ANALYSIS OF THE PHYSIOLOGICAL AND METABOLIC STATUS OF FEMALE ATHLETES IN THE NATIONAL ALPINE SKIING TEAM DURING THE PRE-COMPETITION PERIOD

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Abstract: In-depth knowledge of physiological parameters and how they influence workouts, competitions and recovery processes is essential to ensure effective, well-targeted training.
Aim. This study aims to analyze the hormonal and physiological status of female athletes, with direct implications for the training and recovery plan.
Methods. The physiological tests used (saliva testing, metabolic rate assessment and exercise tolerance test) aimed to assess the neuro-immune, metabolic and aerobic status of the three female athletes.
Results. Overall, the three female athletes show very good aerobic capacity, with VO_2max values ranging from 44.9 to 54.7 ml/kg/min, as well as large ventilatory thresholds, which reflects a solid training base, a moderate activation of the hypothalamic-pituitary-adrenal (HPA) axis (cortisol >25 ng/ml) and a metabolic tendency that requires the introduction of training in the light aerobic zone (Z1) to stimulate lipid oxidation.
Conclusions. Integrated data analysis highlights that the investigated female athletes are in a favourable physiological phase with significant potential for progress, but at the same time with a clear need to regulate their neuro-immune balance. Load control, adequate recovery and continuous monitoring of the response to exercise are key elements for sustaining long-term performance.
Keywords: *physiological parameters, metabolic parameters, tests, alpine skiing.*

Introduction

The complex nature of alpine skiing is recognised by many specialists, as this sport requires a complex combination of physical and technical skills (White & Johnson, 1991, 1993; Saibene et al., 1985; Veicsteinas et al., 1984; Tesch et al., 1978), but also mental and social skills (Nilsson, 2019).

According to Bacharach and Duvillard (1995), no distinct feature can be used to assess the potential for success of an alpine skier.

Maintaining optimal physical fitness for alpine skiers during the snowless season is difficult because of the limited number of places intended for specific training. This lack of dedicated infrastructure makes snow-free periods a challenge for continuing athletic training, which is why they focus on physical training aimed at developing muscle strength and endurance, power, anaerobic and aerobic capacity, as well as balance and coordination. (Polat, 2016; Hydren et al., 2013; Neumayr et al., 2003; Andersen & Montgomery, 1988)

The physical training plan should be designed based on an initial assessment highlighting both the strengths and weaknesses of an individual through tests that are specific to the physiological and muscular parameters and relevant to the sport performed. Regular testing with an appropriate test battery is a fundamental pillar of the sports programme development (Pritchard, 2020). By periodically repeating proper tests at key points in the training programme, the coach can obtain valuable feedback that allows the training content to be adjusted. This ensures constant adaptation and optimization of the athlete's performance, preventing overexertion and maximizing progress towards established goals.

In-depth knowledge of physiological parameters and how they influence workouts, competitions and recovery processes is essential to ensure effective, well-targeted training (Turnbull et al., 2009).

A combined analysis of biomarkers in athletes' saliva, correlated with laboratory and cardiometabolic testing results, provides a comprehensive overview of exercise-induced fatigue, training adaptation and the risk of overtraining (Fu, 2025).

Saliva tests for immunoglobulin A (IgA) and cortisol are used to assess the athlete's immune response and stress levels, which are essential aspects in alpine skiing. Immunoglobulin A (IgA) plays a crucial role in the body's defence by neutralizing infectious agents, so it is an effective marker for preventing respiratory infections in athletes (Keaney et al., 2018; Lamm et al., 1995; Underdown & Schiff, 1986).

Studies in the literature (Rico-González et al., 2021) emphasise the correlation between low IgA values, which are closely linked to the occurrence of respiratory infections induced by stress factors specific to sports training and competition.

Elevated salivary cortisol levels, which represent a significant response to physical and mental stress, have been correlated with periods of high-intensity or high-volume training (Aguiar et al., 2021), which require adjustments to recovery programmes depending on the needs of athletes (Sinnott-O'Connor et al., 2018). Salivary cortisol levels are similar to those in Cushing's syndrome, but they return to normal values during recovery (Daly & Hackney, 2005).

