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Human Evolution, Microgravity, and Challenges Colonizing Mars

Leonard Mermel

INTRODUCTION: Human colonization of Mars has captured the imagination of many. However, the challenges posed are immense. In microgravity, changes in human physiology, immune dysregulation, alterations of our microbiome, and enhanced virulence of various microbes are some of the barriers that stand in the way of a successful endeavor. Countermeasures can be brought to bear, but it remains unclear if success of such a mission in the foreseeable future is realistic or fanciful.

KEYWORDS: spaceflight; Mars mission; microgravity; astronaut health.

Mermel L. *Human evolution, microgravity, and challenges colonizing Mars*. Aerosp Med Hum Perform. 2024; 95(9):720–721.

All of life on Earth evolved under the influence of gravity. Over the millions of years of evolution resulting in the emergence of *Homo sapiens*, our microbiome has been shaped by organisms ingested, inhaled, or touched.[1] Most of the diversity in the gastrointestinal microbiome occurs in the first year of life,[2] and the interaction between the gastrointestinal microbiota and cells lining our gastrointestinal tract early in life are essential for normal development of the immune system leading to immune homeostasis.[3] This interaction entrains our immune system to favorably respond to invading pathogens and, at the same time, minimize the development of autoimmune diseases. All of this occurs under the influence of gravity on Earth. However, when exposed to microgravity, the human microbiome is altered[4] and such perturbation of the microbiome may have potentially deleterious consequences.[5]

On April 24, 2024, "colonizing Mars" yielded about 930,000 results as a Google search term, and NASA, along with various companies such as SpaceX and the Mars One Foundation, are seeking volunteers for such a one-way mission. Prolonged human exposure to microgravity in transit and on Mars, as well as associated radiation exposure, has profound effects on human health at the physiological and genomic levels.[6] Immune system dysregulation occurs when humans are exposed to microgravity,[7] while some bacteria become hypervirulent.[8] As such, getting to Mars safely requires various countermeasures.[9,10] Additional countermeasures should be implemented, such as use of artificial gravity to mitigate immune disruption during prolonged spaceflight.[4,11] Assuming humans arrive safely and attempt to colonize Mars, there will be unexpected consequences. Since the microbiome in microgravity is altered,[4] such changes may disrupt human immune homeostasis leading to the possibility of uncontrolled infections and/or autoimmune disease.[5]

A one-way Mars mission with the aim of colonization may be a successful endeavor at some time in the distant future, but it may be a fool's errand now. Although human colonization of Mars certainly captures our imagination, the risks posed are not inconsequential. We know that 340 d in space leads to altered and, at times, irreversible ocular changes, reduced body mass, genomic instability, transcriptional and metabolic changes, DNA methylation changes involved with immune and oxidative stress-related pathways, changes in the gastrointestinal microbiome, and cognitive decline, among other changes in the human physiology that evolved under the constraints of gravity on Earth.[6] As of this time, no mammals have been born in space, although embryonic development has been studied. It is unclear how fertilization and the forming of a placenta would occur in microgravity, and the challenges of successful reproduction in space has been reviewed elsewhere.[12]

From the Rhode Island Hospital, Providence, RI, United States.

This manuscript was received for review in April 2024. It was accepted for publication in May 2024.

Address correspondence to: Dr. Leonard Mermel, 593 Eddy St., Providence, RI 02903, United States; lmermel@lifespan.org.

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DOI: https://doi.org/10.3357/AMHP.6475.2024

If a baby is born on Mars,[12] it will not be exposed to the microbes in air, water, and food found on Earth. The microbiome that develops will not benefit from the millennia of such exposure on Earth during human evolution, the consequences of which are unforeseen. In addition to microgravity adversely impacting cardiovascular and neurological function, as well as bone and muscle loss, the exposure to increased levels of radiation on Mars will have additional adverse effects ranging from increased risk of cancer to reduced half-lives of drugs that might be used to treat infections, cancer, etc.[13] Going one step further, if attempted procreation on Mars was successful and future generations came back to Earth, they would be exposed to ubiquitous microorganisms they would ingest, inhale, and touch. Their immune systems would not be trained to respond appropriately, potentially leading to invasive infections or triggering autoimmune responses. More obvious difficulties such as ambulation would be a formidable challenge.

In sum, the totality of data suggests that attempted colonization of Mars may be an unwise mission for the foreseeable future. However, it is hoped that continued research will improve the safety of long-term exposure to the space environment and expand the possibilities of successful human space exploration.

ACKNOWLEDGMENTS

Financial Disclosure Statement: The author has no competing interests to declare.

Author and Affiliations: Leonard Mermel, D.O., Sc.M., Division of Infectious Diseases, Rhode Island Hospital, Providence, RI, United States.

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