Development of Second-degree Frostbite in Two Service Members Wearing Issued Cold Weather Footgear Traversing Sea Ice

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ABSTRACT Frostbite, or the freezing of the tissues by exposure to conditions below the freezing point of water, is an unsettling and potentially dangerous condition that one can develop while living and working in cold environments below 0°C without proper protections. Civilians and military personnel operating in prolonged field conditions in temperatures below freezing rely on advanced fabrics and multiple layers to maintain body heat around the extremities to prevent frostbite. Here, we detail the situation and findings of frostbite in 2 American service members who were exposed to temperatures of approximately −19.5°C for 5 hours while hiking on frozen sea ice. Notably, these members were wearing their issued cold weather equipment at the time of their injury. The personnel presented with the classic signs and symptoms of second-degree frostbite with blistering and tingling but went on to have no lasting serious sequelae. We find these cases important as it documents the inadequacy of the footgear utilized, despite being operated in weather conditions within the range of the manufacturer’s safety recommendations. Sea ice and other very cold, conducting surfaces may require other gear considerations when operating in this unique terrain type.

BACKGROUND Cold weather has threatened personnel with frostbite in military operations throughout history. Frostbite, or freezing of the tissues that results in cell damage and death, can lead to long-term disfigurement and handicap. Fortunately, most frostbites are painful but result in no long-term disability. Just like burns, the severity of the injury is determined by the depth of the injury, using a first-, second-, and third-degree system that accounts for damage to the epidermis, dermis, and deeper tissues, respectively. Anytime personnel are found operating in cold and/or wet conditions, frostbite, and other cold weather injuries are a cause for concern. Since the Korean War, American military actions have mostly been in warmer areas where frostbite is an unusual occurrence. However, there are areas of potential conflict in the world where American military personnel may operate in which have conditions favorable to the development of frostbite case. Even in peacetime, American military personnel must function in dangerously cold conditions. At Thule Air Base, the most northern permanent U.S. military base, U.S. Air Force personnel operate a remote base on the coast of Northern Greenland. They are issued special gear to combat the cold, harsh conditions they may encounter on a daily basis. Here, we report on two Air Force personnel who developed second-degree frostbite while wearing issued gear. These 2 personnel were engaged in an approximately 5-hour group hike organized by the base outdoor recreation organization to examine an iceberg in North Star Bay (Fig. 1) where the base is located. This hike involved walking on hard, frozen sea ice (Fig. 2) covered variable amounts of snow; usually, no more than 40 cm of snowpack was present. There were a total of 30 individuals on the hike, most of them military personnel. A miscommunication resulted in individuals planning for an outdoor excursion of approximately 2 hours, not the 5 hours the participants ended up performing. Conditions that day were sunny, clear, and with little wind noted, and the temperature was −19.5°C (−3°F).

CASE PRESENTATIONS The first individual was a 24-year-old African American female with an uncomplicated medical history who had been at Thule for 10 months before she attempted this sea ice hike. A Security Forces Airman, she was experienced with the cold conditions present at the base. She wore her military-issued Belleville 655 boots with heavy socks that are standard for the cold weather Security Forces gear. During the hike, she noticed some increasing pain that prevented her from walking comfortably. Approximately 2.5 hours into the hike she reached the iceberg and noticed that numbness which she noted felt like “frozen toes.” A friend on the hike gave her handwarmers which she applied to the upper part of her feet between her sock and boot toe. During the return hike, she did not notice any change in the condition of her feet. When she arrived back in her room, she stated that her toes were very difficult to move for approximately 1 hour after the hike was finished. As her toes rewarmed, she noted they were extremely painful and worsened through the night. The next day she was seen at the base clinic, where she was diagnosed with second-degree frostbite. She was placed on lighter duty as tolerated for a short period of time before she made a full recovery of her function, albeit with a little residual erythema.

On physical exam, erythema in the distal fourth toes was seen bilaterally. She had a blister filled with clear fluid at
the site that was painful to palpation, noting a burning sensation. She noted a loss of sensation in the fourth toe bilaterally, but proprioception and two-point sensation were preserved for both extremities. Her gait, reflexes, and toe movement were normal. The patient was offered ibuprofen therapy for which she received a prescription of 600 mg 3 times a day for pain and swelling. On repeat examination 1 month later, she was noted to have some mild remaining erythema in the same area as previously seen (Fig. 3).