Metabolic and exercise parameters such as resting metabolic rate (RMR), respiratory quotient (RQ), maximum rate of oxygen consumption (VO_2max), ventilatory thresholds (VT1/VT2) and maximum heart rate (HRmax) are used by sports staff to assess exercise tolerance and monitor athletic progress (Julio et al., 2017; Bentley et al., 2007). Aerobic power is an important physiological marker that is correlated with sports performance (Reid, 2000) and faster recovery of athletes. Neumayr et al. (2003) confirm that the international success of the Austrian National Skiing Team was closely related to aerobic power, with values of 55.6 ± 3.5 mL/kg/min for females and 59.6 ± 4.7 mL/kg/min for males. These values should be compared taking into account age, training history and skiing level (Nielsen, 2022).

The study conducted by Cassirame et al. (2014) reveals that heart rate variability (HRV) allows determining HR and speed at VT2 during a specific ski-mountaineering incremental test.

Materials and Methods

Research Aim

In this study, we aimed to scan the hormonal and physiological status of each female athlete, with direct implications for the training and recovery plan.

Research Methods

The research methods used were: scientific documentation, direct observation and testing.

The physiological tests used (saliva testing, metabolic rate assessment and exercise tolerance test) aimed to assess the neuro-immune, metabolic and aerobic status of the three female athletes.

Through saliva testing (two samples at a 30-minute interval), immunoglobulin A (IgA) and cortisone values were found and the hypothalamic-pituitary-adrenal (HPA) axis was assessed; this axis represents the regulatory system between the brain and the adrenal glands, which is responsible for controlling stress, metabolism and immune response. When the body is subjected to stress or exercise, the hypothalamus and pituitary gland stimulate the adrenal glands to release cortisol. Cortisol increases blood glucose levels and prepares the body for exercise, but prolonged excess can inhibit immunity and slow down regeneration.

When cortisol levels exceed 25 ng/ml (especially in the morning), the body is in a state of heightened physiological stress, which can lead to:

- decreased post-training recovery rate;
- impaired sleep and glycaemic regulation;
- decreased IgA and increased susceptibility to respiratory infections.

IgA is the main antibody secreted in the respiratory and digestive mucous membranes. When values fall below 400 µg/ml, local immunity is reduced and the risk of infections in the throat, sinuses or lungs increases. In winter sports, this threshold is critical because exposure to cold and intense training increase the vulnerability of the respiratory system.

The second test was for metabolic rate assessment (indirect calorimetry). From the seated position with an oxygen mask on the face for 15 minutes, the following metabolic parameters were recorded:

- RMR – resting metabolism rate, which indicates the energy consumed at rest. This is relevant for establishing caloric needs as well as nutrition and recovery planning.
- RQ – represents the ratio between CO_2 released and O_2 consumed, showing which type of energy fuel (carbohydrates, lipids or proteins) the body predominantly uses.

The exercise tolerance test, namely a 15-minute treadmill run with an oxygen mask on the face, was performed to assess physical capacity and physiological response to exercise. The parameters recorded by this test provide a detailed picture of an individual's sports performance capacity and fitness level, which are essential for assessing and monitoring an athlete in the context of training and competition (BodyStats, 2025):

- VO_2max – the maximum volume of oxygen consumed per kilogram of body weight per minute. This is a key index of aerobic fitness and endurance, showing how efficiently the body can use oxygen during intense exercise.
- VT1 (ventilatory threshold 1) – is the point during increasing exercise intensity at which ventilation starts to increase at a faster rate than VO_2 (oxygen consumption). This marks the shift from moderate to more intense exercise.

- VT2 (ventilatory threshold 2) – is the point at which lactate starts to accumulate in the blood. This indicates the onset of anaerobic metabolism, where the body cannot supply enough oxygen to meet the demands of the muscles, leading to increased production of lactate.
- HRmax – the peak heart rate recorded during the test, measured in beats per minute (bpm). This metric helps assess the cardiovascular system's response to maximum effort.

