MARS: HIKERS WANTED. BIOMEDICAL FACTORS ON HUMAN MARS EXPLORATION

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The present study of a continued monitored ascent to Mount Kala Patthar and Everest Base Camp trekking offers a possible extrapolation of scientific data for future expeditions on Mars. The red planet altitude variability, gravitational field, extreme weather changes and the complex astronaut gear offers a unique challenge for human expeditions. On the other hand: extreme territories on earth, severe weather, multilayered gear for climbers, rations, weight carried and low oxygen levels like those presented in the Himalayas may serve as a close simulation to future interplanetary missions. The scientific data obtained by a physician during an ascent to Everest Base Camp reflected that a relative slow pace maintained during the expedition, a continue hydration, diet, and a progressive acclimatization may facilitate adaptation and goal achievements during the arrival to Mars. Data of vital signs including oxygen saturation levels, serve as first objective data of tolerance, adaptation and disease state after landing. Clinical and psychological symptoms and possible evacuation scenarios are discussed. Potential spacesuit modifications and the use of the exoskeleton are brought to light. This paper examines potential simulation protocols to train and to increase stamina, strength, perseverance, and psychological aspects of the human endurance during expeditions. The role of dependability on robotics, communications, and transportation during Mars exploration is reassessed. It is concluded that a training for future missions must emphasize more on mountain hiking to elevate the exercise load after the initial phase at Mars Stations in the arctic region and the Utah dessert. Conditions including a rough terrain, high altitude, cold temperatures, low oxygen levels, deconditioning, psychological challenges, sleeping and appetite pattern disturbances and medical symptomatology might be found only on the earth mountains and the Martian regions.

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INTRODUCTION

The first human settlement on Mars is also a medical challenge. Space exploration and Lunar landing will provide an invaluable source of knowledge, but the colonization of another planet will require a new set of skills. The psychological challenges of settling in a new territory with limited resources, multiple physical tasks, numerous decisions to make on daily bases, different gravitational fields, delayed communications and an unpredictable weather make this voyage the greatest feat of the humankind. An intense physical and a challenging psychological training is a critical requirement before the arrival to a finish line located millions of miles away.

After several months without the benefits of the earth gravity, facing immunological compromise, bone calcium and muscle mass loss, partial social deprivation, and exposed to additional radiation, (1) just to mention few situations, the crew will disembark on a new world. The astronauts will have to move not only on specially designed vehicles, but to climb, trek significant distances, use the belaying and rappelling techniques and develop a new human habitat. A preparation protocol needs to address scenarios for equipment malfunction, rescue, damaged habitat, and in how to conduct surface exploration in areas inaccessible by rovers and where astronauts might have to climb, hike or return to the habitat on their on.

Fortunately the earth mountains hold near perfect training grounds for these type of situations (HI-SEAS) Practiced in remote areas of high altitude mountaineering comes as an ideal sport modality to increase strength, stamina, creativity under pressure, adaptability and to psychologically challenge the team of explorers (2). Territories like Mauna Loa in Hawaii, the Himalayas, the Andes, the Utah dessert and the arctic offer the opportunity to tap on territories "Mars like". The Orocopia mountains have witnessed the training of several lunar landing mission (3). Landing on Mars and staying for a prolonged mission of exploration and settlement is a very different task. A physiological and mental preparation will involve more than the orbital training protocols. It has to address also the psychological aspects of extreme fatigue, survival, isolation, team work, sleep deprivation, and living on rations while working intensively.

SIMILARITIES BETWEEN MOUNTAINEERING AND MARTIAN EXPLORATION

The advantage to practice on earth habitats has been substantially documented (2). High altitude mountain expeditions could complete a more rigorous preparation phase. Some of the similarities between the red planet and the earthly high altitude mountaineering are:

1) **Presence of a rocky type of terrain.** The tree line on earth is below the 4000 meters (13 000 feet). Above this altitude the terrain is almost exclusively composed by rocks, dust and ice, just like Mars. Vegetation is almost non existent, animals if present are very rare and the passes are hundreds or thousands of miles away from the cities.

2) **Unpredictable weather, severe winds, and intense radiation:** like in Mars, but with a lot of less danger. A clear advantage to familiarize with these aspects on a safer ground.

