International Journal of Advanced Technology & Engineering Research (IJATER)
National Conference on Recent Trends in Science, Technology & Management (NCRTSTM-2018)

PHYSIOLOGICAL & PSYCHOLOGICAL ASPECTS OF HUMAN IN SPACE EXPLORATION

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ABSTRACT

The body is an extraordinary and complicated system that automatically detects, and responds to, dramatic environmental changes around it, particularly in an environment of weightlessness. The entire body is involved in the complex and rapid response to micro- or zero-gravity, and space science is just beginning to form a picture of what is happening inside the body under these conditions. When an astronaut goes into space, his or her body will immediately begin to experience a multitude of changes, causing the astronaut to feel and look slightly different. The crew would succumb to massive bone and muscle loss as a direct result of long-term exposure to micro- or zero-gravity, and would suffer cell damage from ionizing cosmic radiation, potential permanent vision problems, and psychological and sociological deterioration due to isolation. The present study identifies the psychological and physiological aspects of a manned mission to space. The International Space Station (ISS), moreover, has an enormously vital role in assessing the health dangers of sending humans to Mars.

Introduction

Prior to the twentieth century, there was little opportunity to explore Mars except via astronomical observations and science fiction .The last few decades, however, have brought forth many significant achievements in space exploration, transforming the human thirst for sending humans to Mars into a technologically achievable goal. Recent breakthroughs in space technology, space medicine, and cooperation among international space agencies, have contributed significantly toward transforming this fiction into a reality. There are, however, substantial differences between low-earth orbit operations and exploring interplanetary space. A manned mission to Mars will place humans in a remorseless environment that will not tolerate human error or technical failure. The challenges, to name a few, will include massive bone and muscle loss as a direct result of long-term exposure to micro- or zero gravity, and cell damage from ionizing cosmic radiation, potential permanent vision problems, and psychological and sociological deterioration due to isolation. Moreover, because the distance between Mars and Earth would require a 2-3 year round trip the massive undertaking of developing nutritional and medical strategies would be required in order for the mission to Mars to succeed.

Physiological Aspects of Space Travel

A journey to Mars would require, at a minimum, two 6-8 month segments of travel in “deep space” before and after a nominally 18-month stay on the surface of Mars. On the trips to and from Mars, the crew will be exposed to micro-gravity and to radiation levels much more severe than that experienced at the ISS in low Earth orbit. During her trip to Mars, for example, the rover Curiosity experienced radiation levels beyond NASA’s career limit for astronauts. On the surface of Mars, moreover, gravity is 38% that of Earth’s and radiation is still very dangerous, but reduced by more than 50% from levels in deep space. Furthermore, the surface of Mars is generally coated with dust containing toxic chemicals such as perchlorates. The key information that we do not have is whether the reduced gravity on the martian surface is strong enough to afford recovery from the physiological effects of zero-g, or at least to reduce the deleterious effects discussed in the sections below

Radiation

Earth’s magnetic field protects astronauts in low Earth orbit from harmful radiation. Although these astronauts are more exposed to radiation than humans on the ground, they are still protected by the Earth’s magnetosphere. A manned mission to Mars, however, will introduce the spacecraft and its crew to an environment outside of this protective shield. During the Apollo program, for instance, astronauts on the moon reported seeing flashes of light, and experienced cataracts; these flashes were due to radiation from cosmic rays interacting with matter, and depositing its energy directly into the eyes of the astronaut . It is important to note, however, that the Apollo missions were comparatively short and are not comparable to a 2-3 year trip to Mars and back. The crew enroute to Mars will be outside of Earth’s magnetosphere and thus will be at risk from radiation capable of critically damaging the spacecraft; absorption of fatal radiation doses from bursts of solar protons due to coronal mass ejection events, with exposures lasting a matter of hours, and/or potential damage to DNA at the cellular level (which may eventually lead to cancer).

The Cardiovascular System in Space

Although the cardiovascular and pulmonary systems (including the heart, lungs, and blood vessels) adapt well in space, they function differently in micro- or zero gravity than on Earth. An astronaut's cardiovascular system begins to adapt to weightlessness as soon as the blood and other body fluids shift from their lower extremities (feet, legs, and lower trunk) to the upper body, chest, and head. The shifting of these fluids causes the heart to enlarge so that it is capable of handling the increase of blood flow. Although the astronaut's body still contains the same total fluid volume at this point, a higher proportion of fluids have accumulated in the upper body (resulting in what is commonly referred to as puffy face and chicken leg syndrome). The brain and other systems in his/her body then interpret this increase in blood and fluids as a “flood” in the upper body.

