PHYSIOLOGICAL PERFORMANCE ASSESSMENT

OPTIMIZATION IN ROAD CYCLING

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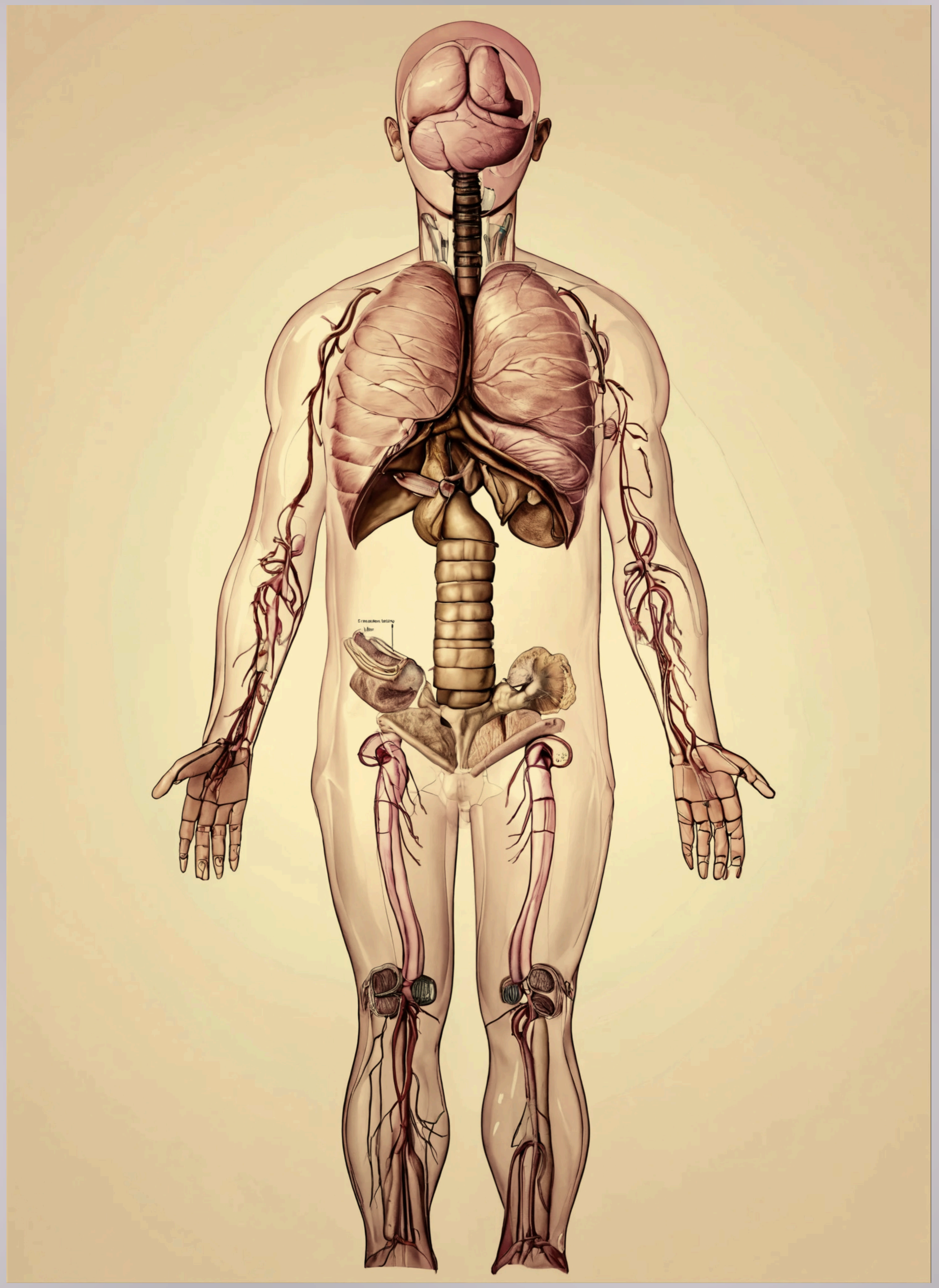

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Abstract

Physiological performance assessment is important in cycling because it provides critical insights into an athlete's physical condition and training effectiveness. Metrics such as HR, HRV, and RHR can serve as valuable indicators of an athlete's physiological fitness. Monitoring these parameters allows cyclists to optimize training and manage stress levels effectively. Biological stressors such as hydration, nutrition, and hormonal fluctuations can significantly influence cycling performance. Proper hydration supports thermoregulation and muscle function, while nutrition ensures energy availability and recovery. Hormonal fluctuations, such as those associated with the menstrual cycle in female athletes add unique physiological considerations, impacting endurance, pain tolerance, and hydration needs. Female cyclists require tailored strategies to address these fluctuations to enhance both training adaptation and performance consistency. In addition, sleep plays a fundamental role in athletic performance, affecting recovery, cognitive function, and overall energy levels. Inadequate sleep can impair decision-making, endurance, and immune function. Exogenous stressors can also lead to episodic acute stress, often from consistent exposure to stressful situations in work and life, leading to reduction in physical and physiological performance.

