

# Human physiology at high altitude and health activity: the erciyes model

## Abstract

High-altitude exposure induces complex physiological adaptations that can be harnessed for both athletic performance and health. Mount Erciyes (2270–3346 m) provides a natural laboratory for studying hypobaric hypoxia and its effects on human physiology. This paper reviews acute and chronic responses to altitude, including ventilatory, hematological, and cellular adaptations, as well as potential risks such as acute mountain sickness. Furthermore, the Erciyes model demonstrates how high-altitude environments can be integrated into sports training, wellness programs, and medical tourism.

**Keywords:** erciyes, high-altitude, physiology, health tourism

Volume 10 Issue 2 - 2026

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**Received:** March 22, 2026 | **Published:** May 26, 2026

## Introduction

High-altitude physiology has long been of interest to clinicians, researchers, and athletes. Reduced atmospheric and oxygen partial pressures at altitude trigger hypobaric hypoxia, leading to both beneficial adaptations and potential risks. Erciyes Mountain, located in central Anatolia, offers altitudes between 2270–3346 m, making it an ideal site for winter sports, endurance training, and health tourism. This article examines physiological responses to altitude exposure

and explores the potential of Erciyes as a model for integrating sports medicine and tourism. This review synthesizes data from physiological measurements at different altitudes in Erciyes (Table 1) and integrates findings from published literature on hypoxia, acclimatization, and altitude training (Figure 1). Parameters analyzed include atmospheric pressure (Patm), partial pressure of oxygen (PO<sub>2</sub>), alveolar oxygen (PAO<sub>2</sub>), alveolar carbon dioxide (PACO<sub>2</sub>), and arterial oxygen saturation (SpO<sub>2</sub>). Clinical and epidemiological studies on altitude-related health outcomes were also considered.<sup>1,2</sup>

**Table 1** Altitude-dependent physiological and atmospheric metrics at erciyes

Location	Altitude (ft/m)	Patm (mmHg)	Effective O <sub>2</sub> (%)	PO <sub>2</sub> (mmHg)	PAO <sub>2</sub> (mmHg)	PACO <sub>2</sub> (mmHg)	SpO <sub>2</sub> (%)
Sea Level	0 m	760	21%	159	105	40	99
Kayseri City	3,500 ft (1,054 m)	665	19%	140	87	38	95
Tekir Gate	7,500 ft (2,270 m)	570	16%	120	70	36.5	90
Keven Facility	8,700 ft (2,650 m)	555	15%	114	66	36	87
Ottoman Facility	11,000 ft (3,346 m)	500	13.50%	105	58	34.5	84

**Note:** PO<sub>2</sub> refers to Alveolar partial pressure of oxygen; SpO<sub>2</sub> indicates peripheral capillary oxygen saturation.



**Figure 1** Topographic representation of three different altitude points given in Table 1 on Mount Erciyes: i- Tekir gate, ii- Keven facility, iii-Ottoman facility.

## Physico-chemical dynamics of high altitude

Being at high altitude has a number of positive and negative effects on human physiology. These effects vary depending on the altitude level, duration of stay, and environmental conditions. It is generally accepted that a healthy individual can easily tolerate oxygen deficiency up to an altitude of 3,048 m (10,000 ft). Although there are indigenous populations living at these altitudes, if someone living at sea level were suddenly taken to an altitude equivalent to Mount Everest at 8,882 m (29,141 ft), oxygen deficiency could become life-threatening.<sup>2</sup>

The primary environmental stressor at Erciyes is **hypobaric hypoxia**. As altitude increases, the barometric pressure (Patm) decreases, which consequently lowers the partial pressure of inspired oxygen (PO<sub>2</sub>).<sup>3</sup>

Due to the composition of the atmosphere, atmospheric pressure and the partial pressures of the gases it contains (oxygen, nitrogen, etc.) decrease with increasing altitude. The partial pressure of oxygen (PO<sub>2</sub>), which is 160 mmHg at sea level, decreases to 80 mmHg at approximately 5,000 m (18,000 feet) altitude and to 40 mmHg at