Participants and Location

The study was conducted with three 16-year-old female athletes, members of the National Junior Alpine Skiing Team, at the "Sydney 2000" Romanian Olympic Centre located in Izvorani. Before the start of the study, all athletes were informed about the testing procedure and the specifics of the investigation. Measurements were carried out in accordance with ethical standards of the Declaration of Helsinki and ethical standards in sport and exercise science research (Harriss & Atkinson, 2015).

Research Design

From October 1 to 4, 2025, the Romanian Ski-Biathlon Federation (FRSB) and the Romanian Olympic and Sports Committee (COSR) organized a training camp at the "Sydney 2000" Sports Complex in Izvorani. The main objective of this training camp was to test female athletes using the protocol of the Olympic Testing and Scientific Assistance Centre (COTAS) – saliva testing, metabolic rate assessment and exercise tolerance test.

The aforementioned tests were conducted on October 3, 2025, when the three female athletes went to the laboratory at 7:00 a.m. The procedure protocol was presented to them, and then the actual testing began.

Results and Analysis

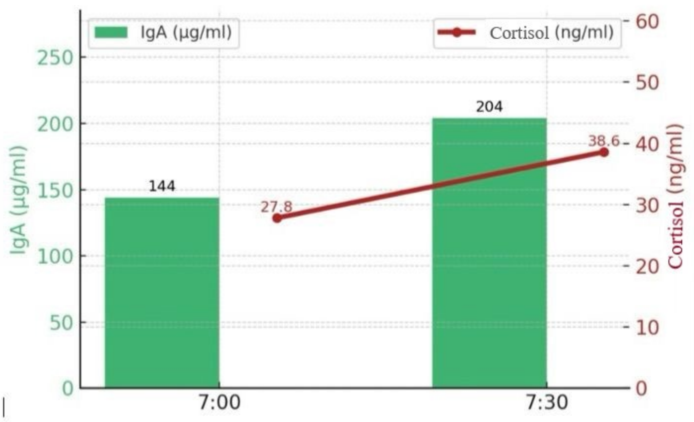
Table 1 shows the values recorded by the three athletes for two parameters: IgA (mucosal protective antibody) and cortisol. For athlete A.I., the fact that she has values below 400 for the IgA parameter indicates reduced immunity but a good response to stress, while the cortisol value above 25 indicates moderate activation of the HPA axis.

Table 1. Saliva testing (two samples at a 30-minute interval)

Athlete	Parameter	7:00 a.m.	7:30 a.m.	Difference (%)
A.I.	IgA (µg/ml)	144	204	+41%
	Cortisol (ng/ml)	27.8	38.6	+39%
B.A.	IgA (µg/ml)	352	740	+110%
	Cortisol (ng/ml)	25	40	+60%
M.E.	IgA (µg/ml)	171	398	+133%
	Cortisol (ng/ml)	40	30	-5%

The values recorded by athlete B.A. show a significant increase in the IgA parameter, which reveals good mucosal immunity and a physiological increase in cortisone that exceeds the attention threshold (>25).

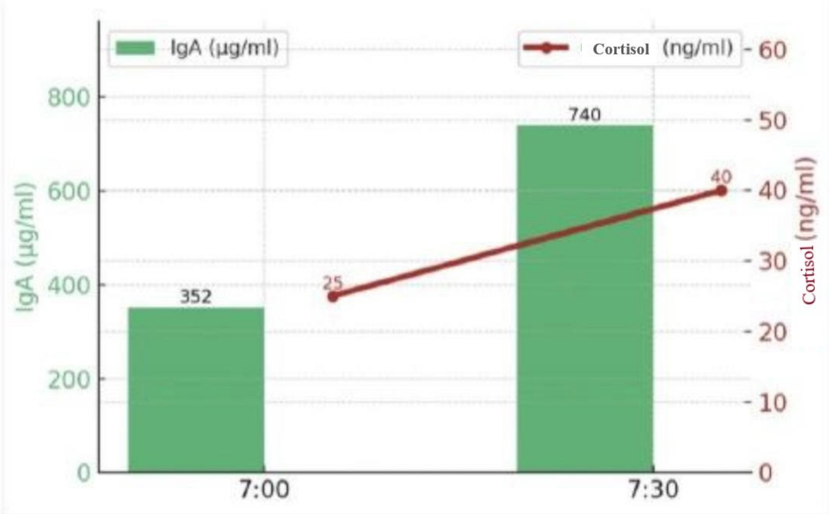
For athlete M.E., there is a significant increase in the IgA parameter when tested at 7:30 a.m. compared to 7:00 a.m., but the final value remains below 400, which indicates a reduced immune level, and regarding cortisol, consistently high values are observed, which exceed the attention threshold (>25).



