

## ORIGINAL ARTICLE

## Frostbite: incidence and predisposing factors in mountaineers

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*Br J Sports Med* 2005;39:898–901. doi: 10.1136/bjism.2004.016097

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Accepted 23 May 2005

**Background:** Frostbite, the most common cold injury, occurs in mountaineers, a major group at risk, more often than in the general population.

**Objectives:** To describe the incidence of frostbite and the situations associated with it in mountaineering, emphasising factors that can be modified to decrease its frequency and severity.

**Methods:** In this cross sectional, questionnaire based study, 637 mountaineers were asked if they had suffered any frostbite injuries during the preceding two years and to provide the personal and circumstantial details.

**Results:** The mean incidence was 366/1000 population per year. Grade 1 injury (83.0%) and hands (26.4%) and feet (24.1%) involvement were most common. There was a significant relation between lack of proper equipment (odds ratio 14.3) or guide ( $p < 0.001$ ) and the injury. Inappropriate clothing, lack or incorrect use of equipment, and lack of knowledge of how to deal with cold and severe weather were claimed to be the main reasons for the injury.

**Conclusions:** In high altitude and winter expeditions, mountaineers should wear appropriate clothing, have the necessary equipment such as quality boots and mittens, use a competent guide, and have training on how to tackle cold weather. They should also avoid wet clothing, windy terrains, and should never remain in the same position for long periods to reduce the risk of cold injuries.

Frostbite is the most common cold injury. From the clinical viewpoint, it is classified into four degrees of progressive injury identified by physical signs and the following sequelae. First degree injury is characterised by epidermal involvement, which causes erythema, mild oedema, and sequelae over the next few weeks such as desquamation and cold sensitivity. Second degree injury is full thickness skin freezing with substantial oedema and formation of clear blisters, which contract and dry within two to three weeks, forming a dark eschar. The sequelae include paresthesia, hyperhidrosis, and persistent or transient cold sensitivity. Third degree injury is characterised by formation of haemorrhagic blisters, blue-grey discoloration of the skin, deep burning pain on rewarming, thick gangrenous eschar formation, and the sequelae of trophic ulceration and severe cold sensitivity. In fourth degree injury, muscle, bone, and tendons are involved.<sup>1,2</sup>

One of the major groups at risk of frostbite are mountaineers, who are mostly affected in cold seasons and at high altitudes. Little work has been carried out, thus far, to study the scope of the problem in this group, and the medical literature is lacking in studies on the epidemiology and predisposing factors of frostbite among mountaineers. We are active members of the Mountaineering Club of Tehran University of Medical Sciences. Having encountered many cases of frostbite sequelae among our fellow mountaineers, we planned this study, describing the settings of the injury in order to gather information to allow implementation of the best possible preventive measures.

## METHODS

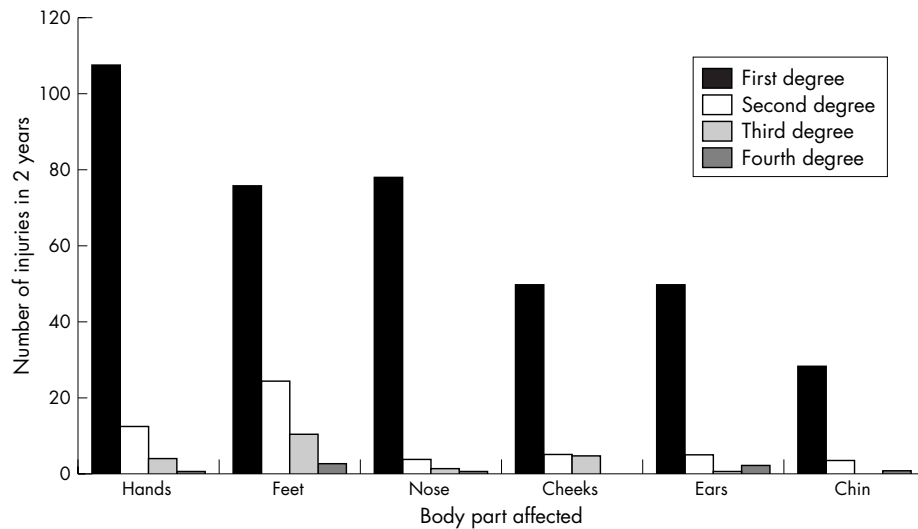
This is a cross sectional descriptive study with data gathered through a questionnaire filled out by a sample population. The sample consisted of 637 mountaineers who were selected by simple non-randomised sampling from active members of the Tehran Province Mountaineering Council, registered mountaineering clubs in the city, and collegiate

