Postflight Rash and Skin Sensitivity Following a Year-Long Spaceflight Mission

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BACKGROUND: While skin conditions are commonly reported in flight on the International Space Station (ISS), postflight skin complaints have generally been limited to foot sole sensitivity upon reloading after landing. In this case report, we describe the postflight skin findings in NASA's first year-long crewmember.

CASE REPORT: The crewmember was a 51-yr-old astronaut who spent 340 d in space on this mission. His in-flight course was unremarkable except for medication use for congestion, likely secondary to microgravity-induced fluid shift and elevated CO_2 levels on the ISS, and an episode of contact dermatitis from electrodes for an experiment. He had a nominal landing in Kazakhstan. During his direct return to Houston, approximately 10 h after the Soyuz landing, he developed erythema and skin sensitivity in gravity-dependent areas. The skin findings persisted for 6 d and were successfully treated with nonsteroidal anti-inflammatory drugs, gabapentin, hydrotherapy, and massage.

DISCUSSION: While vascular, allergic, and immunologic causes cannot be ruled out, we hypothesize that a prolonged lack of skin stimulation over the course of the year-long mission led to the crewmember's postflight rash and skin sensitivity. Previous studies have demonstrated alterations in cutaneous receptor feedback in the sole of the foot in spaceflight and, therefore, it is plausible that skin in other parts of the body can undergo similar changes if they are not stimulated as they normally would be on Earth. More work will be needed to better understand this phenomenon and test potential mitigations.

KEYWORDS: astronaut, dermatologic symptoms, long duration spaceflight, International Space Station.

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Dermatological symptoms are the most frequently reported conditions in long-duration missions onboard the International Space Station (ISS). In the first 38 ISS expeditions, skin rashes and hypersensitivity accounted for 32.9% (23/70) of the in-flight clinical events reported by U.S. astronauts, with an incidence of 1.1 events/flight year that was 25 times higher than reported terrestrially.[3] Skin dryness, peeling, and delayed wound healing have also been reported.[2] These skin complaints may be attributable to a number of causes, including the spacecraft environment, hygiene methods, immune dysregulation, and infection.[2–4]

Anecdotally, astronauts have described calluses on the bottom of their feet shedding after being in space for 1–2 mo and primarily using their hands for locomotion in microgravity. With these protective calluses gone, the sensation on their feet becomes more noticeable upon landing. This skin sensitivity is generally considered a mere nuisance that resolves within days of landing. Other than a description of an astronaut who was asymptomatic on orbit but noticed skin shedding on the inside of his thighs immediately after landing and taking off his Russian Kentavr anti-G garment,[2] there has been little published data on postflight skin changes. Another commonly reported phenomenon is calluses on the dorsum of the feet after months in microgravity: to hold themselves in place when working inside the station, astronauts frequently "hook" their toes under handrails, the inside of which would rub against the top of their feet, leading to callus formation over time.

In 2015, NASA embarked on its first year-long mission on the ISS to gain more experience with missions longer than the typical 4–6 mo. As part of this mission, the U.S. crewmember

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participated in the NASA Twins Study, which investigated the health effects of his year in space. Overall, the study found that extensive multisystem changes occurred in flight. There was evidence of changes to the immune response and inflammatory cytokines in the days after landing, all of which returned to preflight levels within 5 wk postflight.[5]

Clinically, the crewmember developed skin sensitivity and rash in gravity-dependent areas on landing day (return; R+0). He had not experienced any of these symptoms after his three previous spaceflight missions. This case report will describe the crewmember's atypical postflight skin findings and hypothesize their association with his year-long mission. The crewmember has given his consent to have his medical data released for this publication.

CASE REPORT

At the beginning of his year-long mission, the crewmember was a 51-yr-old astronaut with 180 d of spaceflight exposure over two Shuttle missions (8 and 13 d) and one ISS mission (159 d). His past medical history was notable for seasonal allergic rhinitis, for which he would take over-the-counter antihistamines as needed.

The crewmember spent 340 d in space during Expeditions 43/44/45/46. He performed three spacewalks. His science complement included exposure to lower body negative pressure, rodent research, and self-administration of the influenza vaccine, all without sequelae. He maintained good health throughout the mission. Notably, he used the following medications on orbit:

- In the early part of his mission, he took loratadine, pseudoephedrine, and intranasal mometasone as needed for congestion that tended to develop when CO_2 levels on the ISS exceeded 3.0 mmHg. This was on top of the cephalad fluid shift induced by microgravity.
- He developed itching, skin irritation, and localized redness 6 mo into his mission after wearing electrodes for 4 h for an experiment. These symptoms resolved after application of topical diphenhydramine.

Prior to de-orbit, he followed the standard Russian fluid loading protocol and took ondansetron prophylactically for prevention of reentry motion sickness. He wore a Kentavr during deorbit and landing of the Soyuz vehicle. The landing was nominal, with the capsule landing in an upright orientation. The crewmember was extracted in a timely manner and carried to a chair for a brief rest and photo opportunity before moving to the medical tent at the landing site.

