APPLY MODERN STATISTICAL CLUSTERING ANALYSIS ON DETECTING ALTITUDE SICKNESS AND SPORTS FATIGUE BEHAVIOR

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ABSTRACT

This paper will address Altitude Sickness risk when hiking on the high Mountains. It's very risky if the people are not aware of their altitude sickness symptom such as Fatigue, Headache, Dizziness, Insomnia, Shortness of breath during exertion, Nausea, Decreased appetite. The consequence of altitude sickness could be dangerous on the inconvenient high mountains. Pulse Oximeter was used to monitor the Oxygen% and Heart Beat at different altitude levels from near-sea level in San Jose, Denver (5,000 Feet), Estes Park (8,000 Feet), Rocky Mountains Alpine Center (12,000 Feet). 2.5-mins Jumping Rope exercise was conducted to analyze the fatigue behavior associated with Altitude Sickness. Statistical analysis was conducted to verify several hypotheses to predict the Altitude Sickness Risk as well as the Exercise Fatigue Behavior. This paper has demonstrated how to assess their body strength and readiness before they may take a strenuous hiking on the high mountains.

KEYWORDS

JMP, Statistics, Altitude Sickness, Data Mining, AI

1. INTRODUCTION

When go to higher altitudes, the environmental pressure drops and less oxygen available. Your body will need time to adjust to the change in pressure. Any time above 8,000 feet, you can be at risk for altitude sickness. The Oxygen levels are plotted vs. Altitude (feet). There is only 70% Oxygen available at 10,000 feet. At the highest mountain Everest (29,029'), the Oxygen level is only around 32%. In 2019 Spring, with a single route to the Everest summit, delays caused by overcrowding could prove fatal after suffering from what appeared to be altitude sickness. Most climbers can only spend a matter of few minutes at the summit without extra Oxygen supplies in where is known as the "death zone". Even when using bottled Oxygen, supplemental Oxygen, there is only a few hours that mountaineers can survive up there before their bodies start to shut down. If caught in the traffic jam above 25,000 feet, the consequences can be severe. Therefore, how to detect body altitude sickness earlier is critical for these climbers in certain critical situation. This paper would demonstrate the real-time Oxygen Concentration% and Heart Beat Rate measurement on detecting any early altitude sickness symptom. The Fatigue factor would also be addressed.

1.1. Three Kinds of Altitude Sickness

1. Acute Mountain Sickness (AMS) is the mildest form and it's very common. The symptoms can feel like a hangover – dizziness, headache, muscle aches, nausea [1-3]. Most instances of

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altitude sickness are mild and heal quickly. In rare cases, altitude sickness can become severe and cause complications with the lungs or brain as in the following two cases.

2. High Altitude Pulmonary Edema (HAPE) is a buildup of fluid in the lungs that can be very dangerous and even life threatening [4, 5]. HAPE is a noncardiogenic pulmonary edema. Early symptoms of HAPE include a nonproductive cough, dyspnea on exertion and reduced exercise performance. Treatment of HAPE consists of immediate improvement of Oxygenation either by supplemental Oxygen, hyperbaric treatment, or by rapid descent. Early symptoms of HAPE include a subtle nonproductive cough, dyspnea on exertion and reduced exercise performance. Orthopnea may occur. Gurgling in the chest and pink frothy sputum indicate advanced cases. The clinical features are cyanosis, tachypnoea, tachycardia and elevated body temperature generally not exceeding 38.5°C. Rales are discrete initially and located over the middle lung fields. Figure 1 imaging of the thorax reveals patchy opacities with inconsistent predominance of location, but often infiltrates are seen in the region of the right middle lobe.