10,000 m (34,000 feet) altitude. Altitude-related hypoxia (hypobaric hypoxia) falls under the heading of hypoxemic hypoxia among the types of hypoxias. Hypoxia is defined as a decrease in oxygen, which is necessary for energy metabolism and cellular functions, due to any cause. Hypoxia is when the amount of oxygen in the inhaled air, arterial blood, or tissue falls below normal. By remaining at certain altitudes for a long time, tolerance to these altitude conditions can be developed through a process called acclimatization.<sup>4,5</sup> A kind of resistance to hypoxia can be developed. In fact, by staying at these altitudes for a certain period of time or training, an increase in physical condition and exercise capacity at low altitudes can be achieved.<sup>6</sup> The main developments that enable acclimatization are as follows;<sup>2</sup>

- a) Increase in respiratory capacity
- b) Increase in oxygen-carrying red blood cells
- c) Increase in lung gas exchange capacity
- d) Increase in tissue vascularization
- e) Increase in the ability of cells to use oxygen

As soon as one ascends to high altitude, respiratory rate and depth begin to increase. Within 2-5 days, ventilation increases to about 5 times the normal level. During acclimatization, due to hypoxia, the hormone erythropoietin, which increases red blood cell production, begins to increase after about 6-12 hours. When full acclimatization occurs, the hematocrit rises from its normal value of 40-45% to an average of 60%, and hemoglobin rises from its normal value of 15 g/dl to approximately 20 g/dl.<sup>7</sup> The increase in lung gas exchange capacity, which normally increases during exercise, also occurs under high altitude conditions. Cardiac output increases by about 30%, but returns to normal after the blood hematocrit value increases in the later period. Another circulatory adaptation is the increase in the number of capillaries in extrapulmonary tissues. However, as a result of the adaptation that occurs in cells, there is an increase in the energy production mechanisms in cells (mitochondria, oxidative enzyme systems, etc.) compared to people living at sea level.<sup>8</sup>

It is also necessary to be vigilant against dangers that can be defined as side effects of high altitude and which have a very small probability of being encountered.<sup>3</sup> These conditions are:

- a) Acute Mountain Sickness (Acute brain or pulmonary edema)
- b) Chronic Mountain Sickness.

These conditions can be prevented with necessary check-ups and medical follow-up and can be controlled with transfer to lower altitude and medical treatment.

### Physiological adaptations and acclimatization

Exposure to altitudes above 3,048 m (10,000 ft) requires the body to undergo **acclimatization**—a series of compensatory adjustments to maintain cellular oxygen delivery (Figure 2).<sup>2</sup>

#### Hematological response

Within 6 to 12 hours of exposure, hypoxia triggers the secretion of **erythropoietin (EPO)**. This hormone stimulates erythropoiesis, leading to:

- A. An increase in Hematocrit from a baseline of 40-45% to approximately 60%.
- B. An increase in Hemoglobin concentrations from 15 g/dl to 20 g/dl.

#### C. Enhanced systemic oxygen-carrying capacity.

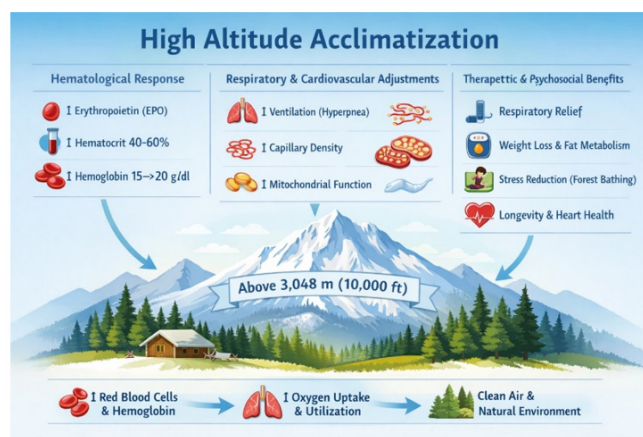


Figure 2 Physiological and therapeutic adaptations to high altitude

### Respiratory and cardiovascular adjustments

- 1) **Hyperpnea:** There is an immediate increase in the rate and depth of ventilation, which may reach five times the normal level within days.
- 2) **Angiogenesis:** Chronic exposure promotes increased capillary density in peripheral tissues, reducing the diffusion distance for oxygen.
- 3) **Metabolic Shifts:** Cellular adaptations include increased mitochondrial density and oxidative enzyme activity, optimizing the efficiency of energy production.