Graph 1. Changes in IgA and cortisol for athlete A.I.
(green bar = IgA; red line = cortisol)

= mucosal immunity = hormonal response – hypothalamic-pituitary-adrenal (HPA) axis

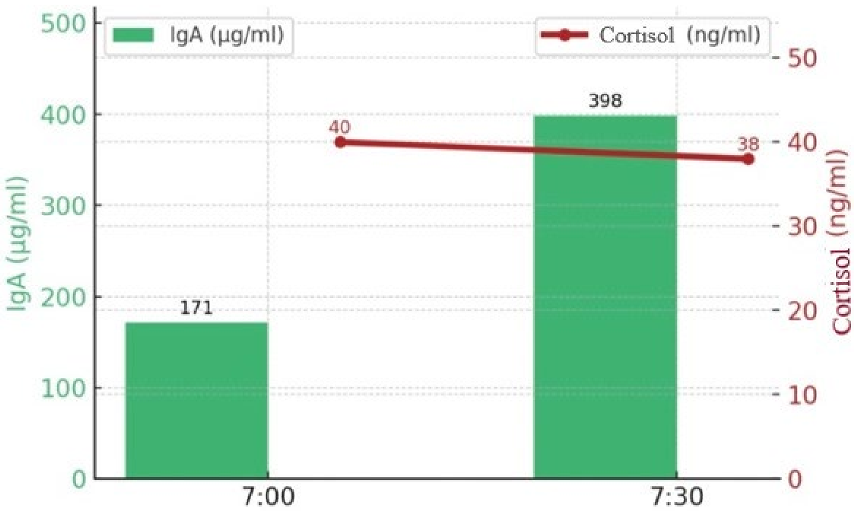
Graph 1 shows that athlete A.I. has an adequate hormonal response, but it is slightly above the optimal threshold (27.8 → 38.6), which indicates a body prepared for exercise although a certain level of physiological stress is present. IgA increases moderately (144 → 204), showing weak immunological reactivity that is still insufficient for complete protection.



Graph 2. Changes in IgA and cortisol for athlete B.A.
(green bar = IgA; red line = cortisol)

= mucosal immunity = hormonal response – hypothalamic-pituitary-adrenal (HPA) axis

For athlete B.A., the values shown in Graph 2 indicate a synchronized increase between IgA (green) and cortisol (red), which suggests a balanced physiological response of the HPA axis.



Graph 3. Changes in IgA and cortisol for athlete M.E.
(green bar = IgA; red line = cortisol)

= mucosal immunity = hormonal response – hypothalamic-pituitary-adrenal (HPA) axis

