Moderate-High Altitude Training

By Matthew Flores and Graduate Student Mentor, Jeremey Ducharme

Introduction

Training at moderate to high altitude training has become increasingly familiar in exercise and continues to gain popularity among athletes and regular individuals looking to improve their endurance performance. Acclimation is the process of exposure to moderate elevations before higher altitudes intended to induce physiological adaptation during hypoxic conditions and reduce the instances of developing altitude illness (2,3,4). Today, people use these practices mainly in competitive sports to increase their endurance performance and create advancements over their competitors (1). Mujika and other esteemed colleagues in a recent review reported the effectiveness of altitude training and associated benefits of adaptations stemmed from improved hematological responsiveness to hypoxia, exercise economy, and buffering capacity of hydrogen ions (1). Endurance performance is still compromised at higher altitudes, but acclimation helps make this less of a drastic decrement (4). While previous data have demonstrated the benefits of altitude training at moderate to high altitudes, there are concerns of chronic exposure to altitude and the development of pulmonary edema causing chronic arterial stiffening over time (3,4,5). Training at high altitudes places a substantial demand on the body from reduced oxygen tissue saturation and decreased efficiency for adequate gas exchange (6). To help alleviate the complication of reduced capacity for exercise during altitude training, athletes use herbal supplements to alleviate high altitude training dysfunction from reduced oxygen levels and improve acclimation and adaptation to hypoxic conditions (6). Specifically, ancient roots and herbs Rhodiola and Cordyceps improved endurance exercise during high-altitude training by improving time to exhaustion and improved performance (6). This is relevant because it represents a potential aid for combating concerns with altitude training. Previous research has distinguished contraindications with altitude training but has yet to conclude if sex-based differences (i.e., female/male sex hormones) impact acclimation during induced desaturation of oxygen (7). Several aspects that limit training at altitude are living at sea level, various health conditions (i.e., pulmonary/cardiac disfunction), and COVID-19 because it affects the cardiovascular system and has the potential to inflict respiratory failure and increase myocardial tissue damage (10). The purpose behind this analysis is to review scientific data that supports the benefits of altitude training, report the associated

risks, potential ergogenic aids to combat concerns with altitude training, and improve acclimation/performance while finally distinguishing how to develop a safe program.

Benefits of Moderate-to-High Altitude Training

Moderate-high altitude training is the process of interaction with hypoxic conditions to inflict adaptations to increase erythropoietic responses intended to cause an increase in hemoglobin mass (1). The purpose of this type of training is to ultimately increase maximal oxygen uptake (VO2max) during competition and improve performance. The benefits of training at moderate-high altitudes are physiological adaptations that increase the amount of oxygen carried through dense hemoglobin that is enforced by exposure to hypoxia. An extensive review by Dr. Mujika and faculty from the Department of Physiology and Medicine at the University of Basque Country showed that hemoglobin mass increased substantially by +11% in elite endurance athletes training at high altitudes (1). In the same study, trained subjects demonstrated improved erythropoiesis that encouraged oxygen diffusion to tissues and increased gas exchange by facilitating transportation of oxygen from increased red blood cells in the blood, contributing to an increased time to exhaustion and enhanced exercise economy (1,2). Additionally, those trained at high altitudes also improved their buffering capacity to hydrogen ions which is essential in reducing muscle fatigue (1). Furthermore, representing the importance and benefit of training at altitude for competitive athletes.

What is Altitude Acclimation?

The term “acclimation” is an adaptation process that occurs during exposure to a new environment (i.e., altitude, temperature, etc.). A mechanism of acclimation is ascending to moderate elevations before progressing to a higher altitude (2,3,4). Despite proper acclimation, individuals can still become sick. Acclimation complications are not removed but hopefully lessened for endurance exercise performance, and triggers hematological adaptations (2,3,4). Gheorghe published his study in the Journal of Romanian Sports Medicine Society on mountaineer climbers to distinguish the importance of altitude acclimation in Muztagh Ata, China for elevations between 3600-6800 m to examine how the subjects adapted to moderate-high altitudes (5). What was discovered is that those who did not properly acclimate to the high altitudes experienced an increased probability of developing acute mountain sickness by +68.7% over those who did adequately adjust to the reduced oxygen at high altitudes (5). Expressing why

acclimation and adapting to moderate-high altitudes is essential for the safety of the athlete being conditioned to hypoxic environments.