3) **Coldest conditions:** this offers a real opportunity to test the space suit, gloves and boots in all their extension on the field. This will allow to perform changes and adjustments to the models and to let the crew feel the advantages and limitations on daily bases.

4) **Specific purpose designed gear:** multilayered clothing, gloves and mittens, special eyewear, helmet and occasionally oxygen tanks are common aspects for missions on both.

5) **Remoteness and continuous exposure to elements**.

6) **Physiological and psychological adaptability:** Expeditions in altitude are challenging. They require significant planning, anticipation for the route, weather, and interpretation of the geological assessment on real time. In addition oxygen deprivation is a critical limiting element, but it might work as a realistic simulation for muscle atrophy and decreased bone density after the long voyage.

7) **Need for self monitoring:** heart rate, oximetry, respiration, hydration and urine output are important for both environments. The crew will learn on earth the real value of those parameters without exposing their lives.

8) **Exploration and discovery:** Mineralogy**,** on the field laboratory, and the search for forms of life are part of the activities to be trained at on the expedition.

9) **Team work:** Buddy check system is performed by both, astronauts and mountaineers. The team addresses common goals, dependability and the value of the individuality. The group value concept can not be emphasized enough.

10) **Rationing supplies:** From water to food, fuel, medications and oxygen. The mountain expedition is a school on how to thrive as a minimalistic in a foreign environment.

SCIENTIFIC DATA COLLECTED ON THE 2016 MEDICAL EXPEDITION TO EVEREST BASE CAMP

The scientific observations and data was recorded by a physician acting also as experimental subject. The subject was a trained 53 years old male. The data was recorded during the ascent on the Everest Base Camp trail. The expedition lasted 11 days. It included two acclimatization days. There was a total of six ascending days. The starting altitude was 2800 meters at Lukla airport. The highest point reached was Mount Kala Patthar at 5643 meters. The lowest altitude was 2600 meters in Phakdin. The exercise parameters and distances (**Table 1**) were register after one minute rest every sixty minutes of hiking at a regular pace. The physical symptoms and the psychological observations were documented during the time for rest after each ascent to a higher ground.

Table 1. **EXERCISE PARAMETERS**

Distance exercised 52.8 kilometers on seven days of ascent.
Average hiking distance 8.8 km a day during six days of ascent
Median hiking distance 8.9 km a day.
Total hiking distance 83 932 steps
Caloric expenditure average 3821 kcal per day hiking
Total caloric expenditure during hiking 22 927 kcal (6 days of non technical climbing)
Maximal heart rate 189
Average maximal heart rate: 158
Average heart rate during exercise: 140

The oxygen saturation variation remained within expected ranges. The lowest saturation reading was registered at Mount Kala Patthar at 5601 meters of altitude (**Table 2**). The median and average pulse oximetry were measured while the subject was on the trail in the process of ascending to Everest Base Camp. The measurements were recorded every one hour during the trek. The subject stop, rest sitting for one minute and take the pulse and oximetry measurements during the second minute avoiding direct sun light.

Table 2. **OXYGEN SATURATION**

HIGHEST pulse oximetry 95-97% at 2600 meters
LOWEST pulse oximetry 71% at 5601 meters
Median pulse oximetry 84%
Average pulse oximetry 87.49%

Symptoms recorded during the expedition to Everest Base Camp included physical and psychological findings. It was noticed that the higher the altitude the more intense was the severity of the symptoms. Most prevalent was dyspnea, followed by palpitations and insomnia. Milder symptoms included arthralgias, myalgias, nausea, headaches, neck pain, constipation, borborygmus, bloating, dizziness, scotomas, epistaxis, nasal obstruction, rhinorrhea and cough.