Introduction

Background

Physiological Performance Assessment is essential to optimizing training and performance outcomes in road cycling, a sport that demands high levels of endurance, power, and mental resilience. The physiological demands of road cycling place significant stress on athletes, requiring a combination of cardiovascular endurance, muscular strength, metabolic efficiency, and mental resilience. As an endurance sport with high aerobic and anaerobic demands, road cycling challenges a cyclist's ability to sustain high-intensity efforts over varied terrain and durations, including short, steep climbs to prolonged, high-speed sections on flat roads.

Statement of Need

Physiological determinants of performance are fundamental to understanding the specific adaptations that contribute to cycling performance, thereby guiding training plans and identifying factors that can optimize cycling efficiency (Wells & Norris, 2009). Although cycling physiology is well documented, the unique physiological characteristics and performance factors relevant to female cyclists have historically received less attention. Female cyclists often face distinct physiological challenges such as lower absolute VO_2 max values, as well as differences in muscle fiber composition compared to male cyclists. Furthermore, the menstrual cycle influences endurance, power output, and recovery rates, thus significantly impacting performance metrics.

Introduction

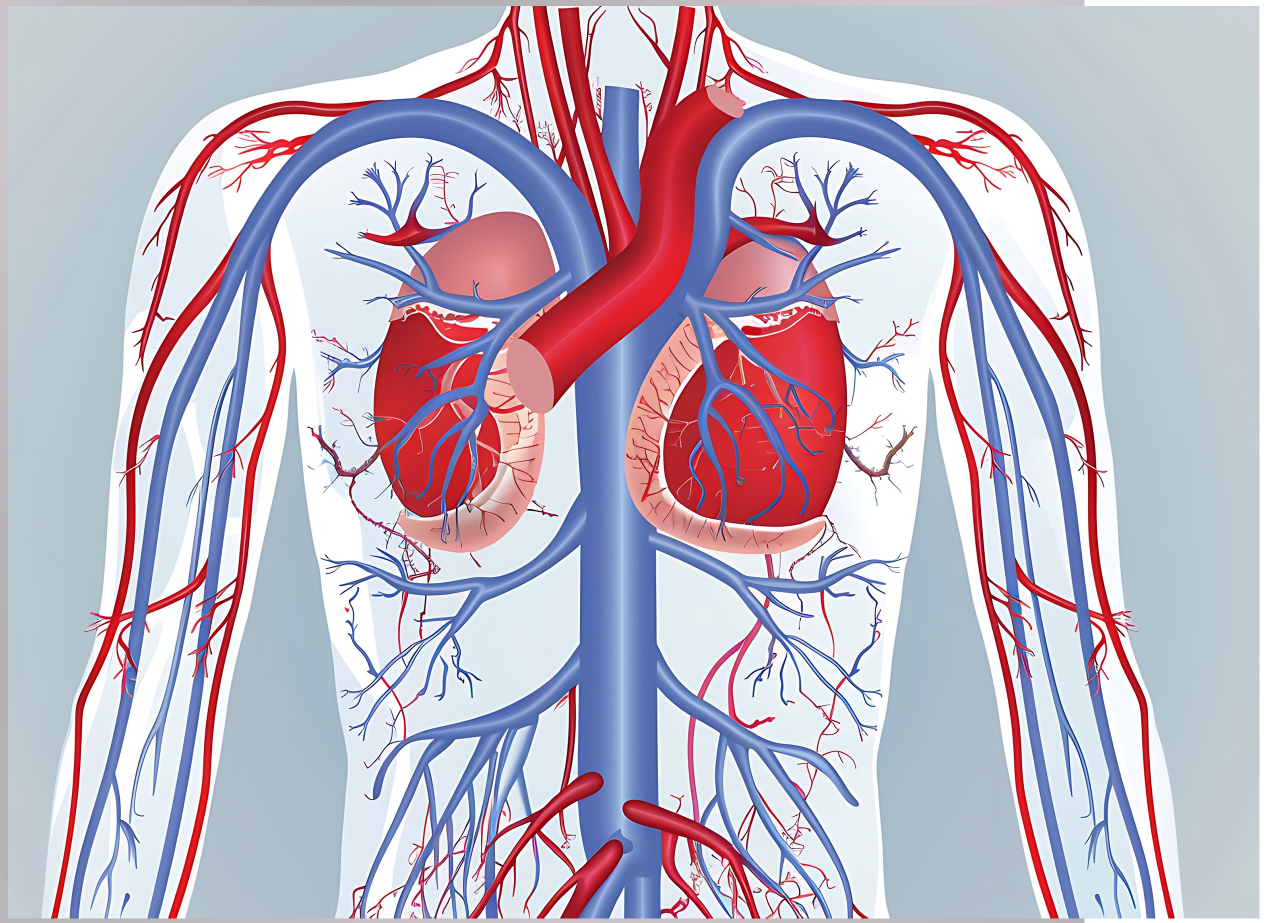
Objective

This PPA aims to demonstrate how physiological markers respond to stress, thereby affecting performance of road cyclists, with consideration for unique variabilities for female cyclists.

Road cycling performance is commonly influenced by several key physiological variables, including maximal oxygen uptake (VO_2 max), heart rate variability, lactate threshold, and respiration rate. Factors such as fatigue resistance, neuromuscular coordination, and psychological endurance can also significantly impact cycling performance. Furthermore, environmental factors and personal life stressors can have a tremendous impact on a cyclist's motivation and resilience.

Advancements in wearable technology and individualized data analytics have allowed for more contextually relevant data, reflecting the specific physiological demands of road cycling more accurately than isolated laboratory tests.

Physiological Systems



Circulatory System

The circulatory system, also known as the cardiovascular system, consists of the heart, blood vessels, blood, and lympathic system. Its primary function is to serve as a transportation system, delivering nutrients and oxygen to all the cells. The arteries carry oxygenated blood away from the heart, while the veins carry blood back to the heart (Maresh et al., 2016).

Homeostasis and the Circulatory System

