasil Levski National Academy of Sciences, located at an altitude of 2000 m. This terrain is set up for the mandatory snow sports course and represents a natural high-mountain environment where students' practical training takes place each year. Therefore, the choice of this altitude is not experimental, but predetermined by the curriculum and the conditions under which the course is traditionally conducted.

### Description of the training program

The training lasts 14 days (84 hours) and includes two training sessions per day—morning and afternoon—with

a total duration of up to 5 hours. The duration and workload may vary slightly depending on weather conditions.

The program is identical for all participants and is structured as follows:

- On the first day, the course begins with a 6-kilometer hike with an elevation gain of 850 m.
- From the second to the thirteenth day, daily practical classes in alpine skiing technique for initial training (class A) are held to master and improve alpine skiing technique.
- As part of the program, each student also undergoes one day of cross-country skiing training, including the basic moves in the classic style.
- The fourteenth day includes a final hike and the group's organized return to Sofia.

### Laboratory tests and test protocol

The functional tests were conducted in the Functional Diagnostics Laboratory at the “Center for Scientific and Applied Activities in Sports” at the National Sports Academy “Vasil Levski” - Sofia, in two stages: the day before the start (day 1) and the day after the completion of the course (day 15).

Due to the nature of the study, no specific altitude acclimatization was performed, as the laboratory measurements were performed in Sofia ( $\approx 550$ – $600$  m above sea level), under stable conditions comparable for all participants. This provided a standardized, comparable environment for assessing indicators such as  $VO_2\max$ , METS, and HRmax, without the influence of hypoxic factors characteristic of the course altitude ( $\sim 2000$  m).

Cardiorespiratory step test (CPET) was used to assess aerobic endurance, performed on an ERGOLINE cycle ergometer. The starting power was 60 watts for men and 30 watts for women, with the load increasing by 30 watts every 90 seconds, in accordance with classical protocol recommendations (9). The test was terminated if the required rotational speed and load could not be maintained.

Gas exchange parameters were recorded in real time using a portable MetaMax 3B-R2 metabolic analysis system (Leipzig, Germany), while heart rate was monitored using a Polar H7 device.

### Data analysis

Inferential statistical approaches were used to analyze the collected data. All quantitative indicators were presented as mean  $\pm$  standard deviation (SD), along with minimum and maximum values.

The normality of the distribution of differences between pre- and post-14-day-course values was assessed using the Shapiro–Wilk test. If a normal distribution was found, a t-test for dependent samples (paired) was applied—a sample t-test to establish a statistically significant difference between the “before” and “after” states. In the absence of

normality, the nonparametric Wilcoxon test (Wilcoxon signed-rank test) is used.

Cohen's *d* was calculated to assess the magnitude of the intervention effect; values  $\geq 0.8$  were considered significant. Statistical analyses were performed using SPSS (version XX), with dependent-samples *t*-tests used to compare pre- and post-course means. Additional checks of the assumptions of normality and homogeneity of variance validated the results.

## Researched indicators

Variable parameters are grouped into three main categories:

### Cardiorespiratory parameters:

$VO_2/ kg /ml/ min$  – The amount of oxygen the body absorbs per minute relative to body mass – a basic indicator of cardiorespiratory endurance.

$VO_2/kg\% Pred$  – Percentage of predicted  $VO_2/ kg$  value compared to norms based on age, gender, and physical condition.

METS – Metabolic Equivalent – measures energy expenditure; 1 MET = energy at rest ( $\sim 3.5 ml O_2/kg/min$ ).

### Heart rate:

HR (bpm) – Heart rate per minute during exercise.

HRmax / pred (%) – Percentage of predicted maximum heart rate (formula: 220 minus age).

### Physical ability:

Watt – A measure of mechanical power generated when loaded on an exercise bike – an indicator of muscular endurance and strength.

## RESULTS

Tables 1–3 present the main anthropometric and functional parameters before and after the 14-day snow sports course. The data are divided by gender (women and

men) and include mean values (Mean), standard deviation (SD), minimum and maximum values, and *p*-values from the *t*-test for dependent samples. Statistically significant improvements were observed in most indicators reflecting aerobic capacity and physical performance.

Weight (kg): minimal changes were recorded, indicating that the course's effect is mainly related to functional adaptation rather than body mass reduction.