mountaineering groups at their scheduled gatherings and ascents. After consultation with mountaineering experts, we used the rough definition of a mountaineer as one with two years of mountaineering experience, which involves at least two ascents per month to summits higher than 3000 m. It means that our climbers made more than 48 ascents during the two year period. Members of the study population generally climb mountains about 4000 m above sea level (2800–4400 m), although there were 157 cases of frostbite in the altitude range 4400–7165 m. More than half the sample (427 subjects) had four years or more mountaineering experience, considered as the number of years since the first ascent to a summit.

After a brief description of the different degrees of frostbite and its differentials (frostnip, chilblain), the participants were asked to complete a questionnaire on the contraction of frostbite while mountaineering over the preceding two years, March 2000 to March 2002. There was written description of symptoms and signs of various degrees of frostbite in the questionnaire. The mountaineers were asked to define the body part affected by choosing from a list of six locations (hands, feet, nose, ears, cheeks, and chin) and to define the degree of injury, the approximate altitude, the season in which the injury occurred, the appropriateness of the equipment being used (checked against a list of indispensables consisting of proper boots, sturdy socks, gloves with cover, and windbreaker), whether they were accompanied by someone familiar with the ascent as a guide, and what they believed was the main cause of the injury.

## RESULTS

A total of 637 mountaineers recruited to the study reported 467 incidents of frostbite in some part of their body during the preceding two years. This was a mean incidence in our study group of 366/1000 population per year (first degree, 304; second degree, 41.7; third degree, 15.7; fourth degree, 4.8). The mean age of our sample was 29.6 years. Of those



**Figure 1** Frostbite injuries in different body parts.

affected with frostbite, the youngest was 16 and the oldest 65 (mean (SD) 28.8 (1.1)). There was no significant relation between age or sex of the mountaineer and frostbite occurrence. Also we failed to find a significant relation between mountaineering experience and frostbite incidence.

Grade 1 injury was the most prevalent in all body parts, with 83.0% of all cases being grade 1 injury. The hands were the most affected part, with 26.4% of all cases having hand involvement. Feet were second in prevalence with 24.1% of those affected, but high grade disease was most common in the feet (fig 1). Also there was a significant relation ( $p < 0.001$ ) between not having a guide during the ascent and contracting frostbite.

Whereas 56% of those with frostbite claimed that they did not have appropriate equipment during the ascent, 92% of those without frostbite had used appropriate equipment, therefore lack of equipment is a major predisposing factor for frostbite (odds ratio 14.3) (table 1).

The injury occurred mostly in ascents to peaks ranging from 2800 to 3960 m, which were the most common expeditions in our study population. This includes Tochal summit, which is the nearest mountain to the city of Tehran, and about 27% of injuries occurred in this popular mountainous area alone (table 2).

The seasonal distribution of frostbite shows the highest occurrence in January and February (with at least three times as many injuries as in other months), with another less striking rise in incidence during summer months when large scale expeditions to high peaks are scheduled (fig 2).

Inappropriate clothing was believed by the mountaineers to be the main cause of the injury followed by lack or incorrect use of equipment and lack of knowledge about dealing with cold and severe cold weather (table 3).

**Table 2** Frostbite occurrence at different altitudes

Altitude (m)	Number affected	Percentage of total
<2800	3	0.6
2800–3960	196	42.0
3961–4400	111	23.8
4401–7165	157	33.6

