FACTORS AFFECTING TISSUE FREEZING

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Low air temperatures and high wind speeds are associated with an increased risk of freezing exposed skin. Siple and Passel (1945) derived their wind chill index (WCI) from cooling experiments on a water-filled cylinder. In addition, they exposed bare skin to different climates and observed at what combinations of air speed (v) and temperature, and thus WCI, skin freezing occurred. They reported that an increased risk of frostbite was prevalent at a WCI above 1400 kcal/(m2•h) (1628 W/m2). Later conducted experiments on finger freezing showed that skin freezing rarely occurred at WCI values below 1400; values above this were often, but not always, associated with skin freezing. These results have been re-examined (Danielsson, 1996). It was found that the WCI underestimated the convective heat transfer coefficient (hc). Therefore, new risk curves were developed based on a corrected convection equation valid for body parts in a cross air flow ($hc \propto v^{0,62}$) and finger frostbite data presented in the literature. An analysis of the data revealed a relationship between the frequency of finger frostbite and the surface temperature. This relation closely follows a normal distribution of finger freezing temperatures, with a standard deviation of 1°C. As the skin surface temperature falls from -4,8°C to -7,8°C the risk of frostbite increases from 5% to 95%. However, finger frostbite at considerably lower WCI values than 1400 has also been reported but these exposures were associated with snow in the air or with the skin wetted. The experience that frostbite rarely occurs in spite of high WCI-values in Antarctic during summertime have been explained by presence of solar radiation. The effects of sunshine and a wetted skin on the cooling rate can be included in the prediction equations describing the frostbite risk. The results confirm that wet skin can cause tissue freezing at a considerably lowered WCI-value, meaning e.g. that the risk changes from 43% (dry skin) to 86% (wet skin) at a temperature of -15°C and an air speed of 6,8 m/s. Calculations show also that solar radiation may prevent the skin from reaching harmful temperatures. If the sky is clear and the sun altitude is 10°, the risk of frostbite is roughly 15% compared with 50% at no solar radiation if the temperature and air speed is -15°C and 9 m/s, respectively. At a sun altitude of 40°, the risk of frostbite is negligible according to estimations. Based on the prediction model, extended risk curves have been developed, now also taking considerations in solar radiation and skin wetness. The effect of acclimation on the risk of tissue freezing, reported in the literature, has also been included as a comparison.

Danielsson, U., 1996. Windchill and the risk of tissue freezing. J. Appl. Physiol. 81, 2666-2673.
Siple, P. A., Passel, C. F., 1945. Measurement of dry atmospheric cooling in subfreezing temperatures. Proc. Am. Phil. Soc. 89: 177-199.}

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