The astronaut's body reacts to correct this “flood” by getting rid of some of the “excess” body fluid (for example, astronauts become less thirsty and the kidneys increase the output of urine). These actions decrease the overall quantity of fluids and electrolytes in the body, which leads to a reduction in total circulating blood volume. Once the fluid levels have decreased and the heart no longer needs to work against gravity, the heart shrinks in size, which can degrade performance in an astronaut's duties. Upon returning to normal gravity, the astronaut will experience postflight orthostatic intolerance. Since the astronaut's cardiovascular system adapted to weightlessness, it will initially be unable to function efficiently upon return to gravity. Nearly 63% of astronauts returning from space experience postflight orthostatic intolerance. Symptoms of post-flight orthostatic intolerance include lightheadedness, headaches, fatigue, altered vision, weakness, sweating, anxiety, and heart palpitations as a result of the heart racing to compensate for falling blood pressure.

The Neuro-Sensory System in Space

The most striking of all of the physiological changes astronauts experience are the changes in the neurovestibular system, which is the part of the nervous system largely responsible for balance mechanisms. Weightlessness during a round trip to Mars will affect an astronaut's neurovestibular system. His or her perception of body orientation, point of reference, and equilibrium will be severely altered during the trip to Mars. As a result, astronauts will experience severe motion sickness symptoms that include disorientation, dizziness, depressed appetite, vomiting, and, in severe cases, extreme nausea. This happens simply in part because weightlessness affects the otolith organs and the semicircular canals, both of which are in the inner ear. Our awareness and perception of our body's orientation on Earth is attributed to the detection of gravity by the otolith organs and the detection of head rotational movements by the semicircular canals. In weightlessness, these organs have trouble computing the body orientation relative to gravity, and the resulting signals no longer correspond with the visual and other sensory signals sent to the brain. In other words, an astronaut's brain has no concept of what is “up” or “down”.

The Musculo-Skeletal System in Space

The human body has about 700 muscles . Many of these muscles operate as cables that pull on bones to make motion possible. Their function is contraction – that is, they all work by shortening the angle between two bones. The force of gravity on the Earth's surface has shaped the structural design of nearly all life; our bodies look and function the way they do partly because of the continuous pull of this ever-present gravitational force on all of our parts. When we don't use certain muscles, however, they can go into “hibernation” mode. In a weightless environment, where an astronaut does not use his or her muscles for a period of time, the muscles themselves begin to waste away, or atrophy. The long-term result on the astronaut's load-bearing tissues will be significant reduction of bone and muscle. Thus, muscle atrophy will cause problems for astronauts on a mission to Mars. For example, research done on rats in space discovered that being in microgravity for two weeks had converted a large portion of their muscle fibers from Type I to Type II. This is due to the fact that, while in a weightless environment, the rats no longer needed their legs to balance and control their bodies against the force of gravity (the rats just floated around from one location to another). As a result, their muscles essentially began to change during space flight.

Potential Risk of Permanent Damage to Vision

The space science medical community has recently realized that long-term spaceflight can cause severe and possibly permanent vision problems in astronauts. NASA researchers are conducting experiments in an effort to comprehend the issue, which, in the case of travelling to Mars, could present a significant hurdle. In the post-flight examination of 300 US astronauts since 1989, studies have demonstrated that 29% of space shuttle astronauts and 60% of International Space Station astronauts experienced significant degradation of visual acuity. The space science community does not know the exact cause for the degradation; scientists believe the eye problems stem largely from an increase in pressure inside the skull, specifically, from increased pressure from cerebrospinal fluid which surrounds the brain, which works its way to the optic nerve and pushes on the back of the eyeball .

Psychological Aspects of Space Travel:

Of all problems that can be encountered enroute to Mars and back, effects on the astronaut’s mind may be the biggest risk factor of them all . As mentioned, a round trip to Mars would take 2-3 years. Anxiety, depression, and loneliness, along with the stress of routine tasks, tensions within the crew, and a daily battle to maintain fitness and avoiding accidents, is the ideal recipe for disturbed behavior in space. Although the psychological effects of living in space for long durations have not been clearly analyzed, similar studies on Earth do exist, such as those derived from Arctic research stations and submarines. Many of these studies confirm psychological stress could be the biggest problem for the crew. For example, unlike crews on the International Space Station, the crew enroute to Mars cannot remain in direct contact with their loved ones and are not steadily supplied with replacement crews, food, or even gifts. Isolation and confinement pose the greatest challenge for the crew – as they approach the Red Planet, communications between the spacecraft and Earth become sparser. For example, they would have to wait up to 21 minutes for a message to reach family members and another 21 minutes to receive a reply . A variety of other psychological and physical effects have also been observed from both operational and simulated isolated and confined environments. These factors include motivational decline, fatigue, insomnia, headaches, digestive problems, and social tensions. Strained crew relations, heightened friction, and social conflict are also expected from isolation and confinement.