**DISCUSSION**

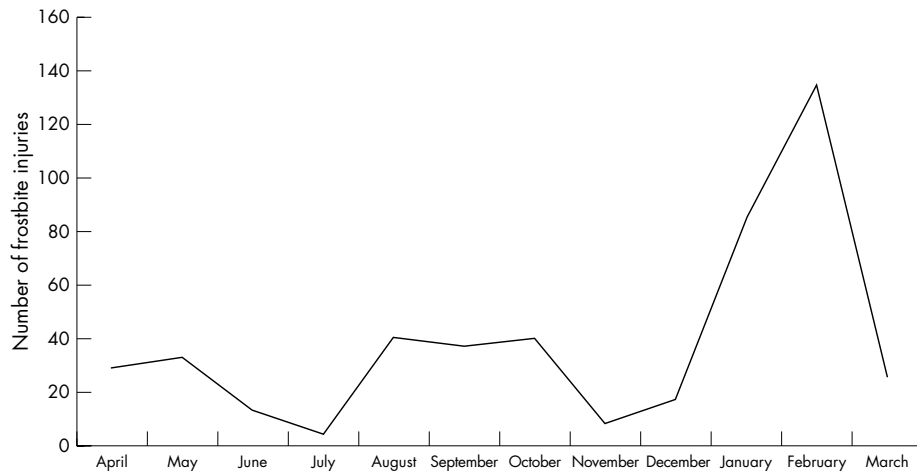
The method used to gather data (a questionnaire) relies on the recollections of the injured climbers and is inevitably prone to inaccuracies. We adopted measures that tend to minimise the effect of this confounding factor. The questionnaires were completed in the presence of one of authors, who provided a description of the injury grading and clarified inconsistencies in the definition, if needed. There was also a written description in the questionnaire. Meanwhile, the fact that people tend to remember painful memories, especially lasting bodily injury, enhances the creditability of the answers. Altogether, we believe that the data gathered are reasonably reliable and can allow us to draw conclusions.

The mean annual incidence of frostbite in our study population of mountaineers with at least two years experience was high: 366 per 1000 mountaineers. Hence it may be asked whether the scope of the injury has ever been clearly identified among mountaineers and if preventive measures are being adequately taken in mountaineering expeditions. Cumulative lifetime incidences have been stated to be as high as 44–68% for all types of frostbite among a civilian northern population in a Finnish study.<sup>3</sup> A retrospective study performed on medical records of the British Antarctic Survey between 1986 and 1995 determined 61 new consultations for cold injury, with an incidence of 65.6/1000 per year.<sup>4</sup> Those working in such a research centre receive adequate training about managing cold conditions, and necessary precautions are undertaken well in advance to prevent cold injury. It is therefore predictable that the incidence among members of the British Antarctic Survey would be lower than among regular mountaineers, who are less prepared and much more poorly equipped. According to the above figures, the incidence reported in our study seems reasonable although unexpected. This result may not be applicable to

**Table 1** Effect of using proper equipment on occurrence of frostbite

	Without frostbite	With frostbite
Appropriate equipment	170 (92)	200 (44)
Inappropriate equipment	15 (8)	252 (56)

Values are numbers of mountaineers with percentage in parentheses.



**Figure 2** Seasonal distribution of frostbite incidence.

mountaineers in other countries, as the occurrence of the injury is related to many climatic and personal factors such as low temperature, high altitude, windy weather, tobacco smoking, presence of peripheral vascular disease, and behavioural response to cold ambient temperature. Because of the low economic status of Iran, which affects accessibility to proper clothing and equipment, and the strong positive attitude of mountaineers toward less dependence on equipment, the incidence may be higher than in Western countries. Furthermore, the study group is relatively young, and younger people may be more adventurous and have less knowledge about dealing with problems of wilderness conditions.

The self claimed reasons for the injury (inappropriate clothing, lack or incorrect use of equipment, and lack of knowledge of dealing with cold) emphasise the necessity of paying more attention to training on how to manage cold, what equipment is needed in high altitude mountaineering or winter expeditions, and when and where they must be used. The result of these measures would be a reduction in the incidence and severity of cold injuries in mountains. The strong correlation between not having a guide and contracting frostbite also indicates the absolute necessity of having a guide in high risk expeditions.

The single most important cause of frostbite according to our figures is inappropriate clothing, accounting for 45% of injuries. Therefore all the mountaineers are strongly advised to receive training on winter clothing. A layering system, which creates a microclimate around the body protecting against cold and wind, is highly efficient in preventing frostbite and hypothermia. Classically a three layer system is

described: an innermost base layer, in direct contact with the skin, ideally made from synthetics (polypropylene and polyester), which are light and strong, absorb very little water, and are quick drying; a mid-layer (made from wool and synthetics), which provides insulation and continues the transfer of moisture away from the inner layer; an outer layer, which protects from the wind and rain/snow allowing air to circulate and excess moisture to escape (Gore-Tex). By knowing the characteristics of fabrics (cotton, down, wool, nylon, polyester, synthetic fiberfills) and the principles of layering, one can obtain adequate warmth without using costly, high tech equipment.

Winter ascents have the highest risk of cold injuries; February and January are the most dangerous months for cold injuries in temperate zones. Tehran and surrounding regions have the highest snowfall and the lowest temperature in these two months, which may account for the peak in frostbite incidence. These findings support the generally accepted advice that any mountaineering club whose members cannot afford the necessary equipment should dispense with demanding expeditions during the winter.

