

Physiological Demands of a British Cross Country Skier Competing in the Nordenskioldsløppet.

In this literature review, the physiological adaptations involved in transitioning from mild weather to cold conditions and moderate altitude to high altitude are examined. This review will focus on evaluating existing research to clarify the mechanisms involved in the acclimation processes. The investigation focuses on the intricacies of cold stress adaptation, encompassing factors such as thermogenesis, shivering, and peripheral vasoconstriction. The review explores the impact of ascending from moderate to high altitudes, explaining the adjustments in cardiovascular and respiratory systems to cope with reduced oxygen availability. This analysis aims to merge current knowledge, offering valuable insights for a British cross country skier competing in Nordenskioldsløppet. The findings contribute to a deeper understanding of the physiological responses to environmental stressors, facilitating the development of targeted strategies for performance optimization and health preservation in cold and high-altitude settings.

This literature review critically examines the physiological stresses endured during Cross-country skiing, it is a winter sport that involves skiing across varying terrains, typically in snowy or icy conditions. Unlike downhill skiing, where the focus is on descending slopes, cross-country skiing emphasizes forward movement over flat or gently undulating surfaces. It is a highly aerobic activity that engages both the upper and lower body, making it an excellent cardiovascular workout.

The Nordenskioldsløppet:

At 220 kilometres, this is the longest cross-country skiing race in the world. The course north of the arctic circle is open to everyone, the number of participants is limited. In the classic style about 1,500 meters of altitude are to be mastered. The course takes you through the forests and frozen lakes of Swedish Lapland, from the small village of Purkijaur to Arrenjarka, where you turn around and walk the same route via Purkijaur back to Jokkmokk. Start takes place at six in the morning. The runners must have completed the course in no more than 30 hours most competitors complete the event within 12 to 15 hours, and there are time limits at eleven other points along the route.

Altitude training and acclimation:

Altitude training and acclimation have gained prominence in the realm of sports science as strategies aimed at optimizing athletic performance in various disciplines. At higher elevations, the reduction in oxygen availability poses unique physiological challenges for athletes. Altitude training involves intentional exposure to these reduced oxygen levels, seeking to induce adaptations that enhance performance at sea level. Acclimation, a term often used interchangeably with adaptation, refers to the process wherein the body undergoes adjustments to function more efficiently in a hypoxic environment.

Recent research (Levine *et al.*, 2016) highlights the multifaceted physiological responses to altitude, encompassing changes in cardiovascular and respiratory systems. These adaptations are crucial for athletes seeking a competitive edge,

especially in endurance-based sports. The strategic integration of altitude training and acclimation into an athlete's regimen requires careful consideration of protocols, including duration, frequency, and altitude levels.

Athletes at high altitudes deal with significant physiological challenges due to lower oxygen levels, a condition known as hypoxia. The reduced availability of oxygen triggers adjustments in the body to ensure sufficient oxygen reaches tissues and organs. The main challenge involves the cardiovascular system, leading to an increased heart rate, cardiac output, and blood pressure to compensate for lower oxygen levels, requiring more energy.

Wilber's research (2017) highlights that hypoxia prompts the body to produce more red blood cells, enhancing its ability to carry oxygen. However, this adaptation takes time, and athletes may initially experience a decrease in aerobic capacity and endurance. Which isn't optimal for athletes wanting to compete at the highest level. The respiratory system also undergoes changes, with an increase in breathing rate and depth to cope with reduced oxygen pressures.

These adaptations collectively pose challenges for athletes at high altitudes, impacting their performance, especially in endurance activities. Understanding these physiological responses is crucial for developing effective altitude training and acclimation strategies. These approaches help athletes benefit from altitude-induced adaptations while addressing the initial challenges posed by hypoxia (Wilber, 2017).

Altitude Training Methods:

There are many different ways of balancing training and living

Living High and Training High (LTH):

Athletes reside at high-altitude locations, typically above 2,000 meters (6,600 feet).

Training is conducted at the same high altitude where they live.

Exposure to reduced oxygen levels during both daily activities and workouts aims to stimulate physiological adaptations, such as increased red blood cell production.

