NASA-Supported Research Illuminates Effects of Microgravity on Human Immune System

"They can send a man to the moon but they can't cure the common cold." Research on space shuttle astronauts is not only adding to scientific understanding of the effects of space flight on the human immune system, but may ultimately help explain why healthy people get viral infections like colds.... and suggest strategies for strengthening the immune system to prevent these common illnesses.

When you come down with a cold or a flu-like infection, you feel miserable and you may have to take a day or two off from work. It's unpleasant and inconvenient but usually not disastrous. However, if an astronaut comes down with a cold or other viral illness on the eve of a space mission—or, worse yet, during a mission—the consequences are potentially serious.

"Minor illnesses can have a significant operational impact if they affect a crew member's ability to do his or her job," says Clarence F. Sams, Ph.D., an immunologist at NASA Johnson Space Center (JSC) in Houston. An astronaut with a cold or a stomach bug could not, for example, don a space suit to perform a space walk, since congested nasal and ear passages would impair the inner ear equalizing of pressure required for space walks. Vomiting in a space suit would be very hazardous. Delay of a mission because of a crew member's illness would be costly and disruptive.

Although astronauts are generally extremely healthy people, like anybody else they are vulnerable at times to stress-related infection. "All of us, by the time we're 30, carry dormant viruses that can cause health consequences when they flare up under stress," says Sams. " The concern is that these viruses could reactivate under the physical and psychological stress of a space mission." These concerns have received support from recent studies by Dr. Duane Pierson of JSC, which indicate increased amounts of herpes virus is shed during space flight.

The Immune System in Space

Studies conducted in astronauts during and immediately after space flight have demonstrated that space flight alters some aspects of the immune system—the complex network of organs, vessels, and highly specialized cells that protects the body from infection.

"The immune system is highly regulated," says Sams. "It has multiple components that communicate with each other using chemical signals." Balance among the system's components is essential for a coordinated response to a threat of infection. Suppression of any aspect of the system decreases its ability to mount the most effective immune response.

U.S. astronaut Dr. Shannon Lucid is immunized by cosmonaut Yuri Usachev during the Mir 21 mission.

"We are interested in understanding precisely how the immune system is regulated and whether shifts in that regulation during space flight might have long-term health effects, such as altered susceptibility to allergies, autoimmune disease, malignancy, or infections during flight," explains Sams. For example, is there any interaction between immune system changes and the space radiation environment that might lead to a greater risk of malignancy?

Vaccination on Mir

Experiments conducted by Sams and his colleagues suggest that the so-called humoral arm of the immune system—which produces antibodies that help to recognize foreign invaders—functions normally in space. Five American astronauts were immunized with a commercially available vaccine while aboard the Russian space station Mir. The vaccine challenges the immune system to produce antibodies that are unique and that can be measured. Blood samples were taken at intervals for several weeks after the vaccination. When the astronauts returned to Earth, the blood samples were tested for antibodies that would indicate a response to the vaccine. Control subjects on the ground also received the vaccine and were tested for antibodies.

"The response to the in-flight vaccination appeared to be normal," says Sams. "We did not see any dramatic problems or an immune system collapse, which some people had thought might happen."

Immune Cell Levels During Space Flight

Sams and his associates were the first researchers to study levels of circulating white blood cells—the infantry of the immune system—in astronauts during flight. In previous studies, investigators had examined levels of these cells before the flight and immediately after the flight. It was assumed that the postflight readings, which showed altered levels of several types of white blood cells, represented levels in effect during flight.

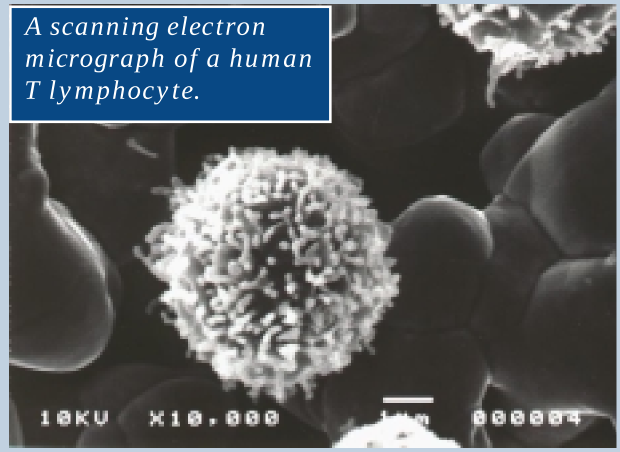
Twenty-four hours before crew members returned to Earth after several months in space, says Sams, their levels of circulating white blood cells "look like they did preflight. Immediately postflight they are very different, but within a few days they return to the preflight pattern."

This suggests that the altered cell levels observed immediately postflight are an acute response to re-entering Earth's gravity. Technical constraints have so far prevented a study of astronauts' levels of circulating white blood cells right after going into space, but Sams hypothesizes that early in-flight levels would closely resemble the immediate postflight readings.

"It's likely that a burst of changes in the circulating cells occur as their bodies adapt to microgravity. After a week or so, their bodies get used to the new physical environment and the levels return to normal. When they return to Earth, there is another burst of changes as their bodies re-adapt to Earth's gravity."

Space Flight Effects on Single T Cells

In another series of experiments, Sams and his colleagues are attempting to better understand the effect of microgravity on the activation of a type of white blood cell that is critical to a well-functioning immune system. These experiments have been performed on two space shuttle missions using Biorack, a facility developed by the European Space Agency to study single cells, plant seedlings, and small invertebrate animals in space.



A scanning electron micrograph of a human T lymphocyte.

T lymphocytes, or T cells, coordinate the body's overall immune response and attack invading viruses and malignancies. In the body, when a healthy immune system detects an invader, T cells are stimulated to reproduce rapidly and support the immune response. In Biorack, the investigators activated T cells using three different methods of stimulation.

They found, as others have also found, that the response to the chemical signals that "turn on" the T cells—stimulating them to begin reproducing rapidly—was suppressed in space. "Microgravity inhibited some of the steps necessary for the cells' activation," says Sams. He and his team are now trying to identify the mechanisms responsible for this breakdown in the T-cell activation process. Results suggest the problem may lie in integration of early signal events that lead to the activation of the T cells.

Much immunology research, Sams notes, is focused on understanding and developing better treatments for severe immune disorders such as AIDS. More research is needed which focuses on the effects of changes in the immune system of healthy individuals under stress.

Knowledge gained from this research could, he says, ultimately help to explain what makes people vulnerable to many disorders in which the immune system plays a role—from rheumatoid arthritis to allergies and the common cold. That understanding could, in turn, suggest strategies for strengthening the immune system to better resist these disorders.

References

1. Hashemi BB; Penkala JE; Vens C; Huls H; Cubbage M; Sams CF. T cell activation responses are differentially regulated during clinorotation and in spaceflight. *The FASEB Journal* 13(14):2071-82, 1999.
2. Crucian BE; Cubbage ML; Sams CF. Altered cytokine production by specific human peripheral blood cell subsets immediately following space flight. *Journal of Interferon and Cytokine Research* 20(6):547-56, 2000.