The second individual involved was a 52-year-old Caucasian male Air Force officer serving in an administrative role for this assignment with a past medical history of hyperlipidemia without diabetes or known neuropathy. He presented to the base clinic 2 weeks after the hike complaining of alternating numbness and burning in the hallux and second toes bilaterally, with the symptoms of the left-side being more prominent. The patient stated that the burning sensation was worse with activity, but rest brought about a transient
necrosis. He first noticed these symptoms after a 2.5-hour hike in $-23^\circ C$ ($-9^\circ F$) weather 4 weeks before the sea ice hike described earlier. He noticed that after this previous hike that his toes were quite cold and he developed some erythema of his left hallux. After this redness resolved, he noted alternating burning and numbness that eventually resolved. He denied any issues with his strength or gait and stated that he felt quite well before accomplishing the aforementioned sea ice hike. Although wearing his issued N-1B Mukluks and heavy weight wool socks, he developed very cold feet and toes during this hike but was never unable to walk. Throughout the next day, he developed blisters and redness in his great and fourth toes, especially in the left great toe, noting that his left foot had greater symptoms. He stated that these blisters resolved within a week, but the burning and numbness continued to persist and was more intense than the last injury. Since that time, the patient has noticed that rest improves his burning, but increases the numbness. As a result of this injury, the patient has avoided extended cold weather exposure since his sea ice hike.

On physical examination 2 weeks after the hike on sea ice, erythema was seen in the distal part of the large and fourth toes bilaterally, with greater erythema seen on the left (Fig. 4). The redness blanched when palpated, and the patient stated that he felt the burning sensation on palpation. Patient tactile sensation in the area of the erythema was diminished with the left side having a greater loss than the right. Proprioception and two-point sensation were preserved bilaterally. Gait, reflexes, and toe movement were all noted to be normal.

**DISCUSSION AND CONCLUSIONS**

Both of these cases are notable because the members experienced their frostbite while wearing familiar, issued gear commonly used by the personnel at Thule AB. Specifically, 600 g Thinsulate Belleville 655 boots and the N1-B Mukluk are rated for temperatures down to $-20^\circ C$ ($-4^\circ F$) and $-35^\circ C$ ($-31^\circ F$), respectively. Despite the fact that the footgear used was being operated in an air temperature they were rated for, it is likely that the extended contact with the cold sea ice resulted in inadequate protection against frostbite. The NOAA windchill chart (found at [http://www.weather.gov/safety/cold-wind-chill-chart](http://www.weather.gov/safety/cold-wind-chill-chart)) suggests that frostbite could potentially result from the conditions experienced during this hike in as little as 30 minutes. It is clear that factors such as prolonged contact with cold surfaces or excessive moisture will potentiage cold injuries beyond the rating of the gear. Given this scenario, we advise that all factors are considered when selecting gear for prolonged exposure to extreme temperatures to best prevent cold injuries like the frostbite suffered in these cases.

Prevention of frostbite remains the most viable means of medically addressing this problem. A key element in the case of the female patient was the fact that the Belleville 655 Cold Weather boot did not come in female sizes, necessitating an imperfect fit. A review of the literature is unclear as to whether women are more or less susceptible to frostbite, but in the U.S. military, women seem to have proportionally greater rates of frostbite injury when they are in contact with cold weather; this may be in part attributable to the lack of female-specific cold weather clothing. Proper fit of gear is paramount when it comes to protection against cold weather. When personnel are operating in conditions conducive for frostbite development, monitoring using a simple symptom checklist every 30 minutes to 1 hour, focused on numbness and tingling in extremities, can be helpful in early diagnosis and prevention. Medics or personnel operating in a medical capacity for the team should promptly evaluate any members complaining of symptoms. Predisposition is another consideration as individuals predisposed to frostbite include personnel of African-descent and individuals who have had prior frostbite injury. A careful assessment of these individuals in cold weather is crucial to preventing frostbite in these susceptible cohorts. Consideration should be given to reassigning to warmer locales the victims of third-degree frostbite or individuals who frequently develop first- and second-degree frostbite.
Pedal Frostbite With Issued Gear on Sea Ice
during operations as previous frostbite is a significant risk factor for the development of future frostbite.¹

Ultimately, in a place like Thule AB where the turnover of personnel is high, maintaining institutional knowledge on cold weather injuries presents a public health challenge. Base educational leaflets, Armed Forces Network public service announcements, and occasional visits by cold weather experts such as Survival Instructors (SERE) could fill the gaps in the local cold weather injury knowledge and keep personnel safe. Advanced frostbite therapies such as thrombolysis⁸ or hyperbaric oxygen⁹ are impractical in remote, high arctic environments, but educating providers in prostacyclin in these remote environs use may be very beneficial to individuals suffering from third-degree frostbite.⁸

Frostbite continues to be a menace for personnel working and living in subfreezing temperatures for long periods. For the 2018-2019 winter season, frostbite was the most common cold weather injury in the Armed Services with 52 documented cases in that season alone.¹⁰ Although textile technology has advanced considerably in the past few decades, frostbite can still develop in personnel who are exposed to conditions conducive for it. In particular, thermally conductive surfaces such as ice or cold metal are particularly adept at sapping warmth from extremities that come into contact with these surfaces. Caution must be emphasized to ensure all extremities are adequately protected for conditions that will be experienced during the cold weather activity being performed.

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