MedCrave
Step into the World of Research
Aeronautics and Aerospace Open access Journal

Review Article
Open Access
CrossMark

Effects of space travel on the immune system

Abstract

As humankind prepares for long-duration missions to the Moon and Mars, understanding the physiological effects of space travel on astronauts becomes increasingly critical. One of the most significantly affected systems is the immune system, which plays a crucial role in maintaining human health. This review explores the multifaceted impacts of spaceflight on immunity, including disruptions caused by microgravity, radiation, and confinement. These factors collectively contribute to immune dysregulation, including impaired function of natural killer cells, macrophages, and T-cells, as well as increased inflammatory responses. Evidence also shows a higher rate of latent viral reactivation during missions, such as Epstein-Barr and varicella-zoster viruses. By synthesizing findings from recent experiments and missions, this article highlights the vulnerabilities of the immune system in space and underscores the need for targeted countermeasures to protect astronaut health on future deep space missions.

Keywords: space travel, spaceflight, immunity, microbial environment, spacecraft

Volume 9 Issue 3 - 2025

A Mardon,[1] K Pham,[1] J Patel,[1] P Johnson,[1] JC Johnson,[1] JL Leong-sit,[1] E Hodgson,[1] C Mardon,[1] Y Khalid,[1] J Banks,[1] S Zaman,[2] Z Hassan,[2] J Harline,[3] H Chaudhry,[4] A Matthew,[5] P Rahimpoor-Marnani[6]

[1]University of Alberta, Canada
[2]University of Toronto, Canada
[3]Carleton University, Canada
[4]Toronto Metropolitan University, Canada
[5]McMaster University, Canada
[6]York University, Canada

Correspondence: K Pham, University of Alberta, Canada

Received: June 30, 2025 | **Published:** September 04, 2025

Introduction

The immune system is an essential part of the human body that plays a vital role in maintaining homeostasis by protecting it against foreign invaders. Over millions of years, the immune system has evolved into a robust defence mechanism capable of protecting humans against pathogens which have also been evolving ways to evade and defeat the immune system in an arms race which has been going on for millions of years. Long-term space exploration missions to the moon and Mars are the next frontiers of space exploration. A large part of the success of these missions will require maintaining the health of astronauts which undergo extreme conditions during their voyage.[1] The effects of space travel on the immune system have been extensively studied. In this article we will discuss some of the impacts which space travel may have on the human immune system.

Immunity

The immune system can be split into two parts, the innate immune system and the adaptive immune system.[2] Innate immunity is the first line of defense against pathogens and the response mounted is the same each time.[3] When the innate immune system is not enough to clear an infection, the adaptive immune system comes into play when lymphocytes are activated by antigens. Adaptive immune responses are specific to a pathogen and can be "remembered" by memory T and memory B cells. This means that the next time the immune system encounters that same pathogen, the body is prepared and will be able to clear the infection more rapidly by activating those memory cells.[3]

Challenging conditions in space

To understand the effects of space travel on the immune system, it is important to first understand the challenges that come with it. There are many risks to human health associated with spaceflight such as radiation, isolation, microgravity and closed/isolated environments.[1,4]

Microbial environment in space

Studying the microbial environment inside of International Space Station (ISS) allows us to examine how microbes might grow and proliferate in a lunar or Martian base. The ISS experiment EXTREMOPHILES has shown that the microbiome of the ISS is primarily composed of human-associated microbes, with bacteria from the genera streptococcus, Corynebacterium, Lactobacillus, Acinetobacter and Staphylococcus being the most common.[5] Studies have also shown that some microbes that are grown in space have greater virulence compared to their earth-grown counterparts.[6]

Effect of space travel on the immune system

Microgravity

Microgravity has been shown to be particularly detrimental to the functioning of the immune system. Studies have shown that immune systems exposed to microgravity display similar characteristics to that of immune senescence which is the deterioration of immune systems with age.[7] During actual spaceflights, NK cells have been shown to have impaired cytotoxic function. Macrophages, cultured on spaceflights were found to have decreased motility, a decreased ability to present antigens, and lower expression of CD18, CD36, ICAM-1 and MHC class II, which are essential for coordinating immune responses. Moreover, some cell lines of macrophages grown on spaceflights were found to have reduced cell volumes.[8]

Inflammation

Space travel has been shown to increase inflammation responses in astronauts.[4] Cortisol, which is a hormone involved in regulating inflammation, tends to spike in astronauts during spaceflight.[9] While inflammation is an integral part of the immune response, excessive inflammation can cause issues such as tissue death and damage to DNA.[10]