### Therapeutic and psychosocial benefits

High-altitude environments contribute to multifaceted health improvements beyond mere physical conditioning:

- a. **Respiratory relief:** The low-allergen, clean air at Erciyes provides symptomatic relief for asthma and chronic respiratory conditions.<sup>9</sup>
- b. **Metabolic regulation:** Altitude exposure is associated with weight loss and the activation of fat-burning metabolic pathways.
- c. **Mental health:** The presence of pine forests and the natural landscape has been shown to reduce cortisol levels, alleviate stress, and foster emotional well-being concept similar to “Shinrin-yoku” (forest bathing).<sup>6</sup>
- d. **Longevity:** Epidemiological data indicates a positive correlation between high-altitude residence and increased life expectancy, particularly regarding cardiovascular health.<sup>4</sup>

### Life at high altitude

High mountains, besides being spectacularly mysterious, inspiring, and seemingly inaccessible, actually have various health benefits that many people are unaware of. Depending on the season, there are many opportunities for sporting activities in mountainous regions. These include climbing, trekking, cycling, canoeing, winter sports, and camping. These activities can be considered one of the most enjoyable ways to lose excess weight. High altitude also has a weight-loss stimulating effect. Studies have shown that the risk of cardiovascular disease is also reduced at high altitudes.<sup>4</sup> Most importantly, mountain air is very clean and free of many harmful substances found in city air. Clean air is very beneficial in alleviating respiratory problems

and, due to its lack of allergens, can help relieve asthma sufferers.<sup>9</sup> Studies have shown that pine trees, which are frequently found in mountainous areas, reduce irritability, tension, and stress. Climbing a mountain can increase endorphin release, making you feel closer to physical danger and helping you appreciate the value of your life. Facing fears can help you see how limited time is, appreciate the beauty of life, and value life.

Being in the mountains helps strengthen family and friend relationships. Fear of heights, struggling, or getting out of breath is a great way to create new memories and stronger bonds with loved ones and have a good laugh. This type of vacation can also be great for couples who are having problems with spouses. Overcoming obstacles and peaks together is an important way to create new bonds and can give couples a chance to motivate each other. Mountains can also be beneficial for finding inner peace. They can help rediscover the beauty of nature. Throughout history, people have turned to the mountains to find peace. It is not surprising that mountains have historically been mentally healing, as constantly encountering different sounds and smells calms the nerves by taking the brain away from the noise of city life.<sup>6</sup>

Sleeping at high altitude or “live high, exercise low” is one of the most widely accepted techniques used in altitude training. First introduced in 1997 by Benjamin Levine and James Stray-Gundersen, altitude training is based on prolonged exposure to nocturnal hypoxia through physical exercise sessions at sea level following overnight sleep at high altitude. As a result, athletes can build performance-enhancing hematological adaptations inherent in altitude training while simultaneously maximizing high-intensity exercise sessions, thereby developing musculoskeletal adaptations that enable improved speed capability. In simpler terms, athletes achieve simultaneous improvements in both speed and endurance.<sup>10</sup> Both anecdotal and several conducted studies have shown a correlation between longevity and living at a higher altitude. And for the reasons listed above, or yet to be discovered, it is probably no coincidence that 11 of the 20 US populations with the highest life expectancy are located above 5,967 feet altitude.<sup>4</sup>

### Athletic conditioning: the “live high, train low” (LHTL) strategy

Exercise under hypoxia has been proven to increase muscle endurance and fitness through intense aerobic and anaerobic exercise sessions.<sup>10–12</sup> Exercise under intermittent hypoxia improves the ability of respiratory muscles to increase oxygen saturation, preparing the individual optimally for competition at altitude or sea level. Ultimately, it leads to less fatigue, faster recovery, and increased physiological adaptation in the athlete. Research proves that high-altitude exercise plays a significant role in physical conditioning parameters such as sprinting ability, anabolic hormonal responses, and increased red blood cell mass.