Psychological symptoms were mild and included insomnia, mood swings, fear to fail, to fall, to develop frostbites or dying. It was also recorded death thoughts, a sense of isolation, and home sickness. All the symptoms were mild, temporary and overcome with a positive attitude, praying, keeping communications with friends and family, writing reports for the media and reading the positive comments under the expedition postings. The value of the group of explorers as an unintended group therapy was also in crescendo with the altitude reached. Low oxygenation and higher altitudes increased the confidence on each other expressed by the sharing of food, medications, and mutual support. The value of a doctor to treat cases of Acute Mountain Sickness was considered important by the rest of the explorers. There was a case of Acute Mountain Sickness (AMS) with a mild High Altitude Cerebral Edema. The until then unknown trekker was treated at 4000 meters on the EBC trail with dexamethasone 10 mg (injectable) and sent climbing down with the sherpas and fellow trekkers for further medical care. The patient progressed well and 72 hours after he expressed his desire of going back climbing. There was another case of moderate AMS successfully treated with one acetazolamide 125 mg by mouth. One case of dyspepsia and diarrhea was treated successfully with *loperamide* 2 mg by mouth and dietary measures. All the cases were presented and managed between 3900 and 4400 meters. Most of the cases that require evacuation are transferred using the patient capability to walk, with the help of the sherpas or (in the more severe cases) by helicopter.

ROBOTICS IN MARS MEDICINE

The role of robotics in long trekking situations like the Everest Base Camp trail might be very positive: A) The long robotic moving range with minimal human energy expenditure for delivery of tools, medications or samples. B) For communication, searching, scanning and probing when topographic conditions are unfavorable. The increased versatility, sizes and capability of different models would make field operations safer. These factors would allow not only a longer range in exploration, but a faster delivery of medications, blood samples, and medical devices. Robots might assess threatening weather changes, and could alternatively communicate messages when telemetric systems are non operational. Robotics would be critical evaluating changing meteorological or topographic conditions that might lead to personnel evacuation.

MOUNTANEERING ADVANTAGES AND APPLICATIONS TO INTERPLANNETARY TRAVELING

Previous experiences with lunar landings are not sufficient to prepare a crew to settle or even staying for a prolonged period on Mars. In addition to the rigorous training to endure the space transition from Earth to the Martian orbit the crew must dwell in dealing with possible fatigue and body wasting after landing. The mental aspects of the training must consider the psychosomatic adaptation during the preparation for a permanent settlement or a prolonged staying. The journey itself would be debilitating from the immunological stand point as well (5). Bone calcium loss, muscle atrophy, and radiation exposure would be associated to at least partial social deprivation. Arrival will mean also more work, physical loads, risk of exposure to the Martian atmosphere, accidents, injuries, and the psychological challenge of being on a very distant point of no return.

Training camps in high altitude on earth meet important requirements to simulate conditions at the red planet. Experiences of the HI-SEAS program in Mauna Loa are proving the value of simulation in high altitude. Morale of the group, communication delay or losing all earth contact, food variety, and biomedical aspects are being analyzed and simulated on a mountain slope by experts of NASA and the University of Hawaii. However, for training and simulation purposes Very High Altitude(3500-5500 meters) and Extreme Altitude (more than 5500 meters) should be the physiological target. Exposing the team members to progressive ascents, simulated crisis, and concurring medical evaluation and psychological testing could bring to reality a post space traveling fatigue and team vulnerabilities. The remoteness will trigger physiological and psychological adaptation mechanisms that can be used during the interplanetary expedition. The irregular terrain, cold weather, solar radiation, rations and pervasive winds could be the perfect environment to perfect techniques for future Martian exploration, to maximize the use of the astronaut gear and to final testing Martian gadgets.

Exercising in the mountains tests and improves physical strength, balance, stamina and dexterity handling equipment. The team will face decisions in regards to use the most appropriate moving routes, assisting and transferring fellow explorers, assessing the weather and conducting research.

During the expedition to Everest Base Camp in 2016 it was found a rare rock, magnet positive, dark in coloration, located at N 27° 54' 42’’ and E 86° 48' 51” near an area with the appearance of a crater. The rock was sent for analysis to the Meteoritical Society Laboratory in Boston, Massachusetts for determination of the rock mineral composition. It was not a meteorite, but it evidenced the presence of an iron foundry ore in the area of Dingboche at more than 4400 meters. The finding was communicated to the Nepal Department of Geology and Mines. This experience can be replicated to simulate future planetary exploration. Research will test also performance of space suit, boots, gloves and it will help to develop team cohesion and improvisation. Mountaineering training may simulate as well future injuries, physical trauma, visual changes and modes of evacuation during interplanetary exploration. It prepares the future crew members for the unknown. It allows to evaluate performance and personal preferences. It is ideal to measure reaction time and to practice for real emergencies.

