THE OCCURRENCE OF FROSTBITE AND ITS RISK FACTORS IN YOUNG MEN

ABSTRACT

Objectives. Previous studies have paid little attention to the occurrence of frostbites and related risk factors. The purpose of this study is to analyse the life-time occurrence of frostbite in young men and its association with the cold-provoked white finger syndrome (CPWF), smoking and hand vibration.

Methods. The study population consisted of 5839 Finnish men aged 17-30 years entering military service. Data was collected for cases of first-degree, or more severe, frostbite affecting the head and extremities. Logistic analysis was used to assess the risk of frostbite with respect to CPWF, smoking and hand vibration.

Results. The life-time and annual occurrences of frostbite were 44% and 2.2%, respectively (n=2555). 2333 subjects (41%) had suffered first-degree freezing injury and 671 (12%) suffered severe injury at some time in their lives. The sites most prone to frostbite were the head, 1668 cases (31%), followed by the hands, 1154 (20%), and the feet, 810 (15%). The risk for frostbite in different body parts was increased among the subjects with CPWF (95 % CI: 1.66 to 3.87), regular smokers (95 % CI: 1.02 to 3.15) and those exposed to vibration (95 % CI: 1.07 to 4.03).

Conclusions. A synergistic increase of frostbite was reported between CPWF and regular smokers, and between CPWF and hand/arm vibration in both exposure classes analysed. The life-time occurrence of frostbite among young healthy men was high. Frostbite, and its association with CPWF, smoking and hand/arm vibration should be noted by the health care personnel in circumpolar countries. (Int J Circumpolar Health 2004; 63: 71-80)

Keywords: epidemiology, freezing injury, inquiry, smoking, white finger syndrome
INTRODUCTION

Frostbite is a form of cold injury in which tissue fluids crystallise after exposure to freezing temperatures (1). Its health effects are associated with the immediate functional disadvantages that it causes and its various sequelae (2-5). Such sequelae are common and involve symptoms ranging from a decline in sensation to impaired functional ability in the cold (2,3,6,7). Although frostbite damage is mostly minor, severe injury may lead to significant tissue loss and functional limitations.

The occurrence of frostbite in the average population and its associated risks have received little attention. According to Lehmskallio et al. (8), the life-time occurrence of face frostbite among young Finnish men is 47%. Most often, however, its occurrence has been studied among special groups encountering extensive cold exposure. Frostbite occurrence among Finnish reindeer herders during the latters’ life-time, for example, is 65% (9), with an annual occurrence of 22% (10). Although occupational exposure to cold has decreased during recent decades, people will continue to encounter frostbite in the future, because maintenance and repair work will continue to be carried out in the cold and because the increasing interest in outdoor recreation in winter is likely to enhance susceptibility to cold injury.

Epidemiological and physiological evidence has revealed certain factors, such as age, fitness, smoking, previous cold injury and peripheral circulatory impairments, that may affect the development of cold injury (7,10-12, for reviews, see 1,13). Here, we investigate the life-time cumulative occurrence and anatomical distribution of frostbite in young Finnish men. The effects of cold-provoked white finger (CPWF) syndrome, smoking and vibration exposure on the occurrence of frostbite were assessed and determined by means of odds ratios and confidence intervals obtained from a logistic regression analysis.
MATERIAL AND METHODS

The study series consisted of 6690 men who entered military service in Northern Finland in July 1995, or January 1996. The questionnaire was given to the subjects upon arrival. The response rate was 87% (n=5839), and the age of the respondents ranged from 17 to 29 years, with a median age of 20 years. 3.5% of the respondents had volunteered to start their military service at the age of 17-18 years, 86.7% had done so at the normal age of 19-20 years, and 9.7% postponed it to the age of 21-29 years. The 2555 respondents who had suffered frostbite formed the index group, while the remaining 3284 respondents made up a control group.

The questionnaire collected information on the experience of frostbite and cold-provoked white finger syndrome (CPWF), smoking habits and vibration exposure. The frostbite was classified as either superficial, or deep, since superficial frostbite does not usually cause the sequelae often encountered with deep frostbite. The experience of deep frostbite was ascertained with the question "Have you at any time had distinct frostbite with blisters, ulcers, or gangrene?", and that of superficial freezing injury with the question "Have you at any time had moderate frostbite, with your skin turning white and hard, but without any blisters forming?". The frostbite data was collected separately for the hands, feet and other areas of the body (in practice only the head area). The reported number of frostbite events for each area of the body was reported separately as the occurrences of frostbite.