In a study of elite male athletes, a 7% increase in VO<sub>2</sub>max and a 7.4% increase in mean maximum power output/kg body weight (Wmax) were observed after 10 days of exercise training at an altitude of 8000 ft/2500 m.<sup>11</sup> There are certain requirements that must be met to achieve optimal performance in all sports. While some sports are mostly based on strength and power (football, rugby, etc.), others provide an advantage in having a high aerobic capacity (basketball, soccer, etc.). When applied correctly, hypoxic exercises are a very valuable and legitimate way to meet these requirements and gain a measurable advantage in competition (Figure 3).<sup>13</sup>

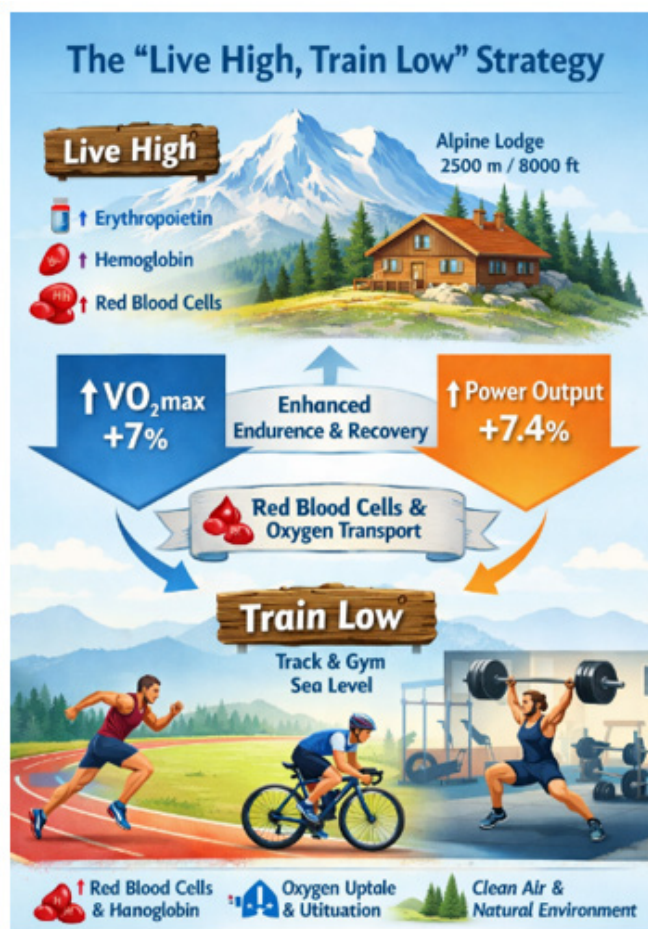


Figure 3 Athletic conditioning through the “live high, train low” strategy.

Erciyes is an ideal venue for the LHTL training modality. By residing at high altitude and training at lower elevations, athletes can induce hematological gains while maintaining the high-intensity workloads necessary for neuromuscular speed and power.

Key performance benefits of hypoxic training:

- 1) VO<sub>2</sub>max and lactate threshold:** Significant increases in maximal aerobic capacity (up to 7% in elite athletes).
- 2) Enhanced recovery:** Improved metabolic efficiency leads to reduced fatigue and faster recovery between high-intensity bouts.
- 3) Endocrine response:** Stimulation of anabolic hormonal responses, including growth hormone secretion.

The Erciyes model highlights the dual role of altitude exposure: a physiological stressor and a therapeutic opportunity. For athletes, “live high–train low” paradigms maximize hematological adaptations while preserving high-intensity training capacity. For health tourism, clean air, reduced allergens, and natural hypoxia provide benefits for respiratory conditions, cardiovascular health, and psychological well-being.

Importantly, Erciyes combines natural altitude exposure with modern medical infrastructure, enabling integration of hypoxic therapies, wellness programs, and sports training. This positions Erciyes as a competitive hub for both domestic and international

health tourism.<sup>14,15</sup>

## Conclusion

The Erciyes Model demonstrates that high-altitude environments offer a potent, natural, and legal ergogenic aid for athletes while serving as a therapeutic setting for clinical health tourism. The combination of barometric challenge and environmental purity creates a unique physiological stimulus that enhances both systemic health and physical performance.

High-altitude exposure at Erciyes Mountain induces measurable physiological adaptations that enhance athletic performance and promote health. While risks such as AMS and HAPE exist, they can be mitigated through medical supervision. The Erciyes model demonstrates how altitude physiology can be leveraged for sports medicine, wellness, and health tourism, offering a unique intersection of clinical science and recreational activity.

## Acknowledgements

None.

## Conflicts of interest

The author declares that there are no conflicts of interest.

## Funding

None.

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