Aerobic performance ( $VO_2/ kg, \% Pred, METS$ ): An apparent increase in oxygen consumption and metabolic equivalent was observed, with a significant number of participants reaching or exceeding 90% of predicted  $VO_2max$ . This indicates an improvement in cardiorespiratory endurance.

Heart rate (HR, HRmax% Pred): in women, a trend towards higher HRmax was observed, while in men, HRmax values compared to predicted were lower after the course—an indicator of better cardiac efficiency and load economy.

Physical performance (Watt): a significant increase in maximum power output, reflecting increased muscular endurance and strength.

Due to proven physiological differences between the sexes in cardiorespiratory adaptation, data were analyzed separately for women and men to assess the effect of the experiment (12) more precisely.

Weight (kg) - After the 14-day winter course, a trend towards a decrease in body weight was observed (mean from 61.7 kg to 60.6 kg), with the change not reaching statistical significance ( $p = 0.072$ , Cohen's *d* =  $-0.35$ ). The effect is moderate, suggesting a possible reduction in mass, possibly related to physical exertion.

Maximal oxygen capacity –  $VO_2/ kg /ml/ min$  - The average  $VO_2$  values significantly increased after the course, from  $37.0 \pm 6.7$  to  $38.9 \pm 6.9 ml/min/kg$ . The two-sample *t*-test showed a statistically significant difference ( $p = 0.0066$ ), with a Cohen's *d* of 0.55. This demonstrates a clear improvement in aerobic endurance.

Table 1. Summary average values for the entire group (n=52)

Tablica 1. Osnovne karakteristike svih ispitanika

Parameters	Before ( Mean $\pm$ SD)	SE	95% CI	After (Mean $\pm$ SD)	SE	95% CI	$\Delta\%$	p- value
Weight (kg)	69.18 $\pm$ 8.40	1.16	66.90–71.46	68.08 $\pm$ 8.20	1.14	65.85–70.31	–1.6%	0.0020
$VO_2/ kg$ ( $ml \cdot min^{-1} \cdot kg^{-1}$ )	40.01 $\pm$ 7.20	1.00	38.05–41.97	41.67 $\pm$ 7.30	1.01	39.69–43.65	+4.1%	0.0005
HR (bpm)	178.69 $\pm$ 9.50	1.32	176.11–181.27	180.25 $\pm$ 9.00	1.25	177.80–182.70	+0.9%	0.0370
HRmax / pred (%)	90.09 $\pm$ 4.20	0.58	88.95–91.23	91.06 $\pm$ 4.10	0.57	89.95–92.17	+1.1%	0.0510
$VO_2/ kg \% Prev$	94.15 $\pm$ 8.10	1.12	91.95–96.35	98.24 $\pm$ 8.40	1.16	95.98–100.50	+4.3%	0.0004
METS	11.71 $\pm$ 2.10	0.29	11.14–12.28	11.89 $\pm$ 2.20	0.31	11.29–12.49	+1.5%	0.0004
Watt	217.45 $\pm$ 55.00	7.63	202.50–232.40	238.77 $\pm$ 56.00	7.76	223.57–253.97	+9.8%	<0.001

**Women:**

Table 2. Statistical indicators in women (N=29)

Tablica 2. Statistički pokazatelji žena (N=29)

Parameters	Before (Mean ± SD)	SE	95% CI	After (Mean ± SD)	SE	95% CI	Δ%	p- value
Weight (kg)	60.48 ± 7.70	1.43	57.68–63.28	59.90 ± 7.70	1.43	57.10–62.70	-0.95%	0.0270
VO <sub>2</sub> / kg (ml·min <sup>-1</sup> ·kg <sup>-1</sup> )	37.25 ± 6.50	1.21	34.88–39.62	38.82 ± 6.70	1.24	36.40–41.24	+4.0%	0.00065
HR (bpm)	178.07 ± 9.00	1.67	174.79–181.35	179.17 ± 9.00	1.67	175.89–182.45	+0.6%	0.0370
HRmax / pred (%)	89.22 ± 4.40	0.82	87.62–90.82	90.22 ± 4.40	0.82	88.62–91.82	+1.1%	0.0510
VO <sub>2</sub> / kg % Prev	93.28 ± 7.90	1.47	90.40–96.16	100.08 ± 8.40	1.56	96.99–103.17	+7.3%	<0.0001
METS	10.49 ± 2.10	0.39	9.73–11.25	11.03 ± 1.90	0.35	10.34–11.72	+5.1%	<0.0001
Watt	174.29 ± 24.10	4.48	165.52–183.06	192.14 ± 24.70	4.59	183.08–201.20	+10.3%	<0.001

Heart rate (HR, bpm) - There was no statistically significant change in heart rate before and after the course (mean 178.0 bpm vs. 179.6 bpm ;  $p = 0.352$ , Cohen's  $d = 0.18$ ). The effect was weak, indicating that no significant influence on HR was observed during this period.