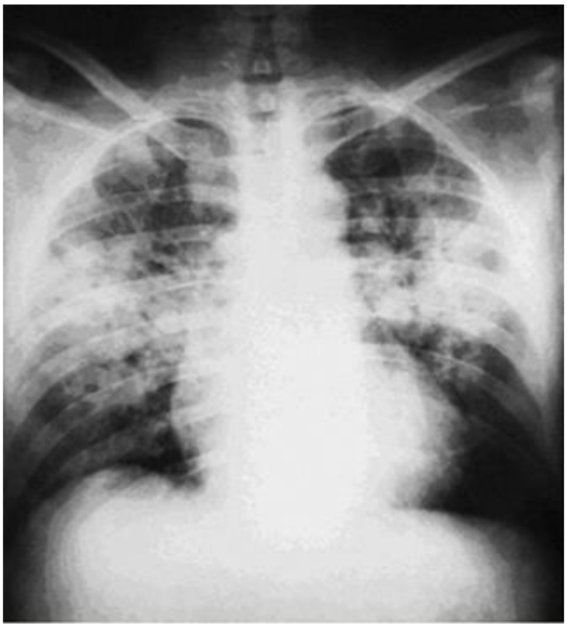

Figure 1. Chest X-Ray showing high altitude pulmonary edema.

(3) High Altitude Cerebral Edema (HACE) is the most severe form of altitude sickness and happens when there's fluid in the brain. It's life threatening, and you need to seek medical attention right away [6]. HACE is often characterized by ataxia, fatigue, and altered mental status, and mat progress rapidly to coma and death as a result of brain herniation if not promptly diagnosed and treated. **High-altitude cerebral edema** (**HACE**) is a medical condition in which the brain swells with fluid because of the physiological effects of traveling to a high altitude. It appears to be a vasogenic edema (fluid penetration of the blood–brain barrier), although cytotoxic edema (cellular retention of fluids) may play a role as well as shown in Figure 2 [7]. Individuals with the condition must immediately descend to a lower altitude or coma and death can occur. Patients are usually given supplemental oxygen and dexamethasone as well.

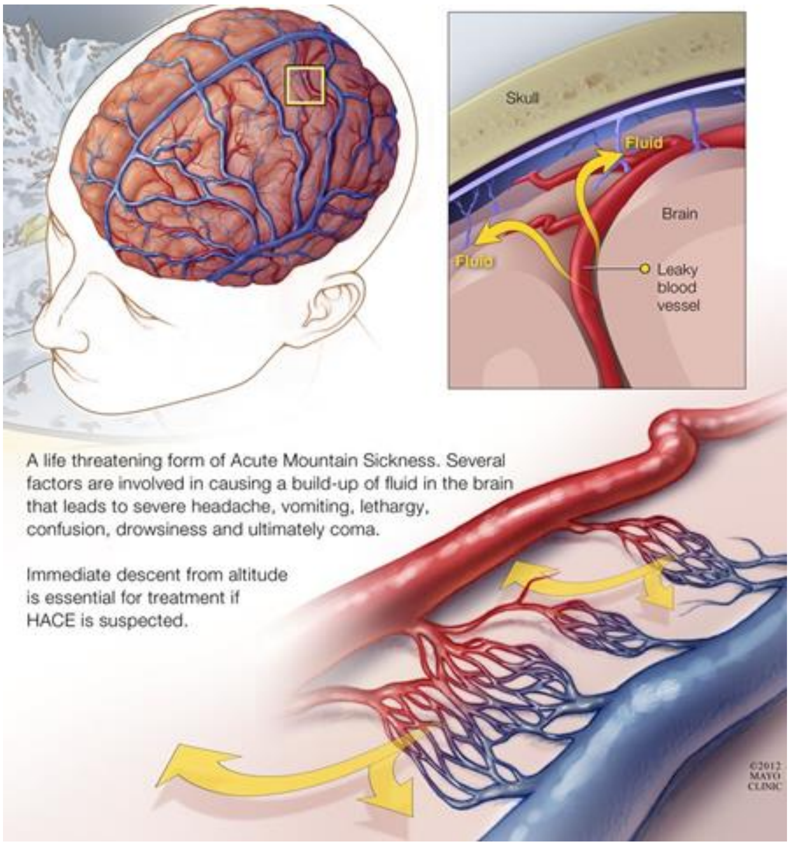

Figure 2. HACE Diagram.

