

Overview:

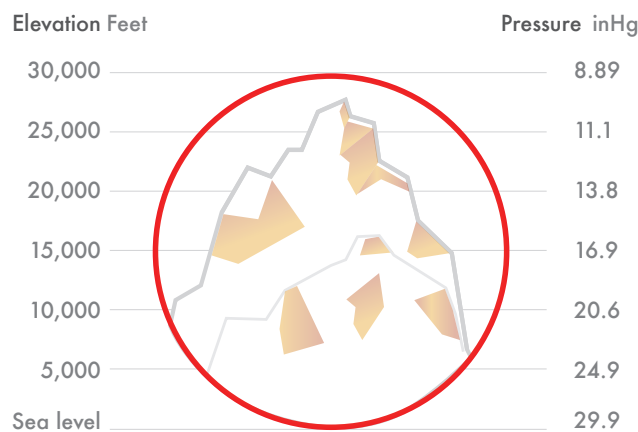
Elevation training (also referred to as altitude training) is used by many competitive athletes to increase their performance potential. Hemoglobin, the protein that binds and carries oxygen throughout the body, increases in response to elevation. This paper is a compilation of key findings on the body's response to elevation and is designed to give you a high level understanding of the concepts involved. It will also explain how your Ember device can help you in your elevation training.

What is the driving force behind altitude-induced changes in the body?

The main force that drives all these changes is the lower pressure of air at high elevations. Upon exposure to significant elevation increase (>1,500 m/4,921 ft.), the lungs, cardiovascular system and kidneys begin to make changes to maintain adequate oxygenation and ventilation.

Lower air pressure means less oxygen

The air you breathe is composed of 21% oxygen, with the rest being carbon dioxide, nitrogen and trace gases. These gases as well as water vapor in the air exert a certain amount of pressure that bears down upon you. This pressure varies depending on the elevation you are at and is lower when you go above sea level (for example Mount Everest, Nepal 8,840 m/29,029 ft.) and higher when you go below sea level (for example Death Valley, Ca -85 m/-279 feet). Although the percentage of oxygen is still 21%, less



pressure at elevation means that for any given amount of air, there will be less oxygen per breath.

Isn't breathing less oxygen dangerous?

Breathing less oxygen would be dangerous to the body if it were not for the compensatory changes the body makes to counteract this. At higher elevations, the breathing rate increases to keep up the oxygen intake despite the lower oxygen.

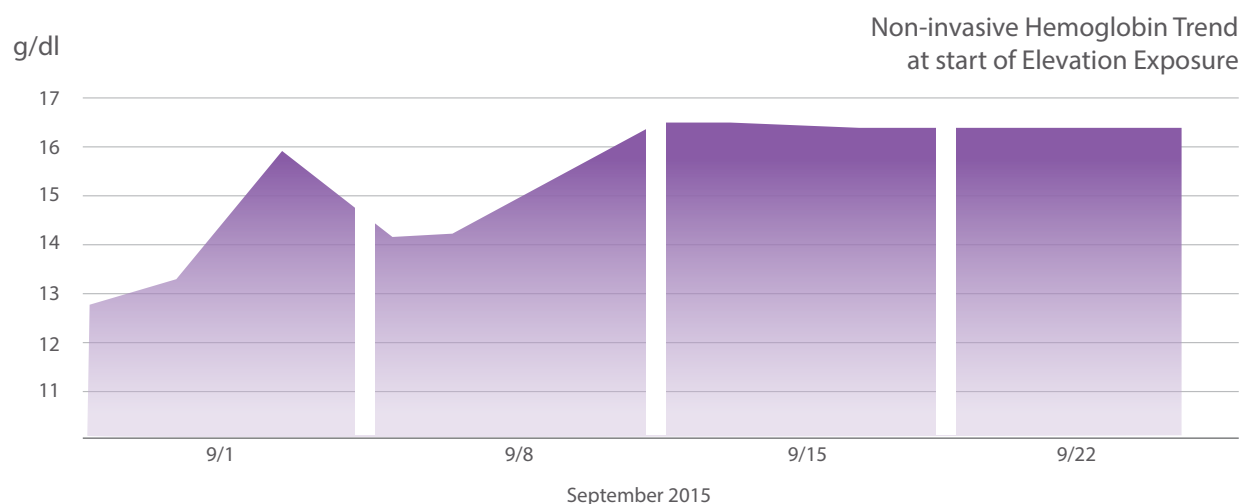
Similarly, the heart pumps faster to keep up the delivery of oxygen to the tissues.

Most importantly for the athlete, however, is that within even a few hours of exposure to high altitude, the kidneys increase their release of a hormone called erythropoietin.

Erythropoietin acts on the bone marrow to increase production of red blood cells and hemoglobin. This surge in erythropoietin, and the subsequent increase in hemoglobin, is the key benefit of elevation training. The more hemoglobin available, the more oxygen that can be delivered to muscles.

How long should an athlete live at higher elevation to see an increase in their hemoglobin?

While the initial increase in erythropoietin is seen within a few hours, the true and sustained increase in hemoglobin is typically within 2-4 weeks.^[1] Furthermore, there is variability in individuals in the amount of erythropoietin their kidneys release in response to elevation, and still further variability as to the extent to which their body reacts to the erythropoietin and produces new hemoglobin.^[2] That is why frequent measurement of hemoglobin would help athletes gauge their response to elevation and help them decide when they have reached their maximum and sustained hemoglobin levels.