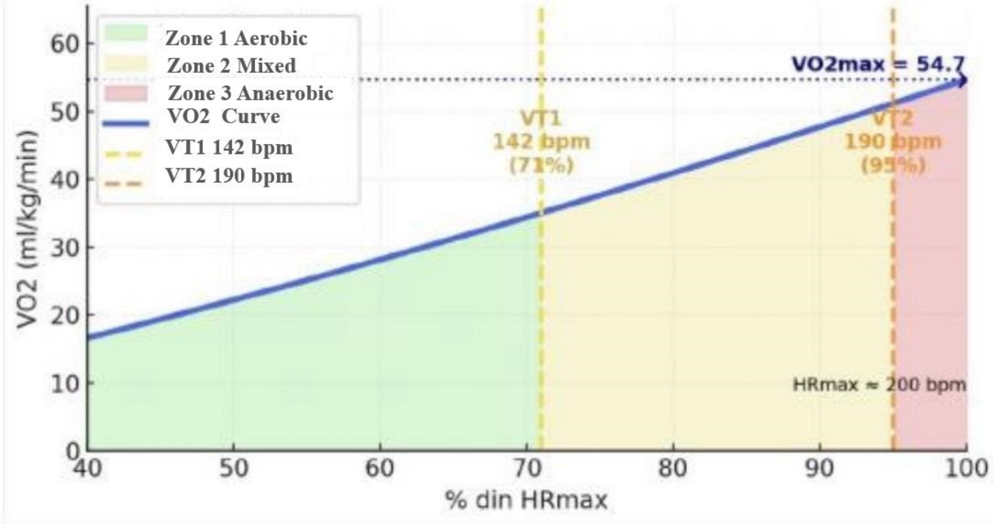
The values represented in Graph 3 show a strongly activated HPA axis:

- Cortisol levels remain high (>25 ng/ml) in both tests, indicating accumulated physiological stress.
- IgA increases, but the final value (398 µg/ml) remains below the optimal immune threshold (400 µg/ml), revealing vulnerable mucosal immunity.

Table 2. Metabolic and exercise parameters

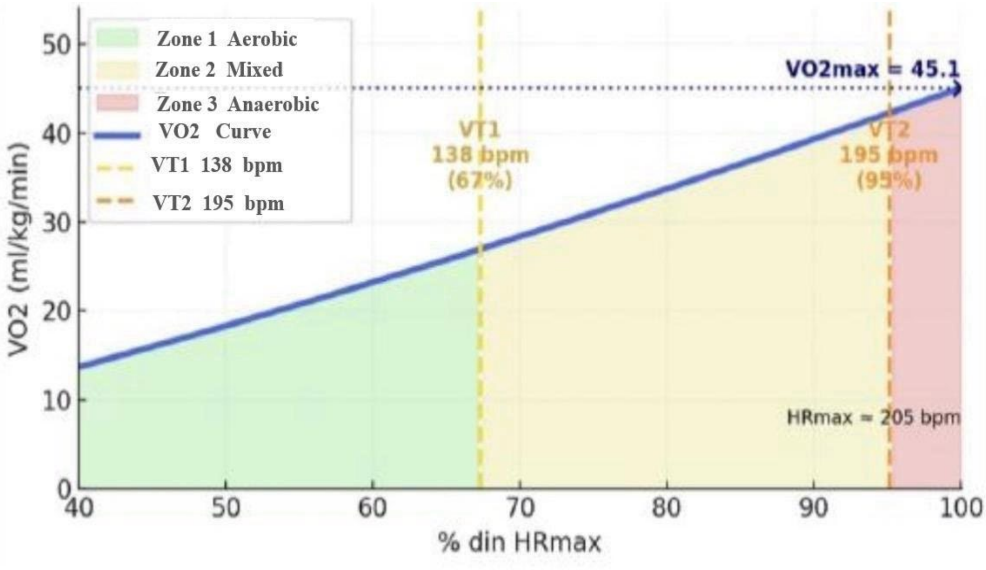
Athlete	Parameter	Value
A.I.	RMR (Kcal)	1950
	RQ (respiratory quotient)	0.79
	VO_2max (ml/kg/min)	54.7
	VT1 (bpm)	142
	VT2 (bpm)	190
	HRmax (bpm)	200
B.A.	RMR (Kcal)	1834
	RQ (respiratory quotient)	0.80
	VO_2max (ml/kg/min)	45.1
	VT1 (bpm)	138
	VT2 (bpm)	195
	HRmax (bpm)	205
M.E.	RMR (Kcal)	2057
	RQ (respiratory quotient)	0.93
	VO_2max (ml/kg/min)	44.9
	VT1 (bpm)	144
	VT2 (bpm)	190
	HRmax (bpm)	200

In terms of metabolic parameters, as shown in Table 2, athlete A.I. has an RQ of 0.79, indicating mixed lipid access with conversion to proteins, which suggests an acute form of fatigue. Supplementation with whey protein and casein (a slow-release protein) before sleep is necessary.
Athlete B.A. has an RQ of 0.80, indicating the use of carbohydrates. For balance, training sessions in the Z1 zone (lipid oxidation) are needed.
The third athlete, M.E., has an RQ value of 0.93, which confirms carbohydrate predominance. Training in the Z1 zone is necessary to increase lipid utilization.