1.2. Prevent Altitude Sickness

Chance of getting altitude sickness depends: how quickly you move to a higher elevation, how high you go up, the altitude where you sleep, where you live and the altitude there, your age (young people are more likely to get it), and whether you've had altitude sickness before. Having certain illnesses like diabetes or lung disease doesn't automatically make more likely to develop altitude sickness. But genes could play a role to handle higher elevations. There are several prevention technologies to lower chance of getting altitude sickness through proper acclimatization: let your body slowly get used to the changes in air pressure as travel to higher elevations as followings.

- Start your journey below 10,000 feet.
- If you walk, hike, or climb over 10,000 feet, only go up an additional 1,000 feet per day.
- For every 3,000 feet you climb, rest at least a day at that height.
- "Climb high and sleep low".
- Drink 3-4 quarts of water daily, and about 70% of your calories are coming from carbs.
- Don't use tobacco, alcohol, or other medications, such as sleeping pills.
- Know how to identify the first signs of altitude sickness.

The most effective detecting Altitude Sickness is to measure the Body Oxygen Level. Oxygen Pulse Technology. Pulse Oximeter was used to monitor the Oxygen Saturation% and Heart Beat Rate at different altitude levels. A clip-like device called a probe uses light to measure how much oxygen is in this blood and how well your heart is pumping oxygen through your body. Transmissive Mode is most popularly used: a small beams or light pass through the blood in the finger, measuring the amount of oxygen by measuring changes of light absorption in oxygenated or deoxygenated blood.

In addition to section 1 Introduction, this paper would be deployed in the following sections. Section 2 would address the methods of two altitude sickness body measurements: Pulse Oximeter and Heart Beat Rate. Section 3 would analyze the collected body measurement data and conducted several modern Data Mining analytics and validate the statistical hypothesis tests. The last section would conclude the paper findings and values added.

2. METHODS

To study the Altitude Sickness, the Pulse Oximeter was used to monitor the Oxygen Saturation% and Heart Beat Rate at different altitude levels from the sea level in San Jose to Boulder (5,000 Feet), Rocky Mountain Estes Park Center (8,000 Feet), and Rocky Mountains Alpine Center (12,000 Feet). The data was collected from one trip from San Jose to Rocky Mountains National Park within 2 days. Five Middle School to High School students were identified to join this Altitude Sickness trip. To ensure the altitude sickness is successful, the authors have taken the following actions: (1) identify the person to be considered in the experiment. To avoid high risk of altitude sickness on the high mountains, all candidates were requested to collect the Oxygen% and Heart Beat Rate at Boulder the night before going to Rocky Mountain National Park. 5 people were selected because they did not detect any Altitude Sickness at Boulder (all their Oxygen% is in 97%-98%), (2) to ensure the measurement is repeatable and reproducible, Gage R&R was conducted to certify each candidate. They are well trained on how to place their fingers and read the curves during the Pulse Oximeter measurement, and (3) each candidate would also exercise 2.5mins Jumping Rope to study the Fatigue Behavior associated with Altitude Sickness. Statistical analysis was conducted to verify several hypotheses to predict how high of the Altitude Sickness Risk at different altitude levels as well as the Exercise Fatigue Behavior.

In Table 1, both Oxygen% and Heart Beat per Minute (HBPM) raw data were collected at different altitude before and after exercise. The analysis focus is to validate several hypotheses: (1) which measurement would detect the Altitude Sickness, (2) which measurement would detect the Fatigue, and (3) any correlation between two measurements. More analysis would be addressed in the next Result section.

Table 1. Oxygen % and Heart Beat per Minute (HBPM) Raw Data.

ID	Sea Level O2%	8,000 Feet O2%	12,000 Feet O2%	12,000 Feet after Rope Jumping O2%	12,000 Feet after Climbing Stairs O2%	8.000 Feet HBPM	12,000 Feet HBPM	12,000 Feet after Rope Jumping HBPM	12,000 Feet after Climbing Stairs HBPM
Julianne	97%	97%	93%	89%	88%	88	92	168	158
Mason	97%	97%	94%	84%		90	96	151	
Brianna	97%	97%	92%	81%		75	88	190	
Alan	97%	96%	91%	80%		65	90	150	
Allison	97%	97%	94%	91%	82%	73	84	161	160

3. RESULT AND DISCUSSION

Several JMP Data Analysis are conducted to study the Altitude Sickness and Fatigue factor. Clustering Variables [8] was used for grouping similar Oxygen and Heart Beat response variables into representative clusters which are a linear combination of all variables in the same cluster.