Concerns with Chronic Exposure to Hypoxia

Mulchrone and colleagues from the Department of Medicine and Biomedical Engineering at the University of Wisconsin-Madison recently reported the concerns with chronic exposure to hypoxia causing arterial stiffening after consistent exposure to high altitudes increasing the pulmonary pressure for which the right ventricle has to overcome leading to potential right heart failure (3). The same research showed the significance behind consequences associated with high-altitude training and susceptibility of developing pulmonary edema after training by subsequently reduced lung distensibility (3). This is important to consider because reduced lung distensibility would prevent proper gas exchange in the lungs and reduce oxygen delivery to tissues. Demonstrating that moderate-high altitude training does possess risk factors and must be considered when following guidelines to limit no more than 85% of max work rate at altitudes of ≥3,810 meters for more than 30 minutes to reduce chances of experiencing detriments to the safety of the athlete or individual at altitude (3). Only then can this method of training be effective and safely applied by reducing the probability of arterial stiffening from chronic development of pulmonary edema during altitude training by following the recommended guidelines discussed.

Ergogenic Aids Improving Adaptations/Acclimation

Because hypoxia reduces efficient gas exchange during high altitude training, alternatives are sought out to combat reduced oxygen tissue saturation and improve their endurance performance. Chung and the Department of Exercise and Health Sciences at the University of Taipei analyzed the effectiveness of Cordyceps Sinensis and Rhodiola Crenulate supplementation on enhancing aerobic capacity during high altitude training (6). Suggesting that taking both herbal supplements improved endurance performance significantly also time to exhaustion by +5.7% after undergoing two weeks of high-altitude training compared to the placebo group (6). When taking both herbal supplements together, the researchers showed enhanced delivery of oxygen to working muscles at moderate-high altitudes (6). Confirming that endurance performance is improved through reduced time to exhaustion with these herbal supplements. Oxygen carrying capacity is limited during hypoxia, therefore, a supplement that may alleviate this reduced physiological mechanism during altitude training presents as an

attractive option for athletes seeking to increase their endurance performance in hypoxic conditions.

Limitations?

Tolerance to moderate-to-high altitudes with age and sex hormones have been reviewed to determine if these may interfere with the acclimation process. Richalet and affiliates with the University of Paris declared that age does not negatively impact physiological adaptations to hypoxia during high-altitude training (7). Separately, the Department of Military Medical Geography reported that there is some support of female subjects being more susceptible to acute mountain sickness due to less testosterone levels compared to men because testosterone has been understood to promote erythropoiesis which would improve the carrying capacity of oxygen when ascending to moderate-high altitudes >2500 meters (8). The problem, however, is that there is data that also refutes these claims making it hard to claim that men are better able at acclimation to high-altitude than females (8). More data needs to be done before suggesting that there is a gender-based difference to altitude acclimation. This section reports that age does not impact acclimation, and sex differences may exist, but more research is necessary.

Designing safe (moderate-high) altitude training programs

Following the COVID-19 pandemic, there are new challenges for exercise specialists to practically apply safe return to physical activity. Professor Wilson at the University of London and the Institute of Sport Exercise and Health have rapidly searched to understand how elite athletes are limited in their return to sports and how to program exercise (9). Through their research, they developed an assessment of cardiac pathways through a 12-lead ECG and respiratory lung functioning while incorporating how COVID-19 infection could impact return to play in sports and general activities (9). They reported that pulmonary constriction was present in athletes who recovered from COVID-19 and demonstrated how new programming training should be conducted through pre-screening guidelines and physical examinations of these individuals. Another programming guideline was designed at the Institute of Physiology reviewing how respiratory distress, lung injury, and myocardial damage could be present in those with or recovering from COVID-19 and being indications of limitation to acclimate when exposed to moderate-high altitudes (10). The initial phase of designing an altitude training program is to administer prescreening tests of blood, antibodies, and oxygen saturation to understand the health condition of someone wanting to participate in moderate-high altitude

