Acclimatization at High Altitudes using Machine Learning

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Abstract: The objective is to classify the fitness level of individuals at high altitudes and their susceptibility to acute mountain sickness (AMS). AMS is caused due to rapid ascent to hypobaric and hypoxic environments the physical variables taken into consideration are the heart rate (HR) and the saturated volume of partial oxygen level (SPO2). HR and SPO2 levels were chosen as they are the factors most affected by hypobaric and hypoxic environments. We aim to build an index of acclimatization that classifies the level of acclimatization based on the values of Heart Rate and SPO2 levels using support vector machines. The model is trained using HR and SPO2 values of 100 individuals over seven days, with six days at high altitude and first day at sea level. Adaptability at higher altitudes varies from one individual to another based on their lifestyle, fitness levels and different factors, so classification may help identify individuals who have adapted inadequately so steps may be taken to acclimatize efficiently. The index classifies individuals into four categories: Highly Acclimatized, Normally Acclimatized, Partially Acclimatized and Susceptible. Classification of acclimatization levels can be used by military personnel training at high altitudes and medical applications.

Keywords: Acclimatization, AMS, Heart Rate, SPO2 levels, Fitness, High Altitude

I. INTRODUCTION

Altitude sickness is an encompassing term used for the range of negative effects that can be experienced by a non-acclimatized individual at high altitudes. This includes acute mountain sickness (AMS) which can progress to High Altitude Pulmonary Edema (HAPE) with associated shortness of breath and High-Altitude Cerebral Edema (HACE) which is associated with confusion. Ascent to high altitudes require adaptation to a hypobaric and hypoxic environment, while failure to adapt may lead to altitude sickness. The ability of an individual to adapt to high altitudes can depend on many variables such as fitness or having spent time in higher altitudes before. Rapid ascent to higher altitudes leads to physiological changes of including a rise in blood pressure and heart rate and fall of SPO2 levels. The values of these variables can be used to estimate the level of adaptability or acclimatization of an individual. By using an acclimatization index, the susceptibility to altitude sickness of individuals can be determined and the changes required to their diet and training to advance their acclimatization levels. The aim is to classify the acclimatization level and the susceptibility to altitude sickness based on heart rate and SPO2 levels.

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II. RELATED WORK

A research was conducted on the influence of induced altitude acclimatization on development of acute mountain sickness associated with a subsequent rapid ascent to high altitude at the Beijing Genomics Institute. The research was published at the 2016 IEEE 16th International Conference on Bioinformatics and Bioengineering (BIBE).

Summary: The objective of the research paper was to establish whether induced altitude acclimatization has an effect on susceptibility to acute mountain sickness. A total of fifty-five male non-smoking and healthy office workers were part of the study. The participants were divided into groups A and B. Group A consisted of 24 participants ascending from 300m to 3658m with a mean age of approximately 29 and an average BMI of 24. Group B had 31 participants stayed at 1520m for 7 days and then ascended to a height of 3658m. Group B had an average age of approximately 26 and an average BMI of 24. The Physiological variables that were used include heart rate, SPO2 levels and Rate Pressure Product (RPP). AMS scores were derived from self-completed LLS Questionnaires which had been regarded as the most useful tool for assessing AMS symptoms.

Results of the study:
- The induced altitude acclimatization above 1500m provided low-altitude residents in certain degree benefit in the prevention of AMS during a subsequent rapid ascent to high altitude.
- AMS during a subsequent rapid ascent to high altitude. The comparison of data between participants with and without an induced altitude acclimatization exhibited physiological significance during acute phase response after a rapid ascent to altitude.
- In addition, the difference in alterations of the physiological variables including RPP, SpO2 and RI might reflect an important mechanistic insight into the development of AMS, even further to HACE and HAPE.

III. PROPOSED METHODOLOGY

1. Dataset: A dummy data set based on ranges obtained from the internet and confirmed with medical professionals of 100 individuals spanning over 7 days with day 1 being at sea level and the others at high altitudes was used to make the model. The physiological variables, heart rate and SPO2 levels were determined as the most important in relation to AMS.[2] [3]

Saturated Level of Pure Oxygen: SpO2 stands for peripheral capillary oxygen saturation, an estimate of the amount of oxygen in the blood. More specifically, it is the percentage of oxygenated hemoglobin (hemoglobin containing oxygen) compared to the total amount of hemoglobin in the blood (oxygenated and non-oxygenated hemoglobin).
According to experts, normal SPO2 levels are between 96% to 99%. These values are affected by altitude due to the hypoxic environment.

Heart Rate: The heart rate is the number of times the heart beats in a minute. Normal heart rate can vary from person to person depending on their fitness level, amount of physical activity etc. but a normal range for adults is between 60 to 100 beats per minute. The resting heart rate of an individual increases with an increase in altitude, and should decrease as a person acclimatizes. [5] [6]

We used support vector machines to categorize our training data.

