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Review Article

Space Medicine: Ensuring The Health and Well Being of Humans in Space

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ABSTRACT

The specialty of space medicine is concerned with resolving the particular difficulties that astronauts have when traveling and exploring space. It has become increasingly important for understanding the psychological and physiological impacts of space travel as missions venture farther into the cosmos. In order to keep astronauts healthy during space travel, medications are essential. These medications can treat anything from cardiovascular problems to space motion sickness. Technologies like wearable health monitoring devices and on-demand drug manufacturing are changing astronaut healthcare as space medicine advances, with the goal of advancing both space exploration and medical knowledge on Earth. The stability of space medications is essential for preserving astronauts' health throughout prolonged trips, taking into account elements like radiation and microgravity that may affect the treatments' efficacy. While future AI applications in space medicine provide great options for enhancing astronaut health monitoring, diagnosis, and treatment, lifestyle management in space, which includes nutrition and exercise therapies, aims to reduce the health hazards associated with space travel. In the end, space medicine is essential to facilitating sustainable and safe space travel, opening the door for human habitation beyond of Earth's borders, and expanding our knowledge of the cosmos.

INTRODUCTION

Space medicine is a specialist discipline of study that focuses on the particular medical challenges that people who travel into the infinite expanse of outer space encounter. The need to learn more about the physiological and psychological effects that space travel has on the human body has grown as space exploration has developed (1). The human body undergoes several physiological changes when traveling across space. Consequently, drugs have been a prevalent and essential component of space travel ever since the first Mercury voyage in 1967 (2). The broad description of space medicine

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is "the practice of all aspects of preventative medicine, including screening, health care delivery, maintaining human performance in the extreme environment of space, and preserving the long-term health of space travellers."(3). The study of space research explores, comprehends, and uses the huge cosmos outside the borders of our world. The goal of this dynamic field is to solve the universe's secrets and realize its potential for the good of humanity through a wide range of scientific investigations, technological developments, and interdisciplinary partnerships. This field guarantees people's survival, functionality, and performance in the demanding and potentially dangerous space environment. (4) In recent years, astronauts have been increasingly at risk of experiencing some of the acute illnesses that are common on Earth as the length of human space adventures increases. To prevent physiological changes (such as cardiovascular degeneration and bone decalcification) and treat acute disorders (such as infections, kidney stones, and allergic reactions), newer medications will be introduced to manage unintentional injuries related to construction and maintenance in space stations (2). This field has experienced substantial growth in past US missions. To show that humans can live and operate in space for extended periods, focusing on overcoming the biomedical challenges associated with long-duration space vehicles, such as the impact of microgravity on human physiology, pathophysiology, pharmacodynamics, and therapy. Advances in human physiology, diagnosis, and treatment brought about by space research have the potential to completely transform healthcare by increasing its effectiveness, efficiency, and accessibility. (4)

Effects Of Space Travel on Human Physiology:

The conditions of spaceflight have a significant impact on the astronauts' physiological systems, with common and anticipated effects such as fluid redistribution from the lower to the upper body leading to head congestion, face edema (5), leg shrinkage, 10% to 15% loss of plasma volume due to increased capillary permeability of intravascular fluids into the extracellular space in the case of hypovolemia (6), decreased baroreflex sensitivity, and orthostatic intolerance (7) .Microgravity exposure causes several physiological problems that may need to be treated with medication or may change how medications work. Two phases are involved in these changes. In the initial acute stage, clear symptoms like text messages, headaches, insomnia, congestion, and back discomfort are described. For instance, during the latter adaptation phase, changes occur in bone and muscle mass and the activities of the central nervous system (CNS) (2). As a consequence of upward fluid redistribution, microgravity initially causes the heart to enlarge and increase cardiac output. Over time, cardiovascular adaptation is accompanied by a decrease in the volume of blood in circulation, cardiac output and size, arterial stiffness, atherosclerosis, myocardial fibrosis, and cardiac contractility (7). Meanwhile, we know from many studies how the physiological development of different systems occurs at this stage, such as in the cardiovascular system and the salt/water balance. A steady equilibrium is then attained around six weeks later. (Fig. 1)