In the medical tent, he doffed his Sokol suit and donned a custom-fit gradient compression garment (GCG)[11] as part of the "Field Test" experiment. Subsequently he boarded an all-terrain vehicle and then helicopter to a staging airport in Kazakhstan approximately 90 min away. There, he participated in a welcome ceremony and interview, and then boarded a NASA aircraft for direct return to Houston, TX, USA.

Once onboard the aircraft, he experienced mild nausea and dehydration, and received 800 mL of an intravenous infusion containing 25 mg of promethazine in 1 L of normal saline. For comfort, he doffed the GCG, which he felt was too tight. He slept on a memory foam mattress for 2 h and napped intermittently during the rest of the 6-h flight. While he was awake, he consumed some snacks and a sports drink. He had seven spontaneous voids.

About 5 h into the flight (now approximately 10 h postlanding), he began to report skin "burning" and bilateral leg soreness. He noted erythema in gravity-dependent areas such as his back and the posterior aspect of his legs when he was supine, which would migrate to wherever the new pressure points were when he changed his body position. He denied itching or urticaria. The affected areas of the skin were painful to light touch and contact with clothing.

The crewmember's vital signs were normal and he was afebrile. His skin examination, limited by the aircraft environment, was unremarkable except for diffuse erythema in the aforementioned gravity-dependent areas. There was no desquamation or ulceration of the skin. He had trace bilateral lower extremity edema that worsened to mild pitting edema as the flight progressed. He reported a sensation of fluid rushing to his feet whenever he stood up.

At the first planned stop in Norway, the crewmember redonned his GCG for another Field Test session. Upon return to the aircraft, he doffed the GCG again for comfort. The second leg of the flight was uneventful. At the second stop in Canada, which required diversion from a previously planned airport due to inclement weather, he took a shower, which neither alleviated nor exacerbated his skin symptoms. In the last leg of the flight, he ate a small meal before beginning fasting per protocol.

He landed in Houston about 27 h after Soyuz landing. He subsequently traveled by car to the NASA Johnson Space Center for postflight medical and science data collection. At the Astronaut Crew Quarters, his skin was examined in good lighting for the first time. There was marked erythema diffusely over the posterior aspect of his legs which was less pronounced on his back and posterior elbows bilaterally. The anterior aspect of his body appeared to be spared. As expected, the dorsum of each foot was callused while the soles were smooth.

His blood work revealed a markedly elevated C-reactive protein (CRP) that was greater than 13 $mg \cdot L^{-1}$ (normal: $< 1\ mg \cdot L^{-1}$). Other laboratory studies, including the complete blood count and white blood cell differential, were within normal limits.

On day R+1, the crewmember was evaluated by a physical medicine and rehabilitation (PM&R) specialist, who recommended nonsteroidal anti-inflammatory drugs (NSAIDs) and consideration of low-dose gabapentin at night if no relief. Other suggestions included hydrotherapy, emollient, massage as comfortable, and avoiding pressure in sensitive areas as much as possible.

Due to his skin sensitivity, the crewmember required frequent breaks and position changes during his first reconditioning session. For the Field Test, he switched to soft-soled shoes and elected not to wear his GCG, and had to stop a portion of the treadmill test secondary to foot pain. He later received a massage and reported feeling much better afterwards.

Overnight he had difficulty sleeping due to general discomfort and inability to find a position to get relief. He took zolpidem 10 mg and slept for 6 h. Upon waking, he reported that his skin looked and felt much better.

On day R+2, he participated in a public outreach event, by the end of which he was noticeably shifting positions due to discomfort on his feet. That night, he had a welcome home celebration and spent several hours on his feet talking with guests.

On day R+3, the crewmember received another massage and did light exercise before hydrotherapy in the form of alternating immersion in warm and cold water to help with muscle soreness. During the scheduled medical examination, he continued to have erythema on pressure contact surfaces, but these findings were improved from the previous examinations. As it was a crew day off, he had no other activities scheduled that day. That evening, he took ibuprofen 400 mg, gabapentin 100 mg, and zaleplon 10 mg.

On day R+4, he reported persistent burning pain and decided to try gabapentin during the day. In addition, his legs and knees felt swollen, for which he used compression stockings. Later in the day, he was able to tolerate several hours in the lower parts of the GCG, an improvement compared to that experienced previously.

On day R+5, his skin continued to improve. He did not need to take any gabapentin. His legs were less swollen than the day before and he was advised to wear compression stockings as much as tolerated. In a follow-up visit, the PM&R specialist had no new recommendations.

By day R+6, the crewmember's skin sensitivity had essentially resolved. He continued to have leg edema and pain, left leg more than right. This was exacerbated by exercise and prolonged activity on his feet. Rest, NSAIDs, hydrotherapy, and massage helped. The leg edema and pain persisted until day R+16. The day R+30 laboratory studies showed that CRP had returned to baseline.

DISCUSSION

This was an unusual case of postflight gravity-dependent rash and skin sensitivity in a crewmember who spent nearly 1 yr on orbit. Commonly, astronauts returning from long- duration missions report skin sensitivity on the foot soles, but in this crewmember, other areas of the skin were also affected. They seemed to be exacerbated by pressure due to weight-bearing or tight-fitting clothing.