Long-term Food and Nutritional Concerns

Unlike short duration space missions or the International Space Station, which gets resupplied periodically, food supply becomes a critical issue for a manned mission to Mars. While the US military and FEMA currently produce food with a long shelf life, astronauts on a mission to Mars will have different nutritional needs. The food that an astronaut must consume must be of the highest quality to combat the effects of long-term exposure to weightlessness, primarily in order to maintain body mass and prevent disease [6]. Once the crew leaves Earth for Mars, no other options are accessible and any further supply of additional food must be sent months or years in advance. The cost of added weight on the spacecraft is also important and another of the problems that must be overcome prior to leaving for Mars. Furthermore, unlike most food with a long shelf life, the nutritional requirements for a mission to Mars must be designed so the crew can look forward to an interesting and varied cuisine while they are away from home. On the International Space Station and Space Shuttle (recently retired), food is prepared on Earth and requires only minimal additional preparation. A mission to Mars, therefore, will require a shift to a system of production, processing, preparation and recycling of nutrients in a closed loop environment.

Operational Medicine and Health Care Delivery

On a mission to Mars, the crew would not have access to an emergency room. Moreover, there will not be much room for a full sick bay, and ambulatory medical care will be out of the question. More importantly, during the astronaut selection process it is unlikely that one would know if a crewmember is in the early stages of a deadly or incapacitating disease that would develop during the journey. Although the probability is low, there are several possible situations where medical or surgical care could be required during a mission to Mars. Medical situations, which have emerged during analogous situations (for example, crews in Antarctica or on submarines), include strokes, appendicitis, bone fractures, cancer, intracerebral hemorrhage, psychiatric Illness, and kidney stones. Decompression sickness, moreover, is another potential problem the crew could encounter, particularly during an extravehicular activity, or when moving between two different pressure environments within the spacecraft.

Exploiting the International Space Station

The ISS is the most complex and largest international engineering and scientific project in history. It is over four times larger than Russia’s Mir space station and longer than a football field. The station’s primary goals are to enable long-term exploration of space, and provide benefits to all people on Earth. In addition to scientific research on space, additional projects that are not related to space exploration, but have expanded our understanding of the Earth's environment, have been conducted. These experiments have included learning more about the long-term effects of radiation on crews, nutritional requirements levied upon astronauts during long-term missions in space, and developing newer technology that can withstand the harsh environment of space. Other experiments conducted over several expeditions on the ISS include:

- *Clinical Nutrition Assessments of Astronauts*
- *Subregional Assessment of Bone Loss in the Axial Skeleton in Long-term Space Flight*
- *Crewmember and Crew-Ground Interaction During International Space Station Missions*
- *Effects of Altered Gravity on Spinal Cord Excitability*
- *Effect of Microgravity on the Peripheral Subcutaneous Veno-Arteriolar Reflex in Humans*
- *Renal Stone Risk During Spaceflight: Assessment and Countermeasure*
- *Validation Effect of Prolonged Space Flight on Human Skeletal Muscle*
- *Bodies In the Space Environment: Relative Contributions of Internal and External Cues to Self*

Conclusion

Over the past few decades, a variety of proposals have depicted spacecraft that are capable of completing a round-trip mission to Mars. Many, of these technical proposals can be used to build a spacecraft using today's technology. The spacecraft itself, however, is only a part of the solution for developing a successful mission. There are still many physiological and psychological challenges the crew destined for Mars must overcome. Although dozens of astronauts have been used as test subjects for physiological and psychological experiments, and preventive strategies and countermeasures have been implemented, we still do not have a lot of knowledge concerning long-term exposure to spaceflight. We can learn more about long-term exposure to a weightless environment, and how it will affect a manned mission to Mars, by simulating such a mission on the International Space Station. We can use the time spent on the station to continue with additional scientific and medical experiments to determine the effects of long-term exposure and, more importantly, develop additional (or better) countermeasures to ensure a successful mission to the Red Planet. Unsurprisingly, there are many unanswered questions about long-term exposure in space and how it can affect the crew physiologically and psychologically. Nonetheless, we have the right technology, personnel, and pioneering spirit to address these challenges, move forward, and conquer this bold goal.

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