

# Critical Care for Frostbite

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## KEYWORDS

• Frostbite • Cold injury • Rewarming • Risk factors • Prevention

## KEY POINTS

- Frostbite occurs when the skin temperature cools to below 0°C with the formation of extracellular ice crystals.
- Injury severity depends on temperature, duration of exposure, and the amount and depth of frozen tissue.
- The mainstays of treatment are rapid rewarming and watchful waiting.
- With rewarming, an inflammatory response develops, contributing to ischemia and tissue loss.

## INTRODUCTION

Cold injuries are divided into 3 categories: freezing injuries, nonfreezing injuries, and hypothermia. Frostbite is the condition whereby damage to skin and other tissue occurs as a result of freezing, and is a preventable injury.<sup>1</sup> Frostbite is a concern for those who live, work, and play in polar and other cold-weather regions. The hazardous environment necessitates the awareness of the potentials for injury related to extreme cold weather, and the knowledge and skills to prevent injury from occurring. Daily activities related to commuting to work, occupations, lifestyles or life situations that require being outside in freezing temperatures, and leisure-time activities that involve prolonged exposure times become opportunities for frostbite to develop.

The military experience with frostbite is well documented. Xenophon, in 400 BC, led an army of Greek soldiers through the mountains of Armenia where they experienced severe cold weather, resulting in amputations from frostbite and death by exposure. Baron Dominique-Jean Larrey, Napoleon's surgeon-in-chief, provided the first detailed description of the management of frostbite based on his observations of frostbite injury occurring during the Russian retreat in the winter of 1812.<sup>2-4</sup> The United States military have suffered casualties related to cold injury, including frostbite, with a majority occurring during World War II.<sup>3,5</sup>

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The author has nothing to disclose.

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Crit Care Nurs Clin N Am 24 (2012) 581–591

<http://dx.doi.org/10.1016/j.ccell.2012.07.001>

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Civilian cases have increased over the years, in part because of increases in social issues such as homelessness, but also because of greater participation in winter sports. The spectrum of injury can range from minimal tissue loss to extensive necrosis necessitating amputation. Long-term sequelae can include chronic pain, sensitivity to cold, and a predisposition to cold injury in the future.<sup>6-8</sup>

## EPIDEMIOLOGY

The incidence of frostbite is difficult to ascertain, as hospital data generally represent the most severe cases.<sup>7</sup> There are estimates of 4800 cases of frostbite each year in the United States.<sup>9</sup> People living in northern latitudes have an especially high incidence of frostbite, with one study of 6000 Finnish men showing 44% had sustained some degree of frostbite at least once.<sup>7</sup> The Alaska Trauma Registry lists hypothermia and frostbite as one of the top 10 causes of nonfatal hospitalized injuries for Alaska residents in the years 2001 to 2010.<sup>10</sup>

Historical data show the US Military experienced casualties from cold injury, with approximately 2000 from World War I, 91,000 from World War II, and 6300 from the Korean War. The Afghanistan Conflict, the first large-scale conflict in a cold-weather region since the Korean Conflict, had only 2 cases of frostbite identified. Advances in types of cold-weather gear, education, and training with acclimation of military personnel to cold weather may account for this difference.<sup>5</sup> Between 1990 and 1995, first- and second-degree frostbite accounted for 99.3% of reported cases of cold-weather injury among US soldiers in Alaska, with male African American soldiers significantly more susceptible than Caucasian soldiers.<sup>11</sup> The period 1996 to 2011 showed a slight decrease in the rate of frostbite but consistently demonstrated the highest rates in females, in those younger than 20 years, and in black, non-Hispanic soldiers.<sup>12-14</sup>

Factors associated with frostbite (**Table 1**) include environmental, individual, behavioral, health related, certain medications, situational, and others.<sup>1,6,8,15,16</sup> Mohr and colleagues<sup>17</sup> characterize factors as the I's of frostbite: intoxicated, incompetent, infirm, insensate, inducted (increased risk during war time), inexperience, and indigent.

Deep frostbite injuries that require hospitalization are usually of the hands and feet. Most minor injuries are superficial and affect the face and head, including the nose, chin, earlobes, cheeks, and lips. Other affected areas include the buttocks and penis.<sup>6-8</sup>

## PATHOPHYSIOLOGY

Frostbite occurs when tissue temperatures fall below 0°C, a temperature slightly below the freezing point of water, because of the electrolyte content of cells and extracellular fluid. Wet skin cools faster, will reach a lower temperature, and will freeze at a higher threshold.<sup>7,15</sup> Air temperature, wind speed, and wetness are determinants of heat loss. At temperatures below -10°C (14°F), wind speed increases the risk of injury from cold. The wind-chill temperature (WCT) index estimates the cooling power of the environment and indicates frostbite times for exposed facial skin in minutes. At -37°C (-35°F) with a wind speed of 8 km/h (5 mph), frostbite could occur in 30 minutes (**Fig. 1**).<sup>18</sup>

The severity and degree of tissue injury are related to temperature and duration of exposure, with duration being the more significant factor.<sup>16,19</sup> The continuum of injury ranges from irreversible cellular destruction to reversible changes occurring after rewarming. Two mechanisms for tissue injury have been identified: cellular death

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