HRmax predicted value (%) - The percentage of maximum heart rate achieved compared to the expected value remained relatively unchanged (before: 89.6%, after: 90.3%;  $p = 0.361$ ,  $d = 0.17$ ), without a statistically significant difference. This suggests maintenance of cardiovascular capacity in this indicator.

VO<sub>2</sub>/kg predicted value (%) – before the course, 17.2% of women reached over 100% of predicted values, and 41.4% after the course.

Metabolic Equivalent (METS) - Mean METS values increased significantly from 10.4 to 11.3 ( $p = 0.0004$ ), with a large effect size of Cohen's  $d = 0.75$ . This indicates an

improvement in overall physical performance and body efficiency under load.

Maximum power (Watt) - Power generated under load increased significantly from 177.6 W to 192.1 W ( $p < 0.0001$ ), with a strong effect (Cohen's  $d = 0.93$ ). This represents one of the most pronounced physiological effects of the course, reflecting significant improvements in muscular endurance and strength.

Weight (kg) - The mean body mass decreased slightly, from  $77.9 \pm 14.3$  kg to  $77.3 \pm 13.7$  kg. Despite this trend, the difference did not reach statistical significance ( $p = 0.055$ ), but Cohen's  $d = -0.42$ , which may indicate a potential practical effect in a larger sample.

Maximal oxygen capacity – VO<sub>2</sub>/ kg /ml/ min - Oxygen capacity increased from  $42.4 \pm 8.3$  to  $44.3 \pm 8.3$  ml/min/kg. The difference was statistically significant ( $p = 0.013$ ) and

**Men:**

Table 3. Statistical indicators in men (N=23)

Tablica 3. Statistički pokazatelji muškaraca (N=23)

Parameters	Before (Mean ± SD)	SE	95% CI	After (Mean ± SD)	SE	95% CI	Δ%	p- value
Weight (kg)	78.45 ± 10.10	2.11	74.32–82.58	77.50 ± 9.40	1.96	73.66–81.34	-1.2%	0.0150
VO <sub>2</sub> / kg (ml·min <sup>-1</sup> ·kg <sup>-1</sup> )	43.53 ± 7.90	1.65	40.30–46.76	45.37 ± 8.70	1.81	41.83–48.91	+4.2%	0.0013
HR (bpm)	178.30 ± 12.00	2.50	173.40–183.20	182.23 ± 10.20	2.13	178.05–186.41	+2.2%	0.0264
HRmax / pred (%)	90.69 ± 3.90	0.81	89.10–92.28	91.82 ± 3.90	0.81	90.23–93.41	+1.2%	0.0376
VO <sub>2</sub> / kg % Prev	96.66 ± 10.50	2.19	92.37–100.95	101.87 ± 10.80	2.19	97.57–106.17	+5.4%	0.0376
METS	11.92 ± 2.90	0.60	10.73–13.11	14.22 ± 1.10	0.23	13.77–14.67	+19.3%	<0.001
Watt	271.30 ± 61.00	12.72	246.37–296.23	295.60 ± 55.00	11.47	273.12–318.08	+9.0%	<0.001