Living High and Training Low (LHTL):

Athletes live at high-altitude locations but purposely train at lower altitudes.

Training at lower altitudes allows athletes to maintain higher training intensity and volume, as oxygen levels are closer to sea level.

This approach combines the benefits of acclimatization with the ability to push harder during workouts.

Living Low and Training High (LLTH):

Athletes reside at lower altitudes, usually at or near sea level.

Training sessions are conducted at high-altitude locations, where the reduced oxygen levels challenge the body to adapt and improve oxygen utilization efficiency.

This method is thought to provide the advantage of more intense workouts while still benefiting from altitude-induced adaptations.

Intermittent Hypoxic Training at Rest:

Athletes expose themselves to intermittent periods of reduced oxygen levels during rest or low-intensity activities.

Specialized equipment, such as altitude tents or masks, may be used to simulate high-altitude conditions.

This method aims to induce physiological adaptations similar to altitude training without the need for intense exercise.

Simulated altitude environments, such as altitude sleeping tents or hypoxic chambers, are designed to replicate the reduced oxygen levels experienced at higher altitudes. The use of these devices is based on the principle of hypoxic exposure, which aims to induce physiological adaptations similar to those observed in natural altitude training.

Altitude sleeping tents offer the convenience of bringing altitude training to an athlete's home or training facility. Athletes can sleep in the tent, exposing themselves to reduced oxygen levels during the night without the need to relocate to high-altitude environments.

The goal of simulated altitude exposure is to stimulate the production of red blood cells and enhance oxygen-carrying capacity, leading to improved endurance and performance. Altitude sleeping tents are often integrated into overall training plans, allowing athletes to combine simulated altitude exposure with traditional training methods. The goal of simulated altitude exposure, particularly through methods like sleeping in altitude tents, is to induce physiological adaptations that enhance an athlete's oxygen-carrying capacity, primarily through an increase in haemoglobin mass. This, in turn, is believed to contribute to improved endurance and overall athletic performance. 'Girard, *et al* 2021'

At high altitude, the cardiovascular system responds dynamically to ensure adequate oxygen delivery to working muscles. Studies by Burtcher *et al.* (2018) and Grocott *et al.* (2017) reveal increased heart rate, stroke volume, and cardiac output during exercise at altitude. Concurrently, respiratory adjustments, including hyperventilation and increased ventilatory drive, aim to optimize oxygen uptake and gas exchange (Latshang *et al.*, 2016).

Altitude training involves exposure to reduced oxygen levels typically found at high altitudes. This exposure stimulates physiological adaptations such as increased red blood cell production and improved oxygen utilization, ultimately enhancing aerobic capacity and performance (Levine & Stray-Gundersen, 1997). Altitude tents mimic these conditions by reducing oxygen levels within a confined space, allowing athletes to sleep and rest at simulated altitudes.

Integrating altitude training into an athlete's periodized training program is essential for maximizing its benefits while minimizing the risk of overtraining or detraining. Periodization models should account for the specific goals of altitude training phases, such as enhancing aerobic capacity or promoting recovery. Strategies may include alternating between altitude and sea-level training blocks, strategically timing altitude exposure relative to competitions, and adjusting training volume and intensity based on individual responses (Chapman *et al.*, 2013).

Physical Demands:

Artificial altitude training, commonly achieved through hypoxic chambers, tents, or masks, simulates high-altitude conditions to induce physiological adaptations that may confer performance benefits.

Training in hypoxic conditions increases cardiovascular adaptations such as increased stroke volume, cardiac output, and capillarization, contributing to improved oxygen delivery to working muscles.

Enhanced pulmonary ventilation and oxygen extraction efficiency are observed following artificial altitude training, aiding in the optimization of oxygen uptake during exercise (Schmitt *et al.*, 2016).

Artificial altitude training prompts the production of red blood cells through erythropoiesis, resulting in elevated red blood cell mass and haemoglobin levels (Wilber, 2017). Research indicates that exposure to simulated high altitude triggers the release of erythropoietin, a hormone responsible for stimulating the production of red blood cells, thus enhancing the body's ability to transport oxygen (Burtcher *et al.*, 2016).