Isolation

The isolating environment inside of a confined spacecraft poses a risk to the health of astronauts. Not only does an isolating environment pose a psychological risk,[11] It can also increase the risk of spreading infectious diseases. While the most obvious factor would be that diseases spread more easily within small, enclosed spaces, another factor that contributes to the spread of diseases is the stress from being in such a space causes the immune system to become weaker.[12]

Latent virus reactivations

Latent viruses are viruses which can switch between the 'latent' phase where it is not replicating to the lytic phase where it is actively replicating; by doing this, some viruses can effectively 'hide' from the immune system,[13] when a virus reactivates, it means that it is going from the latent phase to the lytic phase. Due to the weakening of the immune system during spaceflight, latent virus reactivations appear to be more common in astronauts. Studies have found that the saliva of astronauts contained viral particles of the Epstein-Barr virus (EBV), Herpes simplex type 1 virus (HSV), and the varicella-zoster virus (VZV) (Table 1).[14]

Table 1 Incidence of viral shedding in astronauts during space shuttle and international space station missions

Virus	Total shedding rate in astronauts	Main finding
Epstein Barr Virus	90%	Astronauts demonstrated a 10x increase in viral load during spaceflight.[15]
Varicella Zoster Virus	60%	VZV viral load increases with the total time spent in space.[15]
Herpes Simplex Virus-1	8%	Cases of HSV-1 reactivation in astronauts are very low.[15]

Data include Epstein–Barr virus (EBV), Varicella Zoster virus (VZV), and Herpes Simplex Virus-1 (HSV) detection via PCR assays in saliva, blood, or urine samples.[15]

Long duration missions

Substantial evidence confirms persistent immune dysregulation occurs during long-duration missions, impacting both innate and adaptive responses. The following table shows the effects of long-term space missions on the immune systems of astronauts (Table 2).

Table 2 Study Findings of effects of time spent in space on the immune system of astronauts

Study parameter	Time frame	Findings
T-Cell profliferation[16]	184 days	Impaired thymus function leading to continually decreasing T-Cell development during time in space.
NK Cell function[17]	340 days	Impaired NK cytotoxicity and reduced function.
Bone demineralization[18]	6 months	Loss of 8-12% of bone density over a 6 month stay or about 1-2% loss per month which could influence immune cell proliferation.

Implications

The immune dysregulation observed during spaceflight has significant implications for the health and performance of astronauts, particularly during long-duration missions to the Moon, Mars, and beyond. Increased susceptibility to infection, and reactivation of latent viruses could compromise crew safety and thus, the success of missions. Furthermore, chronic inflammation and reduced immune surveillance may increase long-term risks for conditions such as cancer or autoimmune disorders after returning to Earth. In addition to these effects, the immune effects could compound with other physiological and psychological effects such as social isolation.[11] These findings highlight the need for countermeasures, such as immune monitoring, nutritional and pharmacological interventions. As humanity progresses towards permanent habitation beyond Earth, understanding and mitigating immune dysfunction in space will be critical for the sustainability of human life in extraterrestrial environments.

Counter measures

Pre-flight and environmental controls

Rigorous infection-control protocols remain the first line of defense. NASA's Health Stabilization Program (pre-launch quarantine) and ISS habitat hygiene (HEPA filters, water pasteurization, regular surface/air microbiological monitoring) dramatically lower pathogen exposure.[19] Extensive medical screening (CBC, CRP, allergy panels, nasal MRSA swabs, Helicobacter screening, etc.) is performed before flight. While not directly treating immune dysregulation itself, these measures reduce secondary stressors and the risk of infection during missions.[19]

Psychosocial stress mitigation

Behavioral health countermeasures target the immune-suppressive effects of stress, sleep loss and circadian disruption. Astronauts have regular private psychology sessions (e.g. video conferences every two weeks), guaranteed family communications, personalized care packages and fatigue management protocols onboard.[19] These interventions minimize chronic elevations of cortisol and catecholamines, which are known to blunt antiviral T-cell responses.[19]

Real-time immune monitoring

Novel in-flight diagnostics are being deployed to guide countermeasures. For example, ESA's *Immunity Assay* uses a special reaction tube to perform a cytokine-release assay on the ISS.[20] This lets crew collect and stimulate blood in orbit, then downlink results. Such technology provides immediate insight into a crewmember's immune status (e.g. antigen-response capacity under stress), enabling early intervention. Real-time monitoring of immune cell counts, cytokines and functional responses will be critical for long missions, so that countermeasures can be adjusted dynamically to each astronaut's needs.[20]

Conclusion

The effects of space travel on the human immune system are vast and pose a significant challenge to human health. Microgravity, isolation among other challenging conditions in space all contribute to the potential for immune dysregulation in space travellers. These conditions not only pose a short-term risk to the health of travellers but also may have long-term health effects. Therefore, it is important to understand the conditions of space travel which affect the immune system.