How would the changes experienced at higher elevation translate to the measurements on the Ember device?

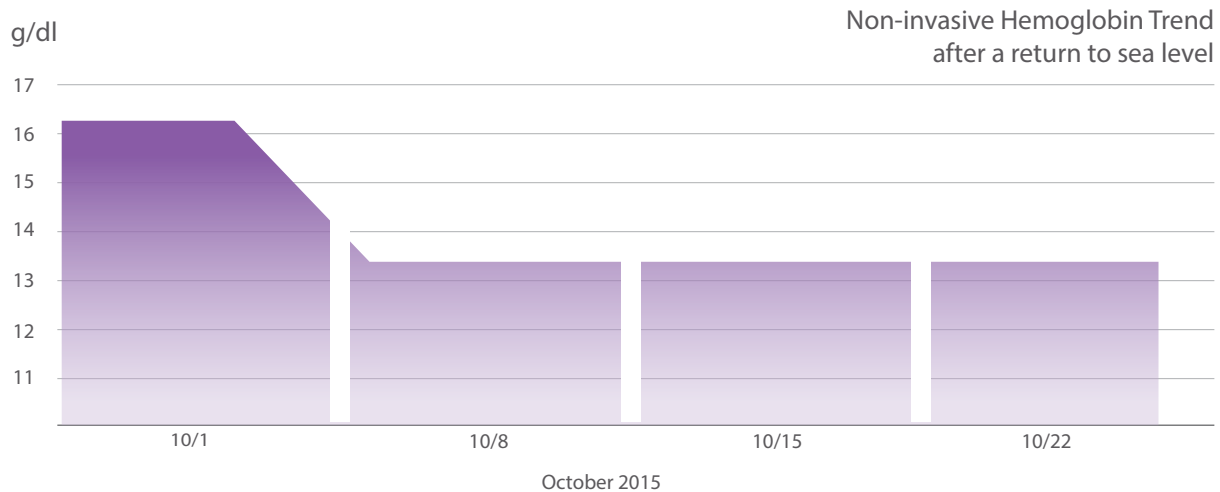
If performed correctly, Ember will help track increases in hemoglobin over time through trended graphs. It is recommended that multiple, daily measurements be performed, with particular attention being placed on consistent measurement techniques. This means testing at the same time, under the same conditions and in the same position/posture whenever possible. In particular, it is recommended that a "1st of day" measurement be done daily when training at elevation. This means performing a measurement upon waking and before getting out of bed, drinking fluids or using the bathroom.

I am seeing an increase in my hemoglobin just after a few days at elevation, despite being told it takes weeks, is that normal and does that mean I've reached my hemoglobin target?

This is a normal response to elevation. However this initial increase in hemoglobin can be misleading. Within the first few hours of arrival at elevation, plasma volume (the "water" component of blood) begins to decrease and reaches a low point days to weeks later. Because hemoglobin is measured as a concentration, when the plasma volume decreases, it will elevate the value of hemoglobin, even though no new hemoglobin molecules have been made. However, over a period of few weeks at elevation, the plasma volume increases back to normal, and thus the hemoglobin value will drop back as well. Continued and sustained elevation training past this point will induce the increase in hemoglobin that the athlete is seeking.

How soon would the elevated hemoglobin levels begin to come down once at sea level?

There appears to be a fairly rapid drop in hemoglobin, even in residents who have been living at higher elevation once they descend to sea level. In one finding, it was reported that long-term residents of Cerro de Pasco, Peru (elevation 4,390 m) experienced a 9.6% reduction in red blood cell mass just 3-7 days after descent to sea level^[3,4]. Since red blood cells are full of hemoglobin, less red blood cell mass means less hemoglobin. In another finding, a group of elite Kenyan runners descending from moderate elevation (2,090 m) to near sea level, (340 m), saw a hemoglobin reduction after 14 days at sea level, reaching a low point at about 30 days^[4].



If my hemoglobin levels drop soon after I return to sea level, then what is the best time to participate in a major competition to optimize my performance?

Recommendations from top coaches and applied sport scientists on when to compete upon returning to sea level vary. Some advocate competing within the first 48 hours upon returning to sea level, while others advocate between 12-17 days^[4]. Because of this wide variability, frequent non-invasive hemoglobin measurements with the Ember device may help in determining the best individual time to compete.

What are the ideal elevations for elevation training?

Typically, most competitive athletes train at elevation between 1,500 m (4,921 ft) and 3,000 m (9,840 ft). Below this, the atmospheric pressure is not low enough to trigger the physiologic response (increase in hemoglobin production). Beyond this, there is the potential for adverse health effects and is generally not recommended^[2]. In a study that appeared in the Journal of Applied Physiology, Chapman et al. suggests that the ideal window is between 2000 m (6,562 ft) and 2500 m (8,202 ft).



References

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3. Kenney, W.L., Wilmore, J.H., Costill, D.L. (2015) *Physiology of Sport and Exercise* 6th Edition, Champaign, IL. Human Kinetics.
4. Chapman, R.F., Stickford, A.S.L., Lundby, C., Levin, B.D. (2014) Timing of return from altitude training for optimal sea level performance. *Journal of Applied Physiology*. 116, 837-843.