Cold-related disturbances in the peripheral circulation, exposure to vibration and smoking habits were investigated by means of the following questions: "Have you occasionally had white fingers in the cold that may be accompanied by coolness of the skin, numbness, tingling and pain?", "Have you used vibrating tools at your work, or in your hobbies?", and "What are your present smoking habits?" The alternative answers to the questions on CPWF and vibration exposure were "yes" and "no", and those to the question on smoking habits "never, occasionally (i.e. not every day), regularly (i.e. daily), and used to smoke regularly, but have quit". The respondents who indicated exposure to vibration were then asked: "What tools have you used and for how many days per year?" The alternatives were: chain-saw, brush-saw, snowmobile, motor cycle, some other tool.
Those exposed to vibration denoted the number of days of exposure per year, which was used to calculate annual exposure to vibration. Two of the classes recognized for the "smoking" variable, "never" and "quit", were merged, as the number of cases in the latter class was quite small: 33.

A logistic analysis was used to assess the risk of frostbite with respect to CPWF, smoking (no smoking, occasionally, regularly) and hand/arm vibration (none, 0-500 h/year, >500 h/year), and smoking. Respondents whose answer regarding frostbite was not complete were excluded from the logistic model. As our aim was to find factors elevating the risk of frostbite, the group of men with no exposure were used as a reference to assign odds ratios (OR) to the classes for each variable (i.e. CPWF, smoking and vibration exposure). The 95% confidence interval (CI) was calculated for the odds ratio.

RESULTS

Life-time experience

The life-time occurrence of frostbite, indicating the proportion of the population (n=5839) that had suffered frostbite at some time during their life-time, was 44% (Table I). 3284 respondents had not had any frostbite, and they formed the control group. Out of the total of 2555 frostbite cases, 21% had had one episode, 52% had two to five episodes, and 37% had more than five episodes. The head was more prone to frostbite than the extremities, the relative occurrences being

| Degree of frostbite | All 2555 (44 %) | Head 1668 (31 %) | Hands 1154 (20 %) | Feet 810 (15 %) |
|---------------------|----------------|-----------------|-----------------|---------------|
| missing             | 12             | 418             | 33              | 393           |
| 1st degree, superficial 2333 (41 %) | 1462 (28 %) | 1064 (19 %) | 738 (14 %) |
| missing             | 83             | 590             | 179             | 591           |
| >1st degree, deep 671 (12 %) | 459 (9 %)    | 213 (4 %)     | 174 (3 %) |
| missing             | 40             | 823             | 79              | 641           |
31% for the head, 20% for the hands and 15% for the feet. Frostbite was mostly mild, with 2333 respondents (41%) having first-degree cases and 671 (12%) having more severe ones. The experience of deep frostbite was higher in the case of the head than in that of the extremities: head 28% (459/1668), feet 22% (174/810) and hands 18% (213/1154).

**Table II.** Proportion of subjects with occurrence of frostbite in different areas of the body in relation to cold-provoked white finger syndrome (CPWF), smoking and vibration exposure. Crude odds ratios (OR) with their 95% confidence intervals (CI) by univariate binary logistic regression analysis.

| Area       | CPWF no | CPWF yes | Smoking | Vibration Exposure |
|------------|---------|----------|---------|--------------------|
| FEET FROSTBITES | total n | n (%)    | crude OR | 95% CI             |
| CPWF no     | 3928    | 92 (2)   | 1.00     | -                  |
| CPWF yes    | 1136    | 72 (6)   | 2.82     | 2.06 to 3.87       |
| Smoking no smoking | 2382 | 63 (3)   | 1.00     | -                  |
| Smoking occasionally | 607 | 29 (5)   | 1.85     | 1.18 to 2.89       |
| Smoking regularly | 2061 | 81 (4)   | 1.51     | 1.08 to 2.10       |
| Vibration Exposure no vibration | 2329 | 52 (2)   | 1.00     | -                  |
| Vibration Exposure 0-500 h/year | 1944 | 72 (4)   | 1.68     | 1.17 to 2.42       |
| Vibration Exposure >500 h/year | 861  | 48 (6)   | 2.58     | 1.73 to 3.86       |

| HAND FROSTBITES | total n | n (%)    | crude OR | 95% CI             |
| CPWF no     | 4308    | 106 (3)  | 1.00     | -                  |
| CPWF yes    | 1267    | 97 (8)   | 3.29     | 2.48 to 4.36       |
| Smoking no smoking | 2662 | 63 (2)   | 1.00     | -                  |
| Smoking occasionally | 686 | 26 (4)   | 1.62     | 1.02 to 2.59       |
| Smoking regularly | 2244 | 119 (5)  | 2.31     | 1.69 to 3.15       |
| Vibration Exposure no vibration | 2589 | 61 (2)   | 1.00     | -                  |
| Vibration Exposure 0-500 h/year | 2157 | 88 (4)   | 1.76     | 1.27 to 2.46       |
| Vibration Exposure >500 h/year | 949  | 60 (6)   | 2.80     | 1.94 to 4.03       |