Homeostasis of hemodynamics pertains to the process by which the body regulates blood circulation to meet the needs of the body's organs and tissues (De Hert, S., 2012). This process involves the body's peripheral metabolic needs, vascular adaptations, cardiac adaptations, and hormonal and neural control systems.

During activity, the circulatory system redirects blood flow to the systems according to their functional needs. Blood flow is preferentially redirected from the gastrointestinal and renal systems during physical stress, and directed toward active muscles through the selective constriction and dilation of capillary beds (Patel & Zwibel, 2019). Blood flow varies based on the type of activity and physical exertion level.

Adaptations To Exercise

Acute Adaptations

- Increased cardiac output - increased heart rate and stroke volume
- Increase in systolic blood flow. Vessels dilate and increase in diameter during physical demands.

Long-term Adaptations

- Cardiac adaptations lead to increased cardiac output while exercising, and a higher VO2 max after exercise (Lavie et al., 2015).
- Post-training heart rate is decreased at rest and during sub-maximal exercise(Shaffer & Ginsberg, 2017).

Physiological Systems

Respiratory System

The respiratory system consists of three major functional components, including the airway, the lungs, and the respiratory muscles. Its primary function is gas exchange, whereby oxygen and carbon dioxide are exchanged betweed the blood the lungs, with the uptake of oxygen and the removal of carbon dioxide (Maresh et al., 2016).

Homeostasis and the Respiratory System

The resipatory system maintains homeostasis through the process of exchanging oxygen and carbon dioxide. As muscles demand higher oxygen to produce energy, the respiratory system responds by increasing respiration to increase the oxygen supply (Seiwert, C., 2024).

In addition, the respiratory system will respond to an increase in carbon dioxide levels with increased ventilation.

Adaptations to Exercise

Acute Adaptations (Patel et al., 2024)

- Increase in respiratory rate
- Increase in pulmonary ventilation
- Decrease in alveolar dead space to accomodate the increase in gas exchange

Long-term Adaptations

- Increased lung capacity: enhancing the ability for the lungs to take in more oxygen during intense activity
- Improved respiratory muscle strength: strengthens the diaphragm and intercostal muscles, leading to efficiency and power when breathing
- Growth of new blood vessels around the alveloi: increasing the surface area for gas exchange

Physiological Systems

Nervous System

The nervous system is composed of the central nervous system (CNS) and peripheral nervous system (PNS). The CNS includes the brain and spinal cord, while the PNS includes the cranial and spinal nerves, ganglia, and sensory receptors. Its primary purpose is to facilitate motor function, process sensory information, and integration of sensory stimuli with the response (McCorry, 2007).