Support Vector Machines: A Support Vector Machine (SVM) is a discriminative classifier formally defined by a separating hyperplane. In other words, given labeled training data (supervised learning), the algorithm outputs an optimal hyperplane which categorizes new examples. In two-dimensional space this hyperplane is a line dividing a plane in two parts where in each class lay in either side.

2. Margin Calculation: We trained an SVM model in Python by training set of sea level and a dummy data set having values from origin (Fig. 1). The datasets having values from 1st day to 6th day were used as test datasets. One by one the datasets from 1st day to 6th day were given as input to training model and margins were calculated (Table 1). The average margin of sea level to 6th day datasets is showing a decreasing trend (Fig. 2) after 1st day margin value. Furthermore, the maximum and minimum margin trends are also showing same downward trend.

![Figure 1: Origin vs sea level data as training set separating by hyperplane. Black colour represents origin points and grey represents sea level points.](image1.png)

Table 1: The margin value from origin to sea level as well as day 1 to day 6 at high altitude

| Margin value | Sea level | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 |
|--------------|-----------|-------|-------|-------|-------|-------|-------|
| Maxim um     | 63.01     | 65.41 | 64.36 | 63.70 | 63.36 | 62.09 | 62.421|
| Minim um     | 56.68     | 62.58 | 60.68 | 58.50 | 53.47 | 58.60 | 59.300|
| Average      | 59.50     | 63.83 | 62.56 | 61.92 | 61.32 | 60.87 | 60.856|

![Figure 2: The line plot of showing maximum, minimum and average trend of margin values from sea level to 6th days. The legend is given at the bottom of the figure.](image2.png)

3. Calculating Percentage of Acclimatization: As we know, there is threshold range of each physiological parameters which can fluctuate up to a certain level. The HR and SPO2 values for an extremely healthy person can lie with 50 and 100 respectively at its best. This trivial value can be used to find out acclimatization percentage. The formula used was following as:

Percentage of acclimatization=(55.9)/(Margin value) ×100

Thus, we will get a matrix of acclimatisation percentage from 1st day to 6th day. The average value of percentage was drawn as graph and found a sharp increase up to 3rd day and again it became stable at 5th day.

Table 2: The percentage of acclimatization value from origin to sea level as well as day 1 to 6 at high altitude

| Sea Leve | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 |
|----------|-------|-------|-------|-------|-------|-------|
| 1        | 99.8  | 90.161| 93.16 | 96.37 | 96.37 | 96.3  |
| 2        | 88.7  | 86    | 87.34 | 88.73 | 88.73 | 90.1  |
| 3        | 87.34 | 3     | 0     | 0     | 0     | 61    |
| 4        | 88.303| 90.17 | 91.02 | 91.80 | 92.5  | 92.6  |
| 5        | 94.7  | 88.303| 90.17 | 91.02 | 91.80 | 92.5  |
| 6        | 91.80 | 90.17 | 91.02 | 91.80 | 92.5  | 92.6  |

Acclimatization Index: An anomalous drift was observed at 4th day. So, the percentage values were being overlapped across 3rd & 4th day and 5th & 6th days. The percentage-based classification will be a perplexing idea. To override this problem, we have given a weightage to percentage value varying with day. Although the weightage given was referred by medical experts.

Table 3: Weightage assigned to each day

| DAY    | WEIGHT |
|--------|--------|
| 1st    | 0.2    |
| 2nd    | 0.4    |
| 3rd    | 0.6    |
| 4th    | 0.75   |
| 5th    | 0.9    |
| 6th    | 1      |

A reference table was designed using the weightage score from table 3. Finally, our datasets suggests that acclimatization percentage exists between 80 to 100. We classify the according to the percentage of acclimatization (Table 4).
Table 4: Reference table matrix for different percentages after applying weights.

| RANGE          | STATUS          |
|----------------|-----------------|
| 100%-95%       | Highly acclimatised |
| 95%-90%        | Normally acclimatised |
| 90%-85%        | Partially acclimatised |
| 85%-80%        | Susceptible      |

Table 5: Acclimatization level based on percentage after applying weights.

| DAY | WEIGHT | 1   | 2   | 3   | 4   | 5   | 6   |
|-----|--------|-----|-----|-----|-----|-----|-----|
|     |        | 0.2 | 0.4 | 0.6 | 0.75| 0.9 | 1   |
| 100%|        | 20  | 40  | 60  | 75  | 90  | 100 |
| 95% |        | 19  | 38  | 57  | 71.25| 85.5| 95  |
| 90% |        | 18  | 36  | 54  | 67.5| 81  | 90  |
| 85% |        | 17  | 34  | 51  | 63.75| 76.5| 85  |
| 80% |        | 16  | 32  | 48  | 60  | 72  | 80  |

IV. RESULTS

A small portable device containing our GUI can be used at high altitudes quite easily. Heart Rate and SPO2 levels will be provided as input and the acclimatization level will be presented as an output (Figure 4).

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