The Biological Problems of Space Travel

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Colonel Richard Covey is a former National Aeronautics and Space Administration (NASA) astronaut who retired in 1994 and made many notable achievements during his time with the space agency. Covey was born in 1946 in Arkansas. He received his Bachelor of Science in Astronautical Engineering from the United States Air Force Academy in 1968 and his Master of Science in Aeronautics and Astronautics from Purdue University in 1969.

Covey is a member of the American Institute of Aeronautics and Astronautics, the Air Force Association, and the Association of Space Explorers to name a few. He has also received many awards, including but not limited to the Department of Defense Distinguished Service Medal, the Department of Defense Superior Service Medal, the NASA Outstanding Leadership Medal, and the American Institute of Aeronautics and Astronautics Haley Space Flight Award for 1988.

As of August 1, 1994, Colonel Covey retired from NASA and the Air Force. He had served on four space flight missions and logged over 646 hours in space.[1] Over the years, NASA has been concerned about the biological and health impacts of time spent in space by astronauts like Colonel Covey. These complications can include problems with metabolism and protein synthesis, muscles, and the amount of radiation that is accumulated from time spent in orbit that could potentially be combatted with more research and advancement in current technology.

Figure 1: The STS-26 Return to Flight crew are, in the back row from left to right: Mission Specialist Mike Lounge, Mission Specialist David C. Hilmers, Mission Specialist George D. Nelson. Front row: Pilot Richard O. Covey and Commander Frederick H. Hauck. The crew is pictured wearing their orange Launch and Entry Suits (LES). The mission emblem is displayed in the background. Source: NASA, CC BY-SA. https://commons.wikimedia.org/wiki/File:The_STS-26_Return_To_Flight_Crew_-_GPN-2000-001174.jpg#/media/File:The_STS-26_Return_To_Flight_Crew_-_GPN-2000-001174.jpg

The -Omics

Genomics

By sequencing the genome, problems in the other -omics are able to be seen more clearly. This is why NASA created their GeneLab database; they wanted to collect as much data as possible on those who had been flown to space or experienced similar stressors in order

[1] NASA, "Biographical Data: Richard O. Covey," September 2007, https://www.nasa.gov/sites/default/files/atoms/files/covey_richard.pdf.

to provide access to this information.[2] The GeneLab database is proof that changes in the transcription or translation in our bodies are able to make a significant impact on the way we are able to function.

Transcriptomics

Transcriptomics is the study of all the RNA transcripts in our bodies. Silveira and his colleagues link the stresses seen in the muscles, tissues, and mitochondria to changes in the RNA.[3] These changes in the RNA can cause anywhere from minor effects to disastrous consequences for the astronaut depending on how the changes affect protein folding and function.

Figure 2: Astronauts experiencing zero gravity. Extended periods of time spent in zero gravity can lead to muscular atrophy.

Proteomics

In NASA's Twins Study, a set of male twins, one on a space flight for a year and one grounded, were analyzed via a systems biology approach to determine the effects of space travels on the -omics. Their -omics were analyzed pre-flight, in flight, and post-flight.[4] It was found and confirmed by Silveira and his colleagues that alterations in ribosomal assembly and translational pathways led to changes in maintaining the functionality of the proteome, which is the entire scope of all the proteins in any given cell, tissue, or organism.[5]

Metabolomics

In a study done by Silveira and colleagues, it was found that mitochondrial dysfunction was a prominent phenotype in those engaging in space travel. They found that the levels of metabolites associated with the mitochondria and nuclear DNA were altered. They also found traces of oxidative stress by increased urinary markers. Previous to this, NASA had found similar results during their Twins Study, ensuring that mitochondrial dysfunction is a contributor to biological complications in space.[6] The implications of an altered metabolism can lead to a decrease in energy for the individual.

Muscular Atrophy

It is a well-known fact that an astronaut's muscles are weaker after spending extensive hours in space. This is due to the loss of gravity experienced in space, which allows the heart to not have to pump blood as hard, thus leading to deoxygenation of the muscles.

In a study done by Grimm and colleagues in 2016, it was reported that calcium is released from the bones during spaceflight, which can

[2] Daniel C Berrios et al., "NASA GENELAB: Interfaces for the Exploration of Space Omics Data," *Nucleic Acids Research* 49, no. D1 (October 20, 2020),https://doi.org/10.1093/nar/gkaa887.
[3] Willian A. da Silveira et al., "Comprehensive Multi-Omics Analysis Reveals Mitochondrial Stress as a Central Biological Hub for Spaceflight Impact," *Cell* 183, no. 5 (November 25, 2020): https://doi.org/10.1016/j.cell.2020.11.002.
[4] Francine E. Garrett-Bakelman et al., "The NASA Twins Study: A Multidimensional Analysis of a Year-Long Human Spaceflight," *Science* 364, no. 6436 (April 11, 2019),https://doi.org/10.1126/science.aau8650.
[5] Da Silveria et al., "Comprehensive".
[6] Garrett-Bakelman et al., "The NASA Twins Study…"

cause detrimental effects to the individual. It was also found that the Wnt-β-catenin signaling pathway, a known oncogenic pathway, is activated and can lead to bone degradation during space flight. [7]

Effects of Radiation

As space flight durations increase, astronauts accumulate radiation damage. The radiation damage accrued during spaceflight is similar to that accrued on Earth but is more harmful due to their closer proximity to the sun. Prolonged radiation exposure can potentially delete bases within the DNA, causing mutations. These mutations can either be incredibly harmful or have no effect depending on what has been changed in the DNA. If these mutations cause major consequences to the cell, DNA repair mechanisms are initiated. New technologies are being made to prevent the complications discussed so that space travel can be safer for astronauts. [8]

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[7] Daniela Grimm et al., "The Impact of Microgravity on Bone in Humans," *Bone* 87 (March 24, 2016): 44-56, https://doi.org/10.1016/j.bone.2015.12.057.

[8] Satoshi Furukawa et al., "Space Radiation Biology for 'Living in Space,'" *BioMed Research International* 2020 (2020): 1–25, https://doi.org/10.1155/2020/4703286.

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