Homeostasis and the Nervous System

The nervous system works with the endocrine system to maintain homeostasis. When a disturbance in the internal environment is detected by the sensory organs, the central nervous system processes the information to determine the appropriate response, sending signals to the effectors, muscles, and glands (Brown, 1991)

Adaptations to Exercise

Sympathetic Nervous System - the body's "fight or flight" response. It increases respiration and heart rate, releases adrenaline and other hormones, and limits other functions like digestion, so the body can cope.

Parasympathetic Nervous System - body's rest and chill response when the body is relaxed, resting, or feeding. The parasympathetic system functions to counteract the sympathetic reaction and return the body's systems to equilibrium.

Determinants of Cycling Performance

PHYSIOLOGICAL MARKERS

HR

Heart rate is the number of heartbeats per minute.
HR is a valuable metric for evaluating physiological performance because it directly correlates with energy expenditure during exercise. By tracking HR during incremental exercise, one can observe the acute adaptations of physiological factors like ventilation and oxygen uptake (Strath et al., 2000)

PHYSIOLOGICAL MARKERS

HRV

Heart rate variability (HRV) is the fluctuation in the time intervals between adjacent heartbeats.

HRV provides insights into health and self-regulatory capacity, and reflects the adaptability or resilience of biological systems. Increased aerobic fitness is linked with higher HRV (Shaffer & Ginsberg, 2017).

PHYSIOLOGICAL MARKERS

RHR

Resting heart rate (RHR) is a determinant of cardiovascular fitness and physiological homeostasis. A lower resting heart rate generally indicates better cardiovascular fitness, with a normal resting heart rate ranging from 60-100 beats per minute (bpm)

STRESSORS

Physical

Physical stressors like wind, elevation, and temperature significantly impact cycling performance by influencing energy expenditure, comfort, and physiological demands.

STRESSORS

Biological

Biological stressors such as hydration, nutrition, and hormonal fluctuations play a crucial role in cycling performance as they directly influence energy production, endurance, recovery, and overall physiological functioning.

STRESSORS

Exogenous

Acute stress is a short-term response to a specific challenge or threat, activating the "fight-or-flight" response via the SNS.
Episodic acute stress involves recurring episodes of short-term stress, often from consistent exposure to stressful situations (e.g., work-life pressures).

SLEEP

Circadian

Circadian rhythm, the body's natural 24-hour biological clock, significantly influences cycling performance by affecting physiological functions such as energy metabolism, muscle function, hormone levels, and sleep-wake cycles.

SLEEP

Sleep Duration

Sleep is essential for recovery, muscle repair, and cognitive function, making its quality and quantity crucial for optimal performance.

Determinants of Performance

7 Weeks of Cycling Performance Tracking						
Week	**Sleep** (Hours)	**HR** (AVG HR during weekly ride)	**HRV**	**RHR**	**Mileage** (Completed cycling miles per week)	**External Factors**
1	7.5	138	41	50	53	
2	7.5	146	42	51	40	
3	7	149	42	50	14	Daylight Savings Time (decrease in daylight hours)
4	6.5	141	45	53	15	
5	6	NA	44	52	0	Menstruation
6	6	160	44	52	11	High Stress
7	7	148	46	52	17	Thanksgiving Week

In the weeks before MSHF 640 started (and PPA tracking), completed mileage was between 60-90 miles per week, with better sleep, lower HRV and lower RHR.

Mileage drops as classes start, indicative of the decrease in available time for cycling and exercise. The season change and DST adjusts sunset from ~8pm to ~5pm, leading to fewer hours of daylight. Menstruation occurs in week 5, leading to fatigue, discomfort, and lack of motivation. Personal factors lead to high stress in week 6, continuing the downward trend in exercise. Week 7 is a holiday week with an increase in family obligations. The increase in stress leads to poor sleep. The drop in exercise leads to a drop in physiological performance, shown by the increase in AVR HR during the weekly ride, higher HRV and RHR.

