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P2_2 Playing at a stadium one mile above sea level

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Abstract

This paper focuses on the decrease in the performance of American football players at high altitude. The central interest is the proportional drop in performance to partial pressure of oxygen in the atmosphere. While inductive interpretation of the available data would lead to the prediction that there is an effect, too little data has been scientifically recorded and no quantifiable predictions to the advantage of American football teams having a home stadium at high altitude is currently possible.

P2_3 Sports Science

Introduction

The Denver Broncos home stadium is known as the "*Mile High Stadium"*, because it is situated one mile above sea level [1]. The stadium has a reputation for being a challenging place to play at. Away teams often commented that they found it more tiring to play at mile high stadium than most other venues. This paper assesses if the altitude that the stadium is situated at could be the cause for this apparent difficulty.

It is a well known fact that the when the muscles of the body are used to perform strenuous activities we breathe more heavily. This heavy breathing is largely to increase the amount of oxygen that we can get to our muscles; oxygen is required to keep our muscles working. If we were in an environment with a decreased oxygen partial pressure it would be harder to keep our muscles supplied with enough oxygen, meaning that we could not perform to our maximum level [2].

Method

The density of oxygen is directly linked to the density of the atmosphere. Atmospheric density decreases with altitude [3]. The relation between atmospheric density and altitude can be expressed as

$$\rho = \rho_0 e^{\frac{-z}{H}} \quad (1)$$

where *z* is the height above sea level ρ is the density at the height *z*, ρ_0 is the density at sea level *H* is the scale height (a temperature dependant constant).

Additionally, temperature is known to change with altitude. One model for the change in temperature with altitude is given by the adiabatic lapse rate [4]

$$-\frac{dT}{dz} = \frac{g}{C_p} \quad (2)$$

where $\frac{dT}{dz}$ is the rate of change of temperature with height, g is gravity and C_p is the specific heat of water at constant pressure.

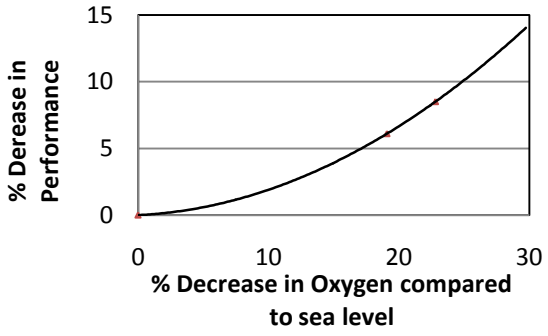
This shows that at higher altitude you can expect a lower temperature; this gives a change in temperature of approximately 20°[4] at "*Mile high stadium*" compared to sea level.

This will have a negligible effect on the scale height and the approximate temperature at Denver is approximated as a constant over the whole altitude change.

The average temperature at Denver is approximately 20°C [5]. At this temperature the scale height *H* is 8500m. *"Mile High Stadium"* sits 1700m above sea level. Substituting all this data into equation (1) gives the air pressure in the stadium as approximately 8.27×10^{4}Pa. This gives an atmospheric density of 81% of that at sea level.

This means that "*Mile High Stadium"* has a 19% decrease in the density of the atmosphere resulting in a 19% decrease in the partial pressure of oxygen at the stadium compared to that at sea level.

There have been studies on the drop in performance at similar altitudes to that of *"Mile High Stadium"* [6] (running 3 miles at an altitude of 1800m) by extrapolating this data and using equation (1) we calculated a 6% drop in performance to a 19% drop in oxygen.



Graph 1. There is limited quantifiable data on this subject. However using what data was available we created a graph showing the drop in performance (in this case performance was measured as the average time to run 3 miles), against the decrease in the partial pressure of oxygen compared to sea level. The fitted curve is illustrative only.

The scarcity of data makes finding the relation between oxygen partial pressure and performance impossible, however it is clear from this and other articles [7,8,9] that the decrease in performance becomes greater with altitude. We have approximated a parabolic function to graph 1 to illustrate a possible trend.

Discussion

The results of performance decrement vary for many reasons; different levels of prior training have an effect, athlete's results differ from that of non-athletes [7]. The type of exercise that is being performed (anaerobic or aerobic) also causes different decreases in performance [8].

The increase in altitude may have an effect on the person beyond the effects of a lower partial pressure of oxygen. There would be a host of other physiological and psychological effects to take into account which are unfortunately too great in number to be reviewed in this article; it would be feasible and useful to perform exercise with reduced oxygen and to perform exercise at increased altitude to find how closely the two effects were related.

Conclusion

Having a stadium one-mile above sea level will reduce the amount of oxygen that is in the air by about 19% compared to sea level. This reduction in oxygen should cause any away teams to find playing at the stadium more difficult. This is based purely on physiological reasons and inductive interpretation of the available data. However the actual drop in performance of football players at an altitude of 1700m ("Mile High Stadium" altitude) has not been quantitatively studied and no direct conclusion can be drawn.

References

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