Graph 4. VO_{2max} curve and effort zones for A.I.
(blue curve = VO_{2max}; zones: green – aerobic, yellow – mixed, red – anaerobic)

As shown in Graph 4, for athlete A.I., the green zone (≤142 bpm) indicates lipid oxidation and active recovery, the yellow zone (142-190 bpm) indicates mixed effort, which is ideal for improving VO_2 and respiratory efficiency, and the red zone (>190 bpm) indicates intense anaerobic effort, which should be rarely reached in the current hormonal context.



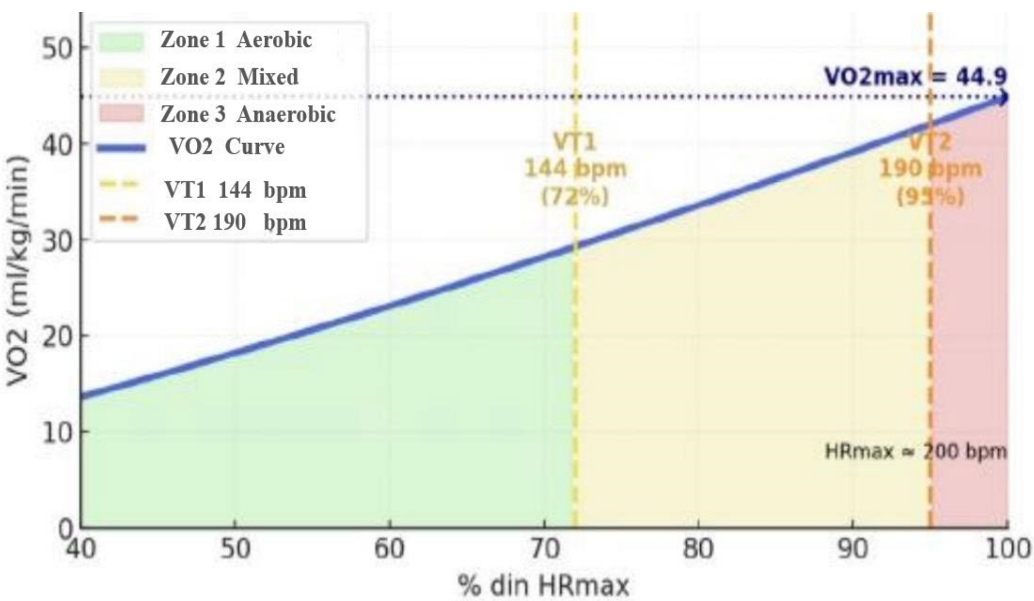
Graph 5. VO_{2max} curve and effort zones for B.A.

(blue curve = VO_{2max}; zones: green – aerobic, yellow – mixed, red – anaerobic)

For athlete B.A. (Graph 5), a clear ascending VO_2 curve is observed, with very well-defined ventilatory thresholds:

- VT1 (138 bpm) marks the aerobic threshold – the lipid oxidation zone, where the effort can be sustained for a long time.
- VT2 (195 bpm) represents the mixed-anaerobic threshold – the upper limit of metabolic efficiency.
- HRmax, with a value of 205 bpm, confirms a cardio-ventilatory profile specific to top athletes.

Thus, the large difference between VT1 and VT2 (-57 bpm) highlights an excellent ability to adapt to variations in intensity, which is an essential characteristic for alpine skiing. The athlete has good tolerance to lactate accumulation and superior respiratory efficiency.



Graph 6. VO_{2max} curve and effort zones for M.E.