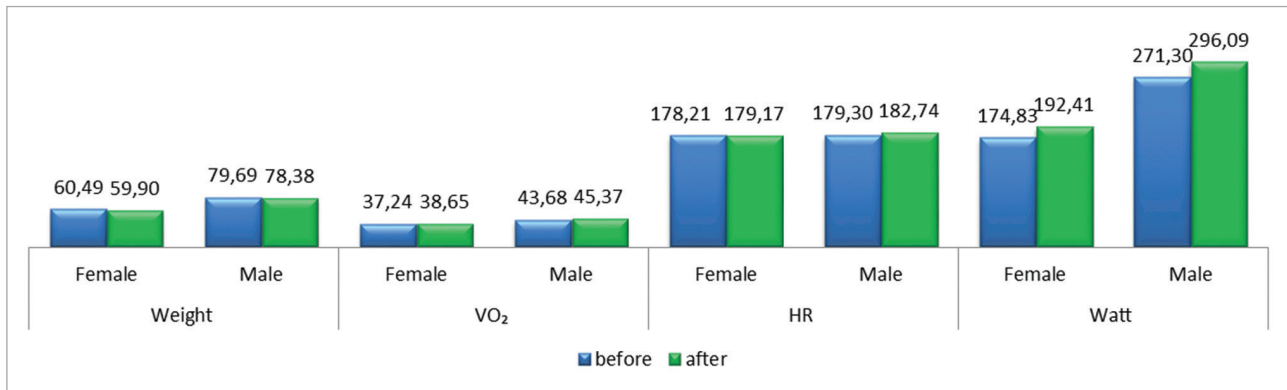


Fig. 1. Changes in indicators before and after the snow sports course.

Slika 1. Promjene praćenih pokazatelja.

had a medium effect size (Cohen's  $d = 0.57$ ), indicating an improvement in aerobic endurance after the course.

Heart rate (HR, bpm) - No statistically significant change was reported in heart rate, from  $179.2 \pm 13.1$  to  $181.1 \pm 10.3$  bpm ( $p = 0.075$ ). Cohen's effect size was small to moderate ( $d = 0.39$ ), suggesting a slight but inconclusive trend toward an increase.

HRmax predicted value (%) - In men, a slight decrease in the percentage of maximum heart rate reached (HRmax % of predicted) was observed after the course, despite increased indicators for VO<sub>2</sub>max, METS, and load (Watt).

VO<sub>2</sub>/ kg predicted value (%) - Before the course, 43.5% reached above 100%, and after it, 52.2%.

Metabolic Equivalent (METS) - The METS score increased from  $11.5 \pm 2.7$  to  $13.1 \pm 1.4$ . The change was statistically significant ( $p < 0.001$ ) and had a large effect size ( $d = 1.15$ ), demonstrating a substantial improvement in physical performance.

Maximum power (Watt) - The maximum load achieved increased from  $258.5 \pm 56.5$  W to  $286.5 \pm 47.7$  W. The difference was highly statistically significant ( $p < 0.001$ ) and had a considerable effect size (Cohen's  $d = 1.27$ ), confirming an objective increase in physical capabilities.

To clarify the changes in the leading indicators of aerobic performance, Figure 1 presents comparisons between men and women before and after the course.

## DISCUSSION

Following a 14-day winter-sports course, significant differences in responses to key physiological parameters were observed between men and women. Well-established differences in cardiovascular and respiratory physiology justify separating data by gender. Men typically demonstrate VO<sub>2</sub>max values 10–20% higher, even when normalized for body mass, due to greater cardiac output, higher hemoglobin concentration, and greater muscle mass (17, 5). Women, in turn, show higher heart rates at submaximal exercise and less pronounced sympathetic regulation, which affects their adaptive potential to aerobic exercise (19).

The current results confirm these differences – men demonstrated greater increases in VO<sub>2</sub>max and mechanical power (Watts), while women showed more modest but statistically significant improvements. This suggests the course's effectiveness in improving aerobic capacity and cardiovascular efficiency in both sexes. However, given the short duration of the intervention, the observed improvements in VO<sub>2</sub>max likely reflect primarily acute physiological adaptations – such as increased ventilation, improved oxygen extraction, and metabolic efficiency – rather than structural changes that require a more extended training period.

The observed increases in VO<sub>2</sub>max, METS, and workload, combined with a relatively stable or slightly decreased HRmax, indicate improved cardiorespiratory economy associated with increased heart rate, better oxygen extraction, and mitochondrial efficiency—typical hallmarks of aerobic adaptation.

VO<sub>2</sub>max was calculated relative to total body mass ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), as changes in muscle composition over 14 days are considered minimal and do not significantly affect the interpretation of the results.

The study participants — students from the Vasil Levski National Sports Academy who are not in a competitive period — are moderately active but not specifically trained. This profile is suitable for assessing the effect of short-term exposure to moderate altitude (~2000 m), where even individuals with limited aerobic fitness exhibit distinct adaptation responses.