Future directions

In order to mitigate the effects of space on the immune system, more research could be done to:

a) Identify genes which are important and make individuals more or less susceptible to immune dysregulation in space.

b) Exploring the role of the human microbiome as it relates to immune function in space

c) Study the effects of long-duration space travel on the immune system for missions for semi-permanent or permanent habitation of other celestial bodies in the solar system.

Acknowledgements

None.

Conflicts of interest

The author declares that there are no conflicts of interest.

Funding

None.

References

1. NASA. 5 Hazards of Human Spaceflight. *NASA*. 2024.
2. Institute for Quality and Efficiency in Health Care (IQWiG). In brief: The innate and adaptive immune systems. In: InformedHealth.org. NCBI Bookshelf. 2023.
3. Buchheim J, Matzel S, Rykova M, et al. Effects of spaceflight on the human immune system. *Front Physiol*. 2019;10:85.
4. Marchal S, Choukér A, Bereiter-Hahn J, et al. Challenges for the human immune system after leaving Earth. *NPJ Microgravity*. 2024;10(1):106.
5. Mora M, Wink L, Kögler I, et al. Space station conditions are selective but do not alter microbial characteristics relevant to human health. *Nat Commun*. 2019;10(1):3990.
6. Wilson JW, Ott CM, Bentrup KHZ, et al. Space flight alters bacterial gene expression and virulence and reveals a role for global regulator Hfq. *Proc Natl Acad Sci U S A*. 2007;104(41):16299–16304.
7. Hicks J, Olson M, Mitchell C, et al. The impact of microgravity on immunological states. *Immunohorizons*. 2023;7(10):670–682.
8. ElGindi M, Sapudom J, Ibrahim IH, et al. May the force be with you (or not): The immune system under microgravity. *Cells*. 2021;10(8):1941.
9. Capri M, Conte M, Ciurca E, et al. Long-term human spaceflight and inflammaging: Does it promote aging? *Ageing Res Rev*. 2023;87:101909.
10. Hannah Six. Novant Health. Chronic inflammation: Why it’s harmful, and how to prevent it. *Novant Health Healthy Headlines*. 2025.
11. Yin Y, Liu J, Fan Q, et al. Long-term spaceflight composite stress induces depression and cognitive impairment in astronauts—insights from neuroplasticity. *Transl Psychiatry*. 2023;13(1):310.
12. Alotiby A. Immunology of stress: A review article. *J Clin Med*. 2024;13(21):6394.
13. Traylen CM, Patel HR, Fondaw W, et al. Virus reactivation: A panoramic view in human infections. *Future Virol*. 2011;6(4):451–463.
14. Mehta SK, Laudenslager ML, Stowe RP, et al. Latent virus reactivation in astronauts on the International Space Station. *NPJ Microgravity*. 2017;3(1):11.
15. Rooney BV, Crucian BE, Pierson DL, et al. Herpes virus reactivation in astronauts during spaceflight and its application on Earth. *Front Microbiol*. 2019;10:16.
16. Benjamin CL, Stowe RP, St John L, et al. Decreases in thymopoiesis of astronauts returning from space flight. *JCI Insight*. 2016;1(12):e88787.
17. Blaber EA, Agha HN, Baker LF, et al. NK cell function is impaired during long-duration spaceflight. *J Appl Physiol*. 2018;125(5):842–853.
18. David W, Andre K, Chiaki M, et al. Acclimation during space flight: effects on human physiology. *CMAJ*. 2009;180(13):1317–1323.
19. Brain EC, Alexander C, Richard JS, et al. Immune system dysregulation during spaceflight: potential countermeasures for deep space exploration missions. *Front Immunol*. 2018;9:1437.
20. Judith IB, Matthias F, Michele B, et al. Monitoring functional immune responses with a cytokine release assay: ISS flight hardware design and experimental protocol for whole blood cultures executed under microgravity conditions. *Front Physiol*. 2024;14:1322852.

Citation: Mardon A, Pham K, Patel J, et al. Effects of space travel on the immune system. *Aeron Aero Open Access J*. 2025;9(3):147–149.
DOI: 10.15406/aaoaj.2025.09.00232