Exposure to simulated altitude results in neuromuscular adjustments, including increased motor unit recruitment and muscle fibre activation, contributing to improved strength and power output (Scott *et al.*, 2019).

Enhanced muscle oxygenation and blood flow regulation following artificial altitude training facilitate muscle contractility and fatigue resistance during exercise (Millet *et al.*, 2016).

Artificial altitude training has been found to speed up recovery after tough workouts by helping tissues heal faster, reducing swelling, and boosting the body's ability to adjust (Roels *et al.*, 2017). Trying out simulated high altitude before regular training at sea level might also make performance improvements even better, possibly increasing the benefits of training (Wilber, 2017).

Nutrition:

Nutrition plays a critical role in the performance and success of long-distance cross-country skiing events. As one of the most demanding endurance sports, cross-country skiing requires athletes to sustain high-intensity efforts over prolonged durations, often in harsh environmental conditions. Optimal nutrition practices are essential to support energy production, enhance recovery, and maintain overall health and performance throughout training and competition.

Carbohydrate supplementation is crucial due to its role as the primary fuel source during endurance exercise. Studies by Hawley and Leckey (2015) have demonstrated that carbohydrate ingestion during prolonged exertion can maintain blood glucose levels, delaying the onset of fatigue and improving overall performance. This is attributed to the body's ability to utilize exogenous carbohydrates, sparing endogenous glycogen stores for later stages of the event.

Carbohydrates serve as a primary and essential energy source during exercise, particularly in endurance events. When ingested, carbohydrates are broken down into glucose, which circulates in the bloodstream and is taken up by muscle cells to fuel contraction during physical activity (Coyle, 2010). Endurance exercise, such as long-distance running or cycling, places significant demands on the body's energy systems, leading to the depletion of glycogen stores—the body's primary storage form of glucose.

As endurance activities progress, glycogen stores within the muscles and liver become increasingly depleted, compromising the body's ability to sustain intensity and duration of exercise. This depletion contributes to feelings of fatigue and exhaustion experienced by athletes during prolonged exertion.

To combat glycogen depletion and sustain performance during long-distance events, athletes strategically consume carbohydrates before and during exercise. Carbohydrate intake during endurance activities serves to replenish glycogen stores, providing a readily available source of fuel to support muscle function and delay fatigue (Burke *et al.*, 2011). Studies have demonstrated that carbohydrate ingestion during prolonged exercise can enhance endurance capacity and improve performance outcomes (Jeukendrup, 2014).

Summary:

In summary, the onset of fatigue in cross-country skiing events can be influenced by various factors, including physiological demands, environmental conditions, and pacing strategies. One primary factor is the depletion of glycogen stores in muscles due to prolonged exertion, leading to decreased energy availability and muscle fatigue. Additionally, the accumulation of metabolic by-products, such as lactate, can contribute to muscle fatigue and impair performance. Environmental factors like altitude, temperature, and wind resistance can further exacerbate fatigue by increasing metabolic stress and altering thermoregulatory processes.

To mitigate or delay fatigue in cross-country skiing events, athletes can employ several strategies. Optimal nutrition and hydration practices are essential to maintain energy levels and sustain muscle function throughout the race. Consuming carbohydrates before and during the event can help replenish glycogen stores and provide a readily available source of fuel. Adequate hydration is also crucial to prevent dehydration and maintain thermoregulation, particularly in cold environments where fluid loss through respiration and sweat may be underestimated.

Training low and living low in an altitude context, supplemented by the use of a hypoxic altitude sleeping tent, offers a comprehensive approach to altitude training. This strategy involves residing at low altitudes for daily activities while incorporating

training sessions at sea level or low altitude environments to optimize performance adaptations. Concurrently, the hypoxic altitude sleeping tent simulates high-altitude conditions during rest, enhancing acclimatization and stimulating physiological adaptations conducive to improved endurance and performance at altitude. By combining these methods, athletes can capitalize on the benefits of both low-altitude living for recovery and high-altitude training for altitude-specific adaptations, ultimately enhancing their overall athletic performance in altitude competitions.

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