training (10). To pass the initial screening, the athlete must be negative for COVID-19 and fall within normal ranges of oxygen saturation between 95-98% during max exercise testing (10). Once cleared for participation, a training volume of 75% is maintained of their initial oxygen capacity measured during pre-screening then slowly increased at low increments to develop acclimation to hypoxia (10). Caution should be placed when monitoring the health of an athlete training at moderate-high altitudes by reviewing cardiac MRIs to identify if a disorder is present with exposure to training and or if an individual develops or is recovering from a COVID-19 infection (9). Post altitude training assesses respiratory condition after hypoxia and reviews if maladaptations arise through cardiac MRIs, chest x-rays, and electrocardiograms (9). If abnormal responses occur throughout the program such as reduced oxygen saturation, irregular heart rate, or new arising COVID-19 symptoms, direct medical examinations are conducted and isolation from other athletes. This stresses the importance of having clear guidelines to adjust and maintain updated standards for training at altitude for athletes especially now that screening is different during the COVID-19 pandemic. Both guidelines reviewed in this section are incorporated into **figure 1** to demonstrate how a safe acclimation program can be designed for moderate-high altitude training**.**

Conclusion

The benefits of altitude training showed improved hydrogen ion buffering capacity and hemoglobin mass. Risk factors however are reported when exposed to hypoxia if chronic development of pulmonary edema occurs following training causing arterial stiffening. Through techniques of herbal supplementation of Cordyceps Sinensis and Rhodiola Crenulate, oxygen delivery can be improved and is good to include in moderate-high altitude training. Finally, medical screening and tests should be done to maintain the health status of the athlete during the entire process of training at altitude. Altogether the takeaway from this article is to show how moderate-high altitude training is beneficial at improving athletic performance and needs to be programmed safely for the health of the participant.