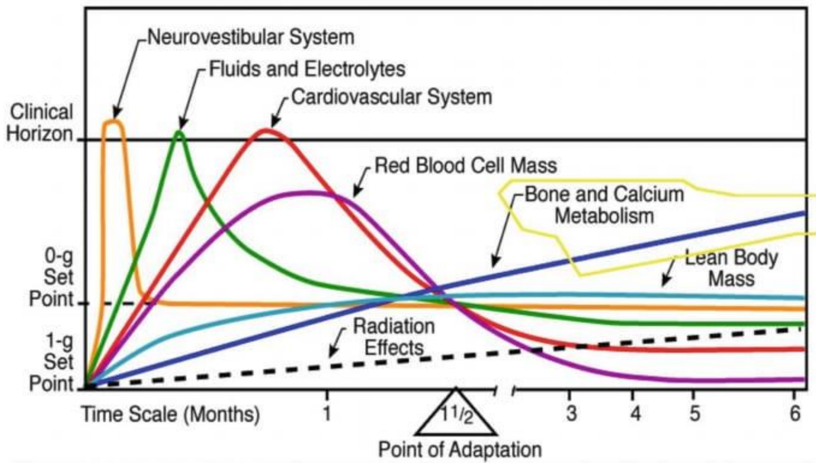

Figure 1: Temporal progression of physiological changes during adjustment to weightlessness.

The 1-g condition represents the physiological situation on Earth. The 0-g condition is a full physiological adjustment to space conditions, which probably could only be achieved by those born in space. The average astronaut takes six weeks to reach a phase of adjustment, where they have at least partially adapted to their new surroundings (8) An estimated 60% to 80% of astronauts have "space adaptation syndrome," which shows common symptoms like migraines, nausea, vomiting, skin rashes, and joint and muscle discomfort. The diagnosis of a headache is linked to dehydration, fluid shift, and elevated levels of carbon dioxide and carbon monoxide; hypoxia and radiation are linked to nausea and vomiting; immunosuppression invites opportunistic infections, pulmonary edema, low humidity, and inhaled irritants like ammonia and ethylene glycol fumes; and musculoskeletal injury is the cause of joint pain. (Fig 2) **(7)**

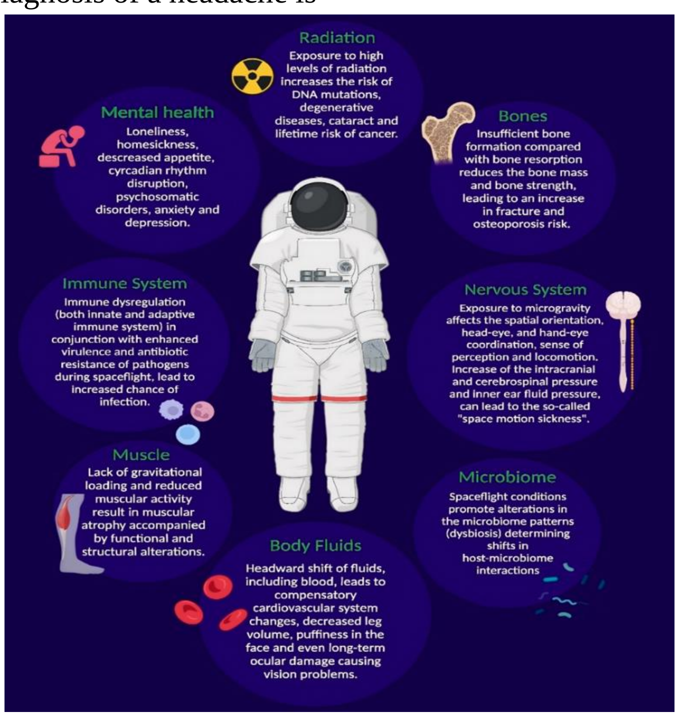

Figure 2: Symptoms Of Space Adaption Syndrome

Over half of all US astronauts said they experienced back pain during their initial days in space. Table 1 illustrates other instances of frequently reported symptoms that could have space-specific differential diagnoses. **(3)**

Table 1: Different Diagnosis in Space

Symptom	Differential diagnosis when in space
Headache	Space adaptation syndrome (SAS), Cephalad fluid shift, Raised CO_2, Carbon monoxide, Dehydration, Caffiene withdrawl.
Nausea /Vomitting	SAS, Raised CO_2, Hypoxia, Radiation illness.
Cough	Infection, inhaled foreign bodies, inhaled irritants-hydrazine, ammonia, ethylene glycol fumes, pulmonary oedema, low humidity.
Joint pain	Musculoskeletal injury, decompression sickness, trauma.

