COMMENTARY

Space Medicine: The Next Frontier of Medical Education

Ethan Waisberg, MB, BCh, BAO;[1] Joshua Ong, MD;[2] Mouayad Masalkhi;[1] Andrew G. Lee, MD[3,4,5,6,7,8,9,10]

1. University College Dublin School of Medicine, Belfield, Dublin, Ireland
2. Michigan Medicine, University of Michigan, Ann Arbor, Michigan USA
3. Center for Space Medicine, Baylor College of Medicine, Houston, Texas USA
4. Department of Ophthalmology, Blanton Eye Institute, Houston Methodist Hospital, Houston, Texas USA
5. Houston Methodist Research Institute, Houston Methodist Hospital, Houston, Texas USA
6. Departments of Ophthalmology, Neurology, and Neurosurgery, Weill Cornell Medicine, New York, New York USA
7. Department of Ophthalmology, University of Texas Medical Branch, Galveston, Texas USA
8. University of Texas MD Anderson Cancer Center, Houston, Texas USA
9. Texas A&M College of Medicine, Bryan, Texas USA
10. Department of Ophthalmology, University of Iowa Hospitals and Clinics, Iowa City, Iowa USA

Correspondence:
Ethan Waisberg
University College Dublin
School of Medicine
Belfield, Dublin 4, Ireland
E-mail: ethan.waisberg@ucdconnect.ie

Conflicts of interest/funding: The other authors declare no conflicts of interest or funding.

Keywords: astronaut health; medical education; spaceflight; space medicine

Abbreviations:
NASA: National Aeronautics and Space Administration
UTMB: University of Texas Medical Branch

Received: May 31, 2023
Accepted: June 17, 2023

Abstract

Spaceflight has always been met with awe by the general public and may also have strong implications for medical training for future physicians, regardless of specialty or practice. Within the near future, the commercialization of spaceflight will lead to an unprecedented surge in travelers to space. With this increase, the understanding of space medicine and potential physiological risks of microgravity will only become more important for doctors to understand. Historically, teaching education on how the body responds to various different environments and environmental changes has been a longstanding core to medical education. Thus, education about the physiological, pathologic, and histologic changes to weightlessness over prolonged periods of time will likely provide additional insights to space medicine, as well as how medicine can be practiced here on Earth. The addition of space medicine to the medical curriculum will likely not only benefit future space medicine physicians, but also likely benefit all physicians and human health on Earth. In this manuscript, we discuss the various risks that astronauts undergo, as well as current space medicine education initiatives on Earth.

Waisberg E, Ong J, Masalkhi M, Lee AG. Space medicine: the next frontier of medical education. *Prehosp Disaster Med.* 2023;38(5):677–679.

Introduction

Within the near future, the commercialization of spaceflight will lead to an unprecedented surge in travelers to space.[1] The large increase of individuals travelling to space will create a population that is more diverse, both in terms of age and in medical comorbidities (such as vasculopathic risk factors).[2] The understanding of space medicine and potential physiological risks of spaceflight will only become more important for doctors to understand in the future.

Physiology is one of the key underpinnings of medicine, and can be investigated at a variety of levels, from cells, to organs, or the entire body. Physiology attempts to explain the mechanisms that are fundamental to human life and their associated interactions. This knowledge is essential to understand how to better treat disease states. A practical example of harnessing physiology for a treatment benefit would be the recent development of a non-invasive method of lowering intra-ocular pressure to treat glaucoma.[3] Physiology knowledge is also highly important to further understand the possible associations between diseases or conditions. For example, the recently-drawn link between idiopathic intracranial hypertension and anemia can possibly be explained by theories based on human physiology, such as anemic hypoxia.[4,5]