Environmental Stressors

→ Biological Stressors

Hydration

- When the body is dehydrated, blood volume decreases, making it more difficult for the heart to pump blood. This can lead to an increase in HR, known as cardiac drift (Kiely et al., 2019; Millet et al., 2018).
- Dehydration can impair exercise performance and contribute to heat illness.
- Exercise-associated hyponatremia (EAH), a condition that occurs when the body's sodium levels become too low, can lead to serious illness when athletes drink too much fluid, but fail to replace electrolytes (Smyth & Piacentini, 2021).

Nutrition

- Carbohydrates are the primary fuel source for high-intensity exercise. They are more efficient than fat at producing ATP. When carbohydrate stores are depleted, athletes experience fatigue, reduced work capacity, and impaired concentration (Vitale & Getzin, 2019)
- During endurance exercises like running and cycling, glycogen serves as a readily available fuel source for the working muscles. As exercise continues, the body's glycogen stores gradually become depleted. When these stores are significantly reduced, the rate of ATP regeneration is compromised, leading to fatigue (Ortenblad et al., 2013).
- In cycling, "bonking" is a term used attributed to the depletion of glycogen stores.

Hormonal

- The menstrual cycle and the accompanying hormonal changes significantly influence how female cyclists respond to training and their overall performance (Bean et al., 2024).
- Fluctuating hormone levels influence how women's bodies respond to training and can affect performance outcomes (Le Douairon & Ohl, 2024).
- Estrogen and relaxin, which fluctuate during the menstrual cycle, work together to increase ligament laxity. This can potentially raise the risk of injuries like ACL tears (Kotler et al., 2023).

Environmental Stressors

→ Physical Stressors

Wind

- Crosswinds can significantly affect a cyclist's performance, stability, and safety, creating aerodynamic forces, including side force and lift force, which can make it challenging to control the bike (Atkinson & Brunskill, 2000).
- Aerodynamic drag is the main force cyclists need to overcome. At speeds over 50 km/h, it accounts for more than 90% of the total resistance (Mao et al., 2024).
- A headwind increases the cyclist’s speed relative to the wind, thus increasing the aerodynamic drag force (Swain, D.P., 1997).

Elevation

- The quick brown fox jumped over the lazy dog into a shimmering pool of rainwater that had gathered since the last frost.
- At higher altitudes, the air contains less oxygen, requiring the cardiovascular system to work harder to deliver oxygen to the working muscles. This can lead to an increase in HR, even at rest (Doherty et al., 2018).

Temperature

- As ambient temperature increases, the body must work harder to maintain its core temperature. This leads to increased sweating and blood flow to the skin, which can raise HR (Black et al., 2017).