(blue curve = VO_{2max}; zones: green – aerobic, yellow – mixed, red – anaerobic)

The curve presented in Graph 6 shows a balanced profile, with a clear distinction between the effort zones and the ventilatory thresholds:

- VT1= 144 bpm – marks the beginning of the lipid oxidation zone (Z1).
- VT2 = 190 bpm – indicates the mixed-anaerobic threshold, which is close to HRmax (200 bpm).
- VO_2max = 44.9ml/kg/min – good level,but it requires consolidation of the intermediate zone (Z2) to increase metabolic efficiency.

The large VT1-VT2 interval (≈46 bpm) shows good tolerance to variations in intensity, but high cortisol and low IgA suggest that the athlete is in a phase of physiological overload. The increase in aerobic capacity should be monitored through controlled training, without excessive stimulation of the HPA axis.

Physiological analysis

For athlete A.I.:

- HPA axis: controlled activation – cortisol above 25 but within physiological limits; alternating loading microcycles with recovery days is recommended.
- Immunity: IgA below 400 – reduced respiratory protection; hydration, sleep and antioxidant intake are priorities.
- Metabolism: RQ = 0.79 – mixed lipid access with conversion to proteins, which suggests an acute form of fatigue.
- Ventilation: the large VT1-VT2 interval (≈48 bpm) shows high performance potential and extended aerobic capacity.

The results recorded by athlete B.A. highlight the following:

- HPA axis: works normally, but cortisol above 25 indicates that the system is already activated; if such values persist for several consecutive days, a decrease in IgA and an increased risk of overtraining may occur.
- Immunity: IgA increased from 352 to 740, indicating good mucosal regeneration.
- Metabolism: RQ = 0.80, which indicates the use of carbohydrates; for balance, training sessions in the Z1 zone (lipid oxidation) are necessary.
- Ventilation: optimal profile, with late transition to anaerobic – a sign of high respiratory efficiency.

For athlete M.E.:

- HPA axis: active, indicating stress response and cumulative load; 1-2 days of recovery are recommended for cortisol normalization.
- IgA <400: risk of respiratory infections and reduced immune protection – important to monitor.
- Metabolism: RQ = 0.93, which confirms carbohydrate predominance; training in the Z1 zone is necessary to increase lipid utilization.
- Aerobic capacity: good, but below optimal potential; the VO_2 curve shows the possibility of increasing VO_2max by 5-10% if working in Z2.

Conclusions

Athlete A. I. has a balanced physiological profile, with excellent aerobic capacity (VO_2max = 54.7) and well-developed ventilatory thresholds (VT1 = 142, VT2 = 190). However, moderately high cortisol and low IgA levels indicate the need for careful recovery.

The physiological profile of athlete B.A. is excellent, with a functional HPA axis, solid immunity and very well-developed ventilatory thresholds. To maintain neuro-immune balance and avoid hormonal overload, the following recommendations are made:

- prioritizing the Z2 zone;
- introducing lipid oxidation training (Z1) on recovery days;
- salivary monitoring every 3-5 days.

The third athlete, M.E., has good aerobic capacity, with a balanced metabolic profile and clear ventilatory thresholds, but with signs of physiological stress (high cortisol, low IgA).

➡ Priority for the next 10-14 days: training in Z1-Z2 to regulate the HPA axis and restore neuro-immune balance.

➡ The increase in VO_2max will be done through mixed training below the VT2 threshold, with continuous salivary monitoring.

Finally, we can state that the test results have confirmed a generally high level of aerobic capacity and good ventilatory adaptation, which are essential elements for performance in alpine skiing. However, the individual differences observed in hormonal and immune parameters show the need for a personalized approach to training and recovery, depending on the characteristics of each athlete.

Integrated data analysis highlights that the investigated female athletes are in a favourable physiological phase with significant potential for progress, but at the same time with a clear need to regulate their neuro-immune balance. Training load control, adequate recovery and continuous monitoring of the response to exercise are key elements for sustaining long-term performance.

The collective process of testing, training and physiologic parameter analysis helps to understand the importance of collaboration between athletes, coaches and specialists, thus strengthening the basis for a culture of performance supported by science, discipline and responsibility.

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