Hands and feet were the most commonly involved regions, therefore there must be more emphasis on using proper boots and mittens. Although more difficult to use, mittens are better than gloves because they decrease surface area exposure to the cold. At the present time, more attention is paid to protecting the feet from cold, and there is widespread use of specially designed, two layered plastic boots. Therefore hands have become the most common site of grade 1 frostbite. In a retrospective study<sup>5</sup> on frostbite referrals to a tertiary care centre that deals with accidents in the

**Table 3** Mountaineers' view of the main cause of frostbite injury

Mountaineers' view of cause of injury	Frequency	Percentage
Inappropriate clothing	212	45.3
Lack or incorrect use of equipment	85	18.2
Lack of knowledge on tackling cold	68	14.6
Severe cold weather	59	12.6
Wet clothing	12	2.6
Long stay in cold weather	4	0.9
Severe wind	4	0.9
Unnecessary contact with snow	1	0.2
Inexperienced guide	1	0.2
Undefined	21	4.5
Total	467	100

**What is already known on this topic**

- Little has been reported about the extent, epidemiology, and predisposing factors of frostbite in mountaineers

**What this study adds**

- This study provides a detailed study of frostbite in mountaineers in Iran and looks at causes and possible methods of prevention

Karakoram mountains in Pakistan, feet were most often involved (64%), followed by hands (32%). This difference from our results is probably because that centre has less access to lower degree injuries, with up to 92% of their patients having second or third degree frostbite, necessitating definitive surgical intervention. We conclude that first degree injuries, which are more prevalent in our study, affect hands primarily, and higher degree injuries are more prevalent in feet. Therefore proper mittens are at least as important as mountaineering boots for preventing cold injuries in high altitudes and winter expeditions. However, other body parts were the primary sites of involvement in other studies—for example, ears were the most affected part in Finnish conscripts.<sup>4,6</sup>

Because in our sample, few cases (seven) occurred at altitudes higher than 5100 m above sea levels, which has been stated to be the “cut off” point for frostbite,<sup>5</sup> we could not confirm any steep upward curve beyond this height in our study. However, most of our cases occurred in the range 2800–3960 m above sea level, which includes the most commonly climbed peaks, thus low altitude must not be a basis for ignoring the threat of cold injuries especially in winter months.

Other studies indicate that the risk of cold injury is increased by alcohol consumption,<sup>7</sup> sedative drugs, opioid meperidine, and the  $\alpha$  adrenergic blocker clonidine.<sup>8</sup> Doctors consulted by mountaineers about winter ascents should consider the appropriate advice for those taking these drugs. Patients with medical conditions such as peripheral vascular diseases, diabetes mellitus, hypothyroidism, and adrenal insufficiency should be advised to avoid winter expeditions because their risk of frostbite is high.<sup>9</sup>

In view of the high incidence of frostbite among mountaineers, especially in winter months and at high altitudes, it would seem prudent to adopt measures to minimise such injuries. To reduce the risk of cold injuries, planning for winter expeditions should focus on the following:

- Sheltering from wind and cold
- Wearing proper clothing
- Taking the necessary equipment such as well fabricated boots and mittens
- Having a knowledgeable guide
- Training the team on how to manage cold
- Avoidance of wet clothing, windy terrains, and remaining in the same position for long periods

## ACKNOWLEDGEMENTS

Drs S Hamidi, B Gharaci, and A Aslani are thanked for their contributions to the preparation of this article.

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Competing interests: none declared

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## COMMENTARY

This article provides a very interesting report of a problem faced by mountaineers and workers in cold environments around the world: frostbite. Completing such a thorough cross sectional study of climbers in that locale is remarkable in itself, and I found their analysis showing inadequate personal protective gear as a primary hazard to be compelling and consistent with other recently published literature.<sup>1–3</sup> The authors' disquisition on the costs of obtaining proper protective boots and clothing posing difficulty in a developing nation is trenchant. Their advice for climbers to learn more about thermal properties of locally available materials and fabrics and about thermal layering is an excellent and inventive response to this problem. I would encourage the authors to distribute this article and any germane educational materials on equipment, clothing, and frostbite prevention to their local climbing clubs and workers who must work outside during the winter, and believe that others elsewhere will find their insights and advice valuable. I thank the authors for this interesting contribution to the world corpus of literature on cold injury.

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The findings and conclusions in this commentary are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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