Innovation Of Space Medicine:

Innovations in space medicine are revolutionizing astronaut health and safety, especially as long-duration missions to destinations like Mars become increasingly feasible. A key focus of these advancements is the creation of on-demand drug synthesis technologies, which facilitate the production of essential medications in space, thereby reducing the risks of drug degradation in microgravity. Leading initiatives such as Pharmacy on Demand (PoD) and Chemputing enable the customized synthesis of pharmaceuticals as required. Furthermore, the integration of wearable health monitoring devices and telemedicine solutions allows for real-time health evaluations, ensuring that astronauts can access immediate medical support. Research employing tissue chips and organ-on-chip technologies is also deepening our understanding of human physiology in space, paving the way for innovative treatments and strategies to counteract the negative effects of microgravity. Together, these advancements not only aim to protect astronaut health but also have the potential to enhance medical knowledge and practices on Earth, highlighting the crucial importance of space medicine for the future of human exploration. **(9)**

Medicine Used in Space:

All commonly administered drugs are tested by astronauts before the mission assignment to detect any possible adverse effects, performance issues, and unique therapeutic effects. To assess the impact of these drugs in space, this process is useful **(2)**. The crew members' reactions to their preferred sleeping drug are evaluated before flight to identify any idiosyncratic reactions or adverse effects. To adjust for the reduced bioavailability of medications due to changes in gastrointestinal function in microgravity, varying dosages are evaluated in each individual **(10)**.Common medications that relieve the effects of spaceflight on the human body consist of medications that treat common medical indications such as space motion sickness, insomnia, circadian rhythm abnormalities, headaches, muscle and joint pain, bone resorption, congestion, nutritional deficiencies, respiratory infections, cardiac disorders, and hypersensitivity reactions. **(11)**. The most frequently used medications for sleep were temazepam (67% of all sleep aids), flurazepam (7.5%), zolpidem (10%), and triazolam (10%). Acetaminophen was the most often prescribed drug for pain (46%), followed by aspirin (33%), and ibuprofen (14%). The primary drug used for SMS was promethazine, either alone or in conjunction with dextroamphetamine. Drugs were mainly taken orally, with intranasal, intramuscular, and rectal methods coming in decreasing order of frequency. A single medication administered orally, intramuscularly, and rectally was promethazine, which was the most efficacious and had the smallest adverse effects when administered intramuscularly. **(12)**

Exploring The Stability of Medicine in Outer Space:

Space medications' stability is crucial for astronauts' health during extended missions due to the impact of microgravity, radiation, and temperature variations on their effectiveness and longevity, ensuring their well-being and safety during extended missions. Antimicrobial drugs may be less effective in space because astronauts' immune systems are weakened and radiation and gravity can change the bacteria. Investigating novel pharmaceutical formulations and using radioprotective packaging are advised to maintain drug stability. **(13)** Space medicine is a growing field that addresses human health and capacities in space, with an emphasis on operational healthcare problems including drug stability and ways to reduce the physiological effects of space travel. The stability of medications is negatively affected by the space environment, where elements like radiation, temperature, humidity, vibration, vacuum, and microgravity may reduce their potency. Current methods require changing medications on board the International Space Station (ISS) before their expiration, but longer missions need drugs that can maintain stability over time. **(14)**

Life Style Managemanage in Space:

In response to microgravity simulation research, the space agency has set forward many potential biomedical countermeasures in space **(15)**. Physical activities which are required in space are essential for preserving physical fitness and minimizing the negative effects of microgravity. Even though these procedures could be helpful, exercise could not be sufficient to prevent some microgravity effects **(16)**. Therefore, study suggests the most effective method for enhancing bone health is to combine resistance training with an antiresorptive medication (such as a bisphosphonate) **(17)**. Apart from physical activity, another possible area for optimization may be dietary changes. There is still controversy on the implementation of a caloric restriction (CR) diet in space. Data from studies carried out on land suggests that calorie restriction may help to improve vascular health; however, the associated osteoporosis and muscle atrophy might compensate for this benefit **(18)**. The only recommendation according to current standards is to consume vitamin D supplements while in space. A, B6, B12, C, E, K, biotin, and folic acid supplements are not currently advised due to the lack of evidence **(19)**. Conventional prescription drug use could not work as planned on Earth. Alternative techniques, such probiotics or synthetic biologic medicines, may therefore be taken into consideration. To find out whether these supplements relate to any health benefits in space, further study is required **(20).** There is currently little information on problems like immune system and sleep deprivation, SANS, skin, etc., although the majority of countermeasures target musculoskeletal and cardiovascular conditions. Artificial Gravity (AG) has been proposed as a suitable countermeasure for multiple systems, particularly for long-term exposure in a system having a large radius **(21)**. The main barrier was to be the significant cost increase. AG, specifically long-radius chronic AG, can be used. Further investigation is needed into the possible application of AG in prolonged space flight **(22).**

Potential Ai Application in Space:

The growing field of artificial intelligence (AI) has become an innovation in many fields, and its applications in space medicine have huge potential for improving human exploration and population of other destinations. In addition to managing specific challenges given by the dangerous conditions of space, the application of AI to space medicine provides several possibilities **(23)**.