The cluster can be represented most by the variables identified to be the most representative members (higher R-Square with own cluster in Figure 3). In general, the first cluster grouped the Oxygen measurement at different altitude levels. The second cluster grouped the Heart beat measurement at different altitude levels. This pattern recognition may indicate Body Oxygen Reaction and Heart Beat Reaction may behave two different mechanisms. One is more sensitive to the Altitude Thickness and one is more sensitive to the Fatigue Factor. The most representative variable in the cluster can be used to explain most of the variation in the data analyzed. Typically, dimension reduction using Cluster Variables is often more interpretable than dimension reduction using principal components. These modern data mining techniques could discover more insights than traditional correlation analysis.

Cluster Members

Cluster	Members	RSquare with Own Cluster
1	8,000 Feet O2%	0.805
1	12,000 Feet O2%	0.876
1	12,000 Feet after Rope Jumping O2%	0.615
1	8.000 Feet HBPM	0.629
2	12,000 Feet HBPM	0.678
2	12,000 Feet after Rope Jumping HBPM	0.678

Figure 3. Clustering Variables of Oxygen and Heart Beat Responses.

The above clustering analysis may indicate two Body mechanisms: Altitude Sickness and Fatigue. The first cluster is more on the Oxygen response of Altitude Thickness. The second cluster is more on the Heart Beat response of Fatigue behavior. Clustering Variables method can effectively explore the Oxygen and Heart Beat clustering patterns which can explain the common Altitude Sickness and Fatigue science well. Adopting this dimension-reduction clustering algorithm can help simplify the predictive modeling by enhancing the signal-noise ratio, particularly in a very complicated/coupled design or system behavior.

Two-Way Hierarchical Clustering: identify which player has a higher or lower risk of Altitude Sickness as shown in Figure 4. Two clusters were identified among 5 Players. Four players were assigned to the 1st Cluster with similar altitude sickness pattern. No.1 and No.2 Player have the closest pattern. No.4 player has the most opposite pattern against the other four players almost across all 6 Oxygen/Heart Beat categories. Among 6 Oxygen/Heart Beat Categories, high O2% correlations between 8,000 Feet and 12,000 Feet before exercise. High Heart Beat correlations between before/after exercise at 12,000 Feet. The Hierarchical clustering analysis may indicate two Body mechanisms: Altitude Sickness and Fatigue. This result could access the risk level across five players and identify the risky client. Also, this methodology may also help players and coach to assess the Body Strength when doing any exercise or sports activity on the high Mountains, for example for competing in the Winter Olympic Games.