The altered human physiology in space provides many interesting learning points for medical students. These interesting learning points also provide practical examples of human physiology which may lead to a better understanding of these concepts by medical students. Astronauts are exposed to a wide variety of risks that have been extensively studied, including skeletal muscle atrophy, bone density loss, neuro-ophthalmic changes, and behavioral changes.[6] Astronauts are also exposed to high doses of radiation exposure from galactic cosmic rays (GCRs) and solar particle events (SPEs).[7] These forms of radiation can

doi:10.1017/S1049023X2300612X

Spaceflight Risk	Summary
Skeletal Muscle Atrophy	Astronauts have been found to have decreased muscle mass following spaceflight. The process is partly due to decreased workload in the microgravity environment, however additional research is being conducted to further understand these mechanisms.
Bone Density Loss	During spaceflight, astronauts experience a reduction in bone density due to the absence of gravity-induced mechanical loading on the skeletal system. This can lead to an increased risk of fractures and long-term bone health complications, such as osteoporosis. Studies have shown that bone loss can occur at a rate of 1%-2% per month during spaceflight, particularly in the hip and spine. Several countermeasures have been developed to mitigate this phenomenon, including exercise regimens and dietary supplementation.
Spaceflight Associated Neuro-Ocular Syndrome (SANS)	Neuro-ophthalmic abnormalities, such as optic disc edema, globe flattening, and impaired vision, are areas of SANS. Those findings have been noted in almost two-thirds of astronauts on board the space station. Numerous studies looked into the fluid shifts, altered intracranial pressure, and genetic predisposition as potential causes of SANS. Exercise routines and innovative head-down tilt positions have also been considered as potential defenses.
Behavioral Changes	Isolation, confinement, altered sleep-wake cycles, and exposure to radiation and microgravity are among the factors that can affect an astronaut's behavior during spaceflight. Studies have shown that astronauts can experience a range of behavioral changes, including mood swings, sleep disturbances, cognitive impairments, and interpersonal conflicts. These changes can affect crew morale and performance, potentially jeopardizing mission success. To mitigate these risks, NASA has developed several countermeasures, such as pre-flight training, psychological support, and maintaining communication with mission control and family members on earth. Continued research is necessary to better understand the mechanisms behind behavioral changes in space and to develop more effective countermeasures to ensure the well-being of astronauts during long-duration spaceflight.
Radiation	Radiation dosage, duration, and type impact astronauts. Acute high-dose radiation exposure can cause vomiting, diarrhea, and fatigue. Chronic low-dose exposure to radiation in space can cause cancer, cardiovascular, and neurological impairments. Space radiation may cause DNA mutations leading to cancer. Astronauts therefore may have higher rates of breast, colon, and leukemia. To prevent long-term health issues, astronauts are evaluated for radiation exposure. Astronauts wear radiation-blocking lead and polyethylene. Solar flares and other radiation sources are considered when designing spacecraft and shelters.

Table 1. Summary of Various Physiological Spaceflight Risks
Abbreviations: SANS, Spaceflight Associated Neuro-Ocular Syndrome; NASA, National Aeronautics and Space Administration.

not only cause cellular damage, but also potentially cause significant damage to organs. For example, from an ophthalmic point of view, increased radiation to the eye can cause cataracts, cotton-wool spots, radiation maculopathy, and radiation retinopathy.[8] Table 1 provides an overview of these physiological and pathological risks that astronauts face in this extreme environment.

Following exposure to microgravity, hypovolemia can occur. This can occur due to a multitude of factors, including: (1) fluid shifts into the interstitial space (due to a decrease in transmural pressure); (2) alterations in urine output; (3) decreased fluid intake; and (4) erythrocyte loss.[9] These same factors can be responsible for hypovolemia terrestrially, and this can serve as an additional learning opportunity for medical students to grasp these concepts.

Microgravity in space can lead to rapid increase in muscle deterioration due to a lesser force exertion required without the terrestrial gravitational field. As a countermeasure, astronauts have detailed exercise regimens that focus on resistance training. Muscle wasting is a common issue terrestrially, seen in nearly every patient in the hospital, and understanding how to combat this issue is essential to improve patient outcomes during long hospital stays.

Current Space Medicine Initiatives for Future Physicians

Space medicine education continues to accelerate towards training future physicians to understand and manage various risks during prolonged microgravity. There are multiple education pathways that are involved in different levels of training, including medical school educational courses, elective rotations, and board-certified space medicine residencies for flight surgeons. In this section, we provide an overview of all these medical education pathways.

Programs for Residents

The United States Air Force School of Aerospace Medicine (USAFSAM; Wright-Patterson Air Force Base, Dayton, Ohio USA) offers the Flight Medicine Residency Program, which trains medical professionals in the management of aircrew members and the medical facets of aviation. The course offers rotations in subjects including aircraft physiology, aerospace medicine, and operational medicine and is available to both Air Force medical personnel and civilian physicians. Also, residents engage in studies in aeronautical medicine.