EXOSKELETON

The experience with the use of exoskeletons in mountaineering is practically non existent. A Mars expedition should include at least one exoskeleton capable of energy endurance and strength enhancement (4). The possible medical applications during a Martian settlement are: a) Rescue operations, b) Carrying astronauts, c) During recovery and rehabilitation, and d) Chronically injured astronauts. An exoskeleton must be part of the tools included for exploration, safety and medical use. The HULC prototype developed by Lockheed Martin is an example of anthropomorphic robotic exoskeleton or Human Universal Load Carrier. This could be of multiple additional uses during Mars colonization.

CONCLUSIONS

The Medical Expedition to Everest Base Camp showed significant evidence of an ideal training model for astronauts on a mission preparation to Mars. Low oxygen levels help to simulate fatigue and mental status after the interplanetary voyage. The mountains geology, the rocky and dusty terrain, weather, rationed food and mountaineering gear are the closest scenario in earth to practice for future Martian exploratory tasks.

Mountain expedition to very high altitude and extreme altitude might help to clarify the need for further physical or mental preparation of the astronauts. The crew although exposed to the risks of mountaineering should be closely monitored in a well known trail to avoid serious dangers. A gradual ascent would follow an acclimatization protocol that starts on ground zero habitats. The acclimatization should extend to high altitude and would move from there to a very high and extreme altitude environment. A 5000 meters mark should be considered a significant simulation of extreme and prolonged fatigue for the astronauts. This scenario would serve as a more accurate method to evaluate the psycho-social integrity of the team and the physical capabilities on the field of each of the crew member. A completion of a balanced mountaineering program will lead to:

1) A better physical and psychological preparation before the Mars landing.
2) Manifestation of the team strengths and vulnerabilities.
3) The occurrence of less accidents on Mars.
4) The introduction of exoskeletons for exploration and medical purposes.
5) The development of safety and treatment protocols.
6) A faster adaptation to the new planet conditions.
7) An improved team cohesion and bonding.

Training in high and very high altitude will help on weather and terrain assessment as well as on the team decision making process. The medical expedition to Everest Base Camp showed favorable evidence of a possible training program for astronauts on a mission preparation. Low oxygen levels help to simulate fatigue after the interplanetary voyage. The mountains rocky and dusty terrain, weather, rationed food and mountaineering gear are the closest scenario in earth to practice for future Martian exploration. Through a combined program including mountaineering in high altitude individual crew members capabilities, endurance, strength and psychological vulnerabilities may surface. The group dynamic must be closely monitored for retraining. Astronaut gear improvements should be taken seriously and will be better tested in a real environment by the supporting expedition team.

A simulation model should include:

1. High altitude site
2. Duration of approximately 10 days
3. Deployment
4. Settlement
5. Acclimatization
6. Ascending expedition
7. Research and documentation
8. Rescue operations simulation
9. Descent
10. Extraction

Training ascending up to very high altitude level will help to develop protocols for exploration, safety, to time the length of operations, and to evaluate realistically the benefits and limitations of some of the present gear. Team organization, bonding, problem solving and physical capacity will be better tested with ascents to altitudes above 5000 meters. The need for at least one medical doctor is superlative. The medical personnel capacity must be tested as well. The training period must follow the premises of a close simulation not only social and psychological, but ultimately a physiological challenge. ***Aspera Ad Astra***.

BIBLIOGRAPHY

1) Meleshko, GI; Shepelev, YY; Averner, MM and Volk, T. Risks to Astronaut Health During Space Travel. Institute of Medicine (US) Committee on Creating a Vision for Space Medicine During Travel Beyond Earth Orbit; Ball JR, Evans CH Jr., editors. Safe Passage: Astronaut Care for Exploration Missions. Washington (DC): National Academies Press (US); 2001.

2) Anderson, AP; Fellows, AM; Binsted, KA; Hegel, MT; Buckey JC. Autonomous, Computer-Based Behavioral Health Countermeasure Evaluation at HI-SEAS Mars Analog. Aerosp. Med Hum Perform. 2016;87(11):912-920

3) Cohen, S. Interview with Leon T. Silver. Archives California Institute of Technology. 2001

4) Cornwall, W. Can we build an ‘Iron Man' suit that gives soldiers a robotic boost? Science Mag. 2015.
5) Sonnenfeld, G. Space flight, microgravity, stress, and immune responses. Adv. Space Res. 1999;23(12):1945-53