Altitudes of around 2000 m provide a moderate hypoxic stimulus, with a decrease in the partial pressure of oxygen of approximately 20–25 mmHg. This triggers well-documented physiological mechanisms:

- increased minute ventilation to maintain arterial saturation;
- a temporary increase in heart rate at rest and during submaximal exercise, followed by improved cardiac efficiency;
- activation of oxidative enzymes and increased mitochondrial density in skeletal muscle;

- stimulation of erythropoiesis and improved oxygen transport (6, 11, 3, 7).

The changes in  $\text{VO}_2\text{max}$  and METS found indicate that even short-term exposure to moderate altitude can stimulate aerobic mechanisms without causing excessive physiological fatigue.

The minimal weight loss in men may be associated with increased energy expenditure and muscle activation, while the stability of mass in women suggests a maintained energy balance. This confirms the program's well-structured workload.

Past studies have highlighted the importance of systematic aerobic training for maintaining fitness and recovery in both competitive and training activities (16). In this context, a snow sports course provides an opportunity for targeted aerobic exercise that improves overall fitness and creates the prerequisites for development in winter disciplines.

Bakhareva et al (2) emphasize the role of anaerobic threshold as an indicator of aerobic reserve and muscle angiogenesis in skiers, further confirming the importance of this type of load for building functional endurance. On the other hand, including balance exercises in winter training programs can improve motor control and energy efficiency (22).

Additionally, the course plays a vital role in building healthy motor habits, mental resilience, and the ability to self-regulate in a busy environment — factors that go beyond the purely athletic aspect of training.

The present study has several limitations that should be considered when interpreting the results. First, the lack of a control group prevents us from completely excluding the influence of external factors, such as spontaneous physical activity outside the course program. Second, the 14-day intervention duration is relatively short for monitoring long-term adaptive changes. Third, strict control over nutrition, sleep, and climatic conditions was not maintained, which may have affected physiological responses. Despite these limitations, the homogeneity of the participants, the standard measurement conditions, and the statistically significant results strengthen the reliability of the conclusions.

Heart rate stability and altitude adaptation: In the present study, heart rate during CPET remained relatively stable before and after the course, suggesting adequate adaptation without cardiac stress. Exposure to moderate altitude (~2000 m) usually results in an acute increase in resting and

submaximal heart rate due to sympathoadrenal activation and reduced arterial saturation; with the accumulation of adaptation processes (differential ventilation, improved oxygen extraction, possible optimization of stroke volume), this increased rate may partially normalize. Therefore, a stable (or only slightly changed) heart rate in conditions of increased  $\text{VO}_2\text{max}$  and mechanical power suggests improved cardiodynamic efficiency — i.e., for a given or higher load, the heart works more economically, due to an increased stroke volume and/or more efficient peripheral oxygen utilization. If the pulse rate was significantly increased after the intervention, this could indicate a compensatory sympatho-excitatory response, dehydration, or incomplete recovery adaptation; in our results, the lack of such a signal supports the conclusion of a favorable functional adaptation to the program, supported by data on cardiovascular adaptation to moderate hypoxia (6, 1, 4).

## CONCLUSION

The results of the present study show that a 14-day winter-sports course leads to significant improvements in physical performance in both women and men. In both sexes, statistically significant increases in  $\text{VO}_2\text{max}$  ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), METS, and achieved mechanical power (Watts) were reported, with moderate to strong effects (Cohen's *d*). While women tended to have higher maximum heart rate (HR<sub>max</sub>), men's HR<sub>max</sub> values remained lower than predicted after the course—a result that, in the context of increased functional indicators, suggests improved cardiac efficiency and aerobic economy. The proportion of participants reaching  $\geq 90\%$  of predicted values for  $\text{VO}_2$  and HR<sub>max</sub> also increased after the course, confirming the positive impact of the load in the winter sports environment.

Systematic 14-day practice at an altitude of about 2000 m is an effective model for assessing physiological impact that stimulates genuine aerobic adaptations even in moderately active students. The improvements in  $\text{VO}_2\text{max}$ , METS, and cardiorespiratory efficiency likely reflect primarily acute physiological adaptations—such as increased ventilation, improved oxygen extraction, and metabolic efficiency—rather than structural changes that require a more extended training period.

However, future studies with longer durations and a control group are needed to confirm the observed trends and distinguish acute from long-term adaptation effects.

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