Programs for Rotation

The National Aeronautics and Space Administration (NASA; Washington, DC USA) has a curriculum called the Space Medicine Rotation Program that trains medical professionals on the medical effects of spaceflight, including radiation, isolation, and microgravity. Medical students, residents, fellows, doctors, and other health care professionals can all enroll in the program. Participants finish a one-month rotation at the NASA Johnson Space Center in Houston, Texas USA where they collaborate with NASA flight surgeons and take part in mock medical situations seen during space travel.

Course Offerings

The University of Texas Medical Branch (UTMB; Galveston, Texas USA) offers a Space Radiation Course Program that examines how space radiation affects people's health and safety in space. The training is intended for those who work in the field of space radiation protection, including medical professionals, radiation safety officials, and others. Participants gain knowledge about the biological impacts of radiation exposure, the sources of space radiation, and methods for reducing radiation dangers in space.

Also, UTMB offers a course on the fundamentals of aerospace medicine, which includes information on space medicine, aviation safety, and the physiological impacts of flying. Medical students, residents, fellows, doctors, and other health care professionals with an interest in the subject of aerospace medicine are all intended audience members for the course. Participants gain knowledge of the numerous medical standards and criteria for aircrew personnel, as well as the medical difficulties that come with flying and space travel.

A third course option is the University of Colorado School of Medicine (Aurora, Colorado USA) offers a course program called Space Medicine and Extreme Environment Physiology that covers both the physiological effects of extreme environments like high-altitude, deep-sea diving, and polar exploration as well as the medical aspects of spaceflight. The training is intended for medical professionals, scientists, and engineers who work on the development and management of space missions as well as for people who want to work in space medicine. Participants gain knowledge of how severe settings affect their bodies and minds as well as the medical issues that must be considered while designing and carrying out space missions.

At the home institution of one of the authors (AGL), Baylor College of Medicine (Houston, Texas USA) provides a Space Medicine Pathway course within the Center for Space Medicine. The program consists of two didactic electives and a space medicine research elective. To our knowledge, this is currently the only in-course pathway in the world for space medicine. This pathway is extremely popular and enjoyed by students, demonstrating the growing need for and interest in space medicine.

Conclusion

All things considered, the addition of space medicine to the medical curriculum would not only benefit future space medicine doctors, but also may potentially benefit future doctors as a whole. We look forward to humanity reaching new frontiers, in both medicine and in spaceflight in the coming years.

References

1. Waisberg E, Ong J, Paladugu P, et al. Challenges of artificial intelligence in space medicine. *Space: Science & Technology.* 2022;2022:1–7.
2. Ong J, Tavakkoli A, Zaman N, et al. Terrestrial health applications of visual assessment technology and machine learning in spaceflight associated neuro-ocular syndrome. *NPJ Microgravity.* 2022;8(1):37.
3. Waisberg E, Ong J, Masalkhi M, Lee AG, Berdahl J. Wearable, dropless reduction in intraocular pressure as an emerging therapy for glaucoma. *Eye (London, England)*. 2023.
4. Yu CW, Waisberg E, Kwok JM, Micieli JA. Anemia and idiopathic intracranial hypertension: a systematic review and meta-analysis. *J Neuro-Ophthalmology.* 2022;42(1): e78–e86.
5. Waisberg E, Yu CW, Sverdlichenko I, Micieli JA. New onset severe anemia and fulminant idiopathic intracranial hypertension. *Canadian J Neurological Sciences.* 2022;49(5):713–715.
6. Patel ZS, Brunstetter TJ, Tarver WJ, et al. Red risks for a journey to the red planet: the highest priority human health risks for a mission to Mars. *NPJ Microgravity.* 2020;6(1):33.
7. Onorato G, Di Schiavi E, Di Cunto F. Understanding the effects of deep space radiation on nervous system: the role of genetically tractable experimental models. *Frontiers in Physics.* 2020;8:362.
8. Waisberg E, Ong J, Masalkhi M, Lee AG, Berdahl J. Anatomical considerations for reducing ocular emergencies during spaceflight. *Irish Journal of Medical Science.* 2023. Epub ahead of print.
9. Diedrich A, Paranjape SY, Robertson D. Plasma and blood volume in space. *Am J Med Sci.* 2007;334(1):80–86.