Braun et al. found no difference in skin thickness or dermis density between preflight and postflight measurements,[1] so it was unlikely that skin sensitivity increased due to changes in mechanical barrier properties. Lowrey et al. demonstrated that 55% of the 11 astronauts studied had increased sensitivity to high-frequency vibration in the foot soles on R+0 following short-duration spaceflight, and suggested that during spaceflight, "the central nervous system may selectively increase or decrease the weighting of individual channels of skin receptors."[6] These sensory changes occur even in flights as short as 12–16 d.[12] Therefore, it is plausible that skin in other parts of the body can undergo similar changes if they are not stimulated as they normally would be on Earth.

We hypothesize that the postflight skin sensitivity experienced by the year-long crewmember resulted from prolonged lack of skin stimulation over the time he was on orbit. In microgravity, loose clothing makes little contact with the skin, and cleansing wipes likely do not sufficiently stimulate the skin. Then, upon landing, that skin becomes hypersensitive to normally innocuous stimuli, such as light touch and clothing. The effect would be exaggerated when there is additional pressure on the skin, such as in gravity-dependent areas or where tight-fitting clothing (e.g., GCG) makes contact. There may be some threshold of time for this effect to manifest, since other crewmembers have not reported the same skin sensitivity after their 4- to 6-mo ISS missions, and this crewmember did not have this problem after any of his prior missions.

The crewmember's leg edema and reported sensation of fluid rushing to his feet suggest a possible vascular component as well, perhaps due to atrophy of vascular tone from prolonged exposure to microgravity. Systemic vascular resistance has been demonstrated to decrease by 14% after 1 wk of Shuttle flight and 39% after 3–6 mo on orbit, suggesting a time-dependent adaptation whose mechanism remains unclear.[10] Combined with attenuations of the peripheral arterial vasoconstrictor reflexes after spaceflight,[10] this could explain why there was inadequate peripheral vasoconstriction in response to gravitational loads after landing that resulted in edema. Terrestrially, both lower extremity edema and skin changes, particularly a maculopapular rash, are known side effects of calcium channel blockers, which are thought to cause a preferential arteriolar dilatation that increases the pressure gradient in the capillaries and subsequently leads to extravasation of intravascular fluid.[7,13] Perhaps a similar process was responsible for the crewmember's symptoms.

Extended exposure to microgravity could also impact the venous system, resulting in relative venous insufficiency after landing. The crewmember's skin findings could be due to venous eczema, also known as gravitational eczema, which can develop when there is incompetent venous backflow causing venous hypertension, distention of superficial capillaries, and skin that is typically erythematous, scaly, and frequently pruritic.[8,9] While this does not fully match the crewmember's skin findings, the treatment for venous eczema would have also included elevation, emollients, and compression stockings.

Also on the differential diagnosis are allergic reactions, contact dermatitis, drug hypersensitivity, and photosensitivity. The latter two are less likely since the crewmember was neither introduced to new medications after landing nor exposed to sunlight during the flight back to Houston. The crewmember does have a history of atopy, both on the ground and on orbit, so an allergic or immunological response is plausible. While he did not have leukocytosis or eosinophilia commonly seen in allergic reactions, the timing of his symptoms coincided with the increased immune response and inflammatory markers (including CRP, interleukins, and proinflammatory lysophospholipids) that the Twin Study found in the first days after landing.[5] Nonetheless, the "burning" quality the crewmember described and his clinical response to gabapentin supported a neuropathic cause of his postflight rash.

Working under our presumptive hypothesis of lack of skin stimulation, we provided full-length leggings to a 56-yr-old female astronaut whose mission was extended to 289 d, NASA's second longest mission at the time. (She consented to her information being discussed here.) The crewmember wore the leggings routinely for exercise and sleep. A veteran space flyer, she preferred to exercise sock-footed and continued the practice during her mission. In addition, she used over-the-counter lotion regularly for dry skin. Interestingly, she did not have any skin issues postflight. With one data point, it is impossible to ascertain why she did not develop the same problem as the year-long crewmember—was she not susceptible, was her stay on orbit not long enough, or did the skin countermeasures work?

While it remains to be seen whether this case of postflight skin sensitivity in the 1-yr crewmember was an isolated incident or an emerging clinical problem for spaceflight missions longer than a to-be-determined threshold, operationally simple measures can be taken to reduce the risk, as demonstrated by the comparative case. Otherwise, the symptoms can become significant enough to require pharmacological treatment and modifications to the crewmember's postflight activities. As more missions longer than 6 mo are being planned, flight surgeons should discuss the risk with their crewmembers and encourage concerted efforts to stimulate the skin on a regular basis, such as using tight-fitting clothing and lotions.

In this report, we presented an unusual case of postflight rash and skin sensitivity in NASA's first 1-yr crewmember. While vascular, allergic, and immunological causes could not be ruled out, the most plausible explanation appeared to be neuropathic changes secondary to a prolonged lack of stimulation of the skin. More work will be needed to better understand this phenomenon and test potential mitigations.

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