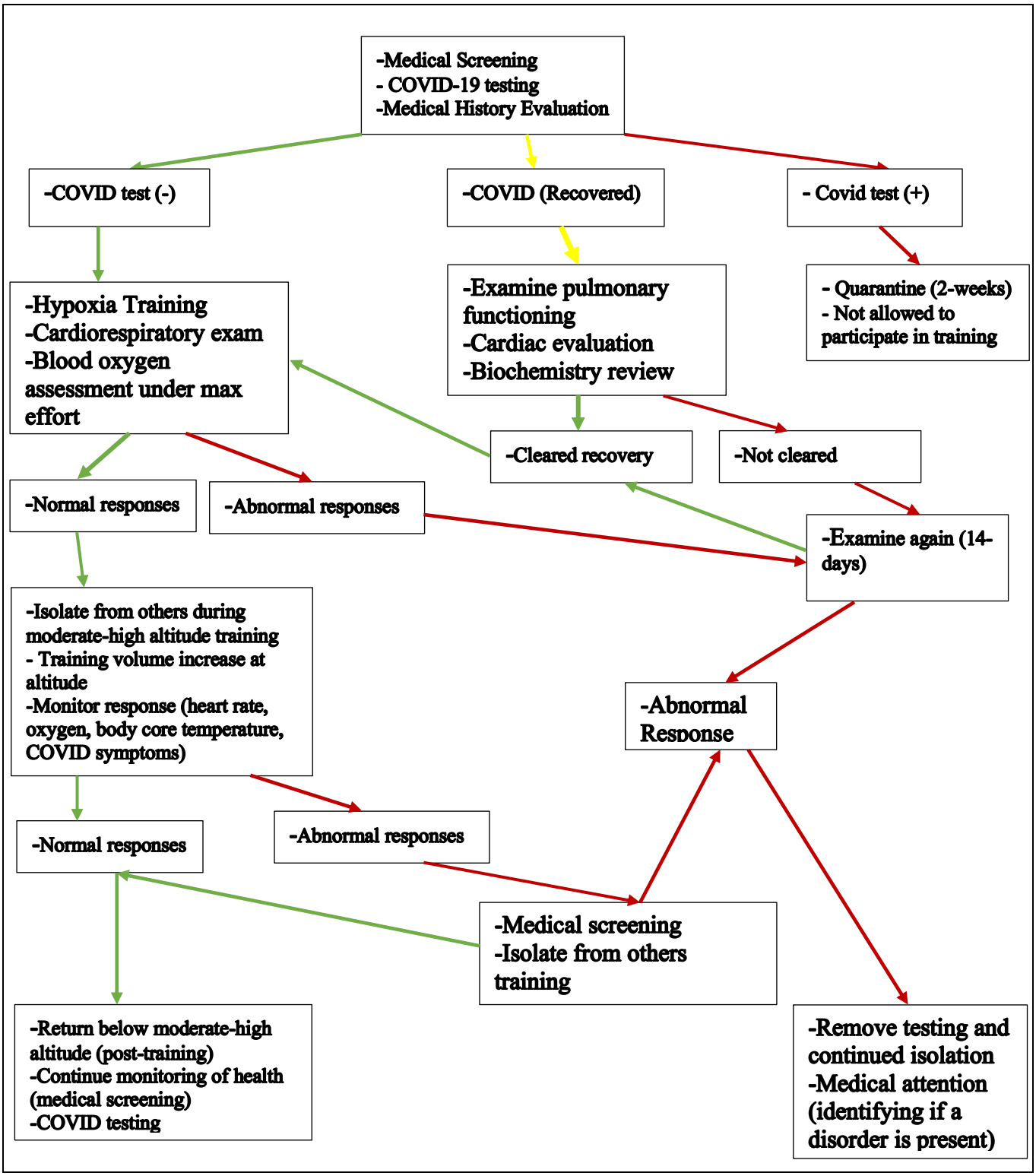

Figure 1. Program design for moderate-high altitude training. Involves pre, during, and post-training guidelines. Based on recommendations from the Department of Molecular Medicine and Institute for Sport Exercise and Health (9,10)

*(Red arrow=contraindication to altitude training, Yellow arrow=caution, Green=cleared for moderate-high altitude training)

Apply it

- Use cordyceps sinensis and rhodiola crenulate to increase time to exhaustion by +5.7 % during altitude training.
- Incorporate guidelines of no more than thirty minutes of exercise at ≥3,810 meters of elevation at the individual's 85% max work rate initially during altitude training.
- Use **figure 1** to safely structure training at moderate-high altitudes.

Bridging the Gap

Hypoxia causes adaptations to occur through moderate to high altitude training encouraging sufficiently improved hematological responsiveness during exercise that improves endurance performance. Following training, guidelines ensure that benefits of endurance performance are present and not risks with improper acclimation. Improper acclimation can be avoided through structured programing to moderate-high altitudes to encourage improved endurance performance with training.

Summary Statement

Altitude training causes physiological adaptations to occur during hypoxia improving endurance performance through increased hemoglobin mass, making it beneficial for those participating in competitive sports.

Pulled text

"A mechanism of acclimation is through ascending to moderate elevations before progressing to a higher altitude. Despite acclimating properly, individuals can still become sick, it does not remove the possibility, it rather reduces instances of altitude illness development and removes compromised endurance exercise performance and trigger adaptations."

Bio

Matthew Flores., is currently completing his undergraduate at the University of New Mexico with a double major in Exercise Science and Psychology. Interests are incorporating knowledge of exercise programing to guide further involvement in the field of rehabilitation as a physical therapist technician and apply for graduate school.

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