There are many possible uses of AI in space medicine, such as:

Advancements in Risk Prediction Models:

- Animal models are utilized for predicting the risk of developing cancer as a result of exposure to ionizing radiation. **(24)**
- With the guidance of AI, a multi-omics study on flight produces new risk prediction scores. **(25)**
- Cardiovascular disease risk prediction models based on carotid-femoral pulse wave velocity measured by Doppler ultrasound or AI-guided evaluation of 3D printed tissue models **(26)**
- Risk prediction models like the modified Astro-CHARM model identify patients at risk for accelerated atherosclerosis through the combination of their CAC score with non-traditional risk factors related to space travel, such as radiation exposure, microgravity exposure, gut microbiota dysbiosis, etc. **(27)**

Preflight Screening and Inflight Health Monitoring:

- Applying smart bathroom facilities to detect imbalance in the intestinal microbiota before, during, and after flight **(28)**
- using immunological characteristics to screen for latent viral infection or reactivation, which can then serve as a biomarker to measure adaptive immune function **(29)**
- AI using facial recognition and voice analysis to screen for mental illness **(30)**
- Deep learning methods for the telediagnosis of a variety of conditions during flight (e.g., skin lesions or SANS) **(31)**
- Wearable technology utilizing AI integrated into space suits (such exoskeletons) for monitoring biodata (including blood pressure, body temperature, sleep cycle, and ECG) **(32)**
- AI detection of biomarkers based on metabolomics to monitor circadian rhythm and sleep quality **(33)**

Integrating Robotic Surgery with Telemedicine:

- Automated or remote medical treatments using robotic surgical system
- Technologies such as augmented reality and telepresence for remote healthcare guidance and consultations **(4)**

Revolutionizing Diagnosis through Medical Imaging:

- Automated medical image analysis and interpretation for early detection and diagnosis (e.g., radiology, pathology, dermatology)
- Using a computer to identify and evaluate abnormalities, lesions, or disease markers **(4)**

Advancing Healthcare with Personalized Medicine:

- personalized dosage regimens and treatment methods based on real-time health data and astronaut profiles
- Optimizing therapies and countermeasures for physiological changes induced by spaceflight **(34)**

In addition, the combination of blockchain technology with AI provides significant chances in areas such as:

- Space Object Connectivity: Decentralized, safety tracking and communication with space assets
- Satellite communication: strong and impenetrable networks for data transfer
- Protecting Data on Spacecraft: Distributed and unchanging storage of significant mission information

AI has shown promise in analysing large, complicated datasets, identifying trends, understanding medical pictures, and recommending personalized treatment for long-term conditions. For space medicine applications, such as making accurate treatment suggestions, reducing medical errors, and increasing clinical trial participation, these capabilities can be used and modified. It is expected that artificial intelligence (AI) will be essential in enhancing or supporting human abilities as space exploration moves close to establishing sustainable human settlements past Earth. For the next generation of space-born people and future space-faring crews, intelligent systems having human-like thinking, decision-making, and data-analysis skills are going to be important for our safety, health, and well-being. **(4)**

The following are some particular difficulties in integrating AI in space medicine, though:

- Adjusting to changing patient demography and spaceflight-induced physiological changes
- Ensuring privacy, security, and data integrity in separated and restricted environments
- Addressing ethical issues in crucial medical decisions, such as responsibility, openness, and human oversight **(35)**

CONCLUSION:

The safe and effective exploration of space by human beings is made possible in large part by space medicine. It covers the psychological and physiological difficulties caused on by the particular conditions of space travel, including radiation, confinement, isolation, and microgravity. Space medical advancements will be essential to the health of space travellers and future generations of space-born people as human beings explores the limits of space travel, eventually allowing for a continuous human presence throughout the universe. To improve our diagnostic capabilities while providing excellent medical treatment in the space environment, researchers must make use of modern technologies like artificial intelligence.

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