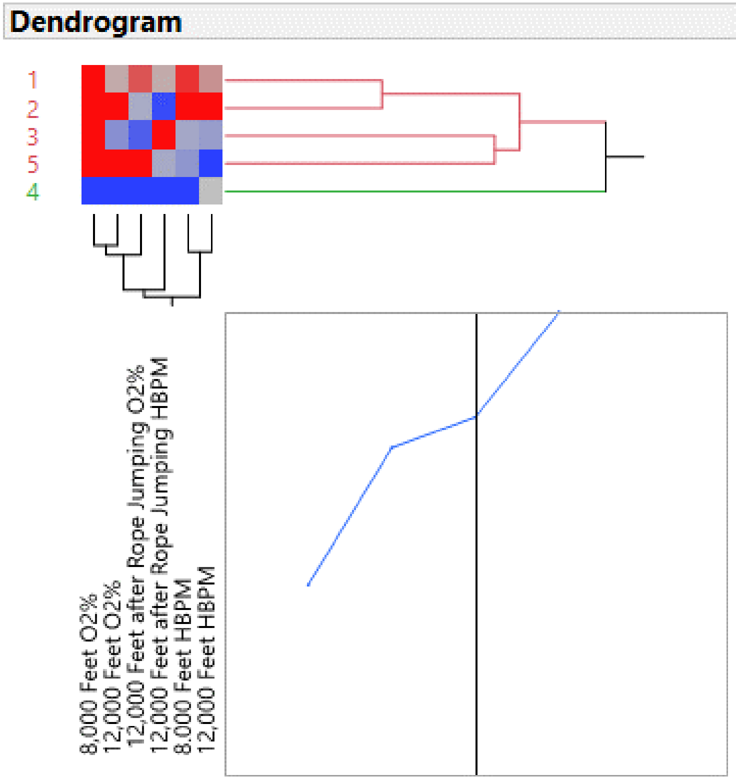

Figure 4. Two-Way Hierarchical Clustering of Altitude Sickness.

Descriptive Statistics was conducted to study any Altitude Sickness and Fatigue trending in Figure 5 which has shown clear Altitude Sickness Body Reaction: lower Oxygen% mean and Higher Heart Beat mean at higher Altitude. The heart beat rate has significantly increased during the 2.5mins Rope Jumping exercise. This has also indicated that Human Body would get fatigued faster on the high-altitude levels.

Univariate Simple Statistics

Column	N	DF	Mean	Std Dev	Sum	Minimum	Maximum
8,000 Feet O2%	5	4.00	0.9680	0.0045	4.8400	0.9600	0.9700
12,000 Feet O2%	5	4.00	0.9280	0.0130	4.6400	0.9100	0.9400
12,000 Feet after Rope Jumping O2%	5	4.00	0.8500	0.0485	4.2500	0.8000	0.9100
8.000 Feet HBPM	5	4.00	78.2000	10.5688	391.000	65.0000	90.0000
12,000 Feet HBPM	5	4.00	90.0000	4.4721	450.000	84.0000	96.0000
12,000 Feet after Rope Jumping HBPM	5	4.00	164.000	16.3248	820.000	150.000	190.000

Figure 5. Descriptive Statistics.

Multiple Box-Plot in Figure 6 was conducted and shown a similar trending in visualization. As compared to Descriptive Statistics, Box-Plot can provide better insight information and correlation among Oxygen% and Hear Beat responses. Both the Altitude Sickness and Fatigue behaviors are well demonstrated in the Box Plot. The focus of looking at Box Plot is to look at each distribution shape and compare the difference. There is no outlier detected and most shapes were near-normal or at least near-symmetric. Therefore, it's safe to conduct the Parametric Mean Tests in next section.

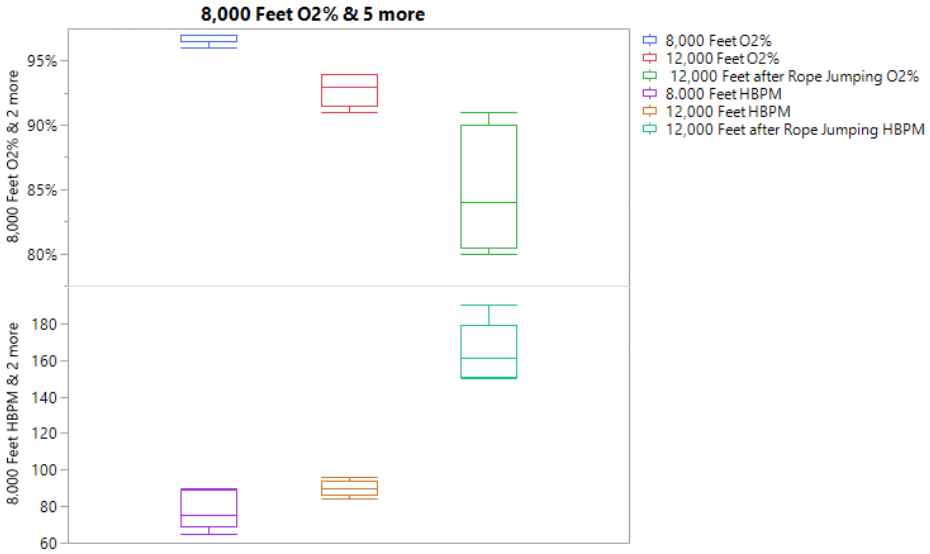

Figure 6. Multiple Box-Plot of Oxygen and Heart Beat responses.