Environmental Stressors

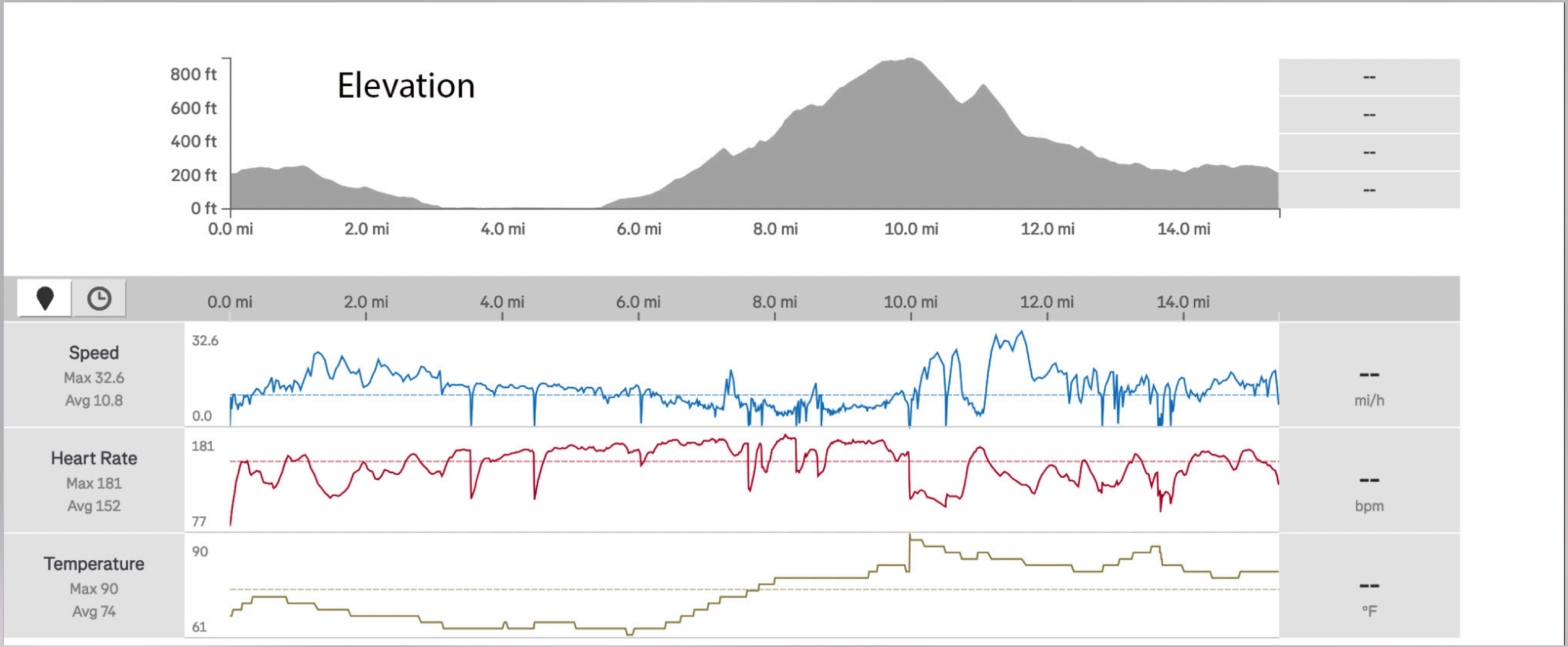


Figure 1 (Strava) Graph showing the metrics for 10/28/24 ride to Twin Peaks

This shows how stressors such as elevation and temperature affect performance (i.e. speed and heart rate). HR is low when beginning ride, steady during flat terrain (drops reflect stops), then rises considerably during climbing/ascending. HR drops again when descending. Speed has an inverse effect, with speed slow when ascending and higher when descending. Temperatures in SF are mild, and wind is a better determinant of acute performance.

Sleep Variables

Insufficient sleep can have a significant negative effect on cycling performance by causing fatigue, reduced endurance, impaired reaction time, decreased muscle coordination, and a perceived increase in effort, essentially making it harder to maintain power and speed on the bike due to the body's inability to adequately recover from training without sufficient rest (Lopes et al., 2023).

Sleep is essential for recovery, muscle repair, and cognitive function, making its quality and quantity crucial for optimal performance.

Insufficient sleep can increase an athlete's risk of injury. This connection may stem from sleep loss's effects on reaction time and cognitive abilities, making athletes more prone to accidents (Simpson et al., 2017).

Adequate sleep plays a crucial role in protecting athletes from illness.

Individuals sleeping less than 7 hours nightly were three times more likely to develop a cold after exposure to the virus compared to those sleeping 8 hours or more (Simpson et al., 2017).

Athletes who have irregular sleep patterns may experience impaired heart rate-derived markers of the ANS. Higher sleep consistency is moderately associated with lower RHR. This suggests that irregular sleep patterns may impair the ANS, which can negatively affect athletic performance. (Sekiguchi et al., 2019).

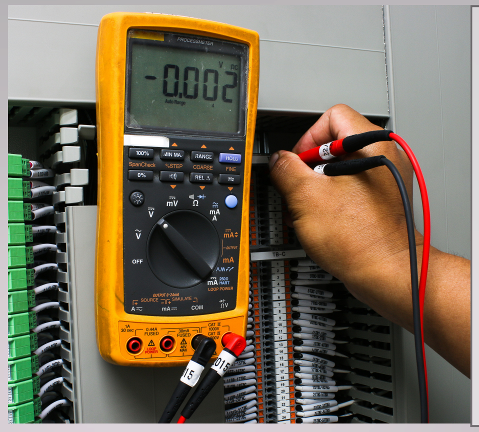
Limitations of The Study

Wearable Technology

tness trackers have limiations involving accuracy and limited data context. Optical heart rate sensors can be inaccurate, especially during high-intensity exercises or excessive movement.

Bike Computers

The accuracy of bike computers depends on several factors, including the type of sensors used, the calibration, and the environmental conditions.



Calibration

Fitness trackers use generalized algorithms for calculations, but personal factors like body composition, fitness level, or movement patterns can affect accuracy. Activities like cycling are harder to track without specialized calibration or sensors.

Data Consistency

Data consistency is a common issue with fitness trackers, where measurements can vary even for the same activity under similar conditions. Individual consistency in wearing the device and tracking activity can affect accuracy.

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