Paired-t test was conducted to compare both the Altitude Sickness and Fatigue of Oxygen% on the same player. As compared to traditional 2-sample t test, Paired-t test is a proper hypothesis test to test any difference between a homogeneous pair (here is the Oxygen or Heart Beat on the same player). In Figure 7, paired-t tests are significantly positive which has demonstrated strong Altitude Sickness and Fatigue on the high Mountains at 12,000 feet. The P-values are well below 0.05 threshold (95% confidence). Only one Oxygen plot is provided while the other Paired-t test shows similar trending (P-values < 0.05). The paired-t tests have demonstrated a clear Altitude Sickness at 12,000 Feet and a clear Fatigue Factor there. People could become Fatigue easily at high Altitude Mountains as shown by behaving much higher Heart Beat Rate after 2.5mins Rope Jumping at 12,000 Feet. It's very risky to climbers who are taking aggressive exercise on the high mountains.

12,000 Feet O2%	0.928	t-Ratio	-8.94427
8,000 Feet O2%	0.968	DF	4
Mean Difference	-0.04	Prob > |t|	0.0009*
Std Error	0.00447	Prob > t	0.9996
Upper 95%	-0.0276	Prob < t	0.0004*
Lower 95%	-0.0524		
N	5		
Correlation	0.77174		

Figure 7. Paired-t Test of Oxygen%.

4. Conclusion

This paper has demonstrated on understanding Altitude Sickness and Fatigue "Science". Understanding the Human Body Oxygen% and Heart Beat responses on the high Mountains can be done effectively through a systematic "Engineering" problem solving framework. Modern "Artificial Intelligence" Clustering methods can explore the Altitude Sickness and Fatigue Patterns which can further help climbers evaluate their Altitude Sickness based on the Ztransformed mathematically Parallel Plot. Both “Descriptive Statistics”, “Box-Plot”, and “Paired-T” can help draw more Oxygen and Heart Beat insight response to address Altitude Sickness and Fatigue. This method could detect the real time Altitude Sickness and Fatigue risk by measuring the Oxygen% and Heart Beat Rate at frequent base. The measurement data could provide the Body Reaction Risk and guide the high risk identified person to take immediate actions to avoid situation getting worse. In the modern Big Data era, most scientists and engineers shall adopt such Interdisciplinary methodology and integrate subjective root cause analysis and objective data-driven seamlessly and collectively.

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REFERENCES

[1] Luo, Elaine (2017), “Acute Mountain Sickness”, Healthline.
[2] Lukes, Andrew, Swenson, Erik & Bartech, Peter (2017), “Acute High-Altitude Sickness”, European Respiratory Review 2017 26:160096
[3] Paralikar, J. Swapnil (2012), “High Altitude Pulmonary Edema-Clinical Features, Pathophysiology, Prevention and Treatment”, Indian Journal of Occupational and Environment Medicine, P.59-62
[4] Bartsch P, Mairbauri H, Swenson ER, & Maggiorini M. (2003), “High altitude pulmonary edema”. Swiss Med Wkly.
[5] Schoene RB. (2008), “Illnesses at high altitude. Chest”.
[6] Jensen, Vincent AL (2017), “High Altitude Cerebral Edema (HACE)”, Stat Pearls Publishing LLC.
[7] Hackett PH, Yarnell PR, Hill R, Reynard K, Heit J, & McCormick J. (1998), “High-altitude cerebral edema evaluated with magnetic resonance imaging: clinical correlation and pathophysiology”. JAMA. 280(22):1920-5.
[8] Milligan, G.W. (1980), “An Examination of the Effect of Six Types of Error Perturbation on Fifteen Clustering Algorithms,” Psychometrika, 45, 325–342.