| HEAD FROSTBITES | total n | n (%)    | crude OR | 95% CI             |
| CPWF no     | 3794    | 291 (8)  | 1.00     | -                  |
| CPWF yes    | 1099    | 152 (14) | 1.93     | 1.57 to 2.38       |
| Smoking no smoking | 2297 | 156 (7)  | 1.00     | -                  |
| Smoking occasionally | 592 | 56 (10)  | 1.43     | 1.04 to 1.97       |
| Smoking regularly | 1990 | 237 (12)| 1.86     | 1.50 to 2.29       |
| Vibration Exposure no vibration | 2262 | 162 (7)  | 1.00     | -                  |
| Vibration Exposure 0-500 h/year | 1857 | 173 (9)  | 1.33     | 1.07 to 1.67       |
| Vibration Exposure >500 h/year | 834  | 118 (14)| 2.14     | 1.66 to 2.75       |

| ALL FROSTBITES | total n | n (%)    | crude OR | 95% CI             |
| CPWF no     | 4331    | 416 (10) | 1.00     | -                  |
| CPWF yes    | 1274    | 228 (18) | 2.05     | 1.72 to 2.44       |
| Smoking no smoking | 2674 | 233 (9)  | 1.00     | -                  |
| Smoking occasionally | 693 | 86 (12)  | 1.48     | 1.14 to 1.93       |
| Smoking regularly | 2262 | 338 (15)| 1.84     | 1.54 to 2.20       |
| Vibration Exposure no vibration | 2602 | 238 (9)  | 1.00     | -                  |
| Vibration Exposure 0-500 h/year | 2175 | 263 (12)| 1.37     | 1.14 to 1.65       |
| Vibration Exposure >500 h/year | 957  | 161 (17)| 2.01     | 1.62 to 2.49       |
CPWF, smoking, vibration exposure and the occurrence of all types of frostbite
Logistic regression gave odds ratios and 95% confidence limits of the odds ratios for the various classes within each explanatory variable. The numbers of all frostbite cases are presented separately for the different body areas in relation to each risk factor in Table II. All the differences between the healthy subjects and those with CPWF, smokers, or those having been exposed to vibration, had limits of their confidence intervals greater than one. The presence of CPWF was associated with an increased occurrence of frostbite in all body parts, but which was stronger in the feet and hands than in the head. Frostbite among the smokers was associated with smoking as an occasional, or regular habit; the highest values in the limits of confidence interval of crude odds ratios were seen for regular smokers and hand frostbite. Vibration exposure was also associated with the occurrence of frostbite: i.e. already with those who were exposed for less than 500 hour per year, but especially those exposed for >500 hours per year. In hands this association was stronger than in the feet or head.

Table III. Proportion of subjects with occurrence of deep frostbite in all areas of the body studied. Adjusted odds ratios (OR) with their 95% confidence intervals (CI) among group with cold-provoked white finger syndrome (CPWF) and healthy controls by multivariate logistic regression analysis

|                  | OR     | 95% CI          |
|------------------|--------|-----------------|
| CPWF             |        |                 |
| Smoking          |        |                 |
| no smoking       | 1.000  | -               |
| occasionally     | 1.626  | 0.988 to 2.677  |
| regularly        | 1.914  | 1.373 to 2.669  |
| Annual vibration exposure |        |                 |
| no               | 1.000  | -               |
| 0-500 h/year     | 1.484  | 1.052 to 2.091  |
| > 500 h/year     | 1.919  | 1.282 to 2.871  |
| Healthy          |        |                 |
| Smoking          |        |                 |
| no smoking       | 1.000  | -               |
| occasionally     | 1.418  | 1.024 to 1.963  |
| regularly        | 1.648  | 1.316 to 2.065  |
| Annual vibration exposure |        |                 |
| no               | 1.000  | -               |
| 0-500 h/year     | 1.170  | 0.925 to 1.481  |
| > 500 h/year     | 1.689  | 1.281 to 2.225  |
**CPWF, smoking, vibration exposure and the occurrence of deep frostbite**

Logistic regression gave odds ratios and 95% confidence limits of the odds ratios for the various classes within each explanatory variable (Table III). The results showed that regular smoking and exposure to vibration for more than 500 hours a year act as risk factors, both in healthy subjects and in those suffering from CPWF. In addition, occasional smoking was a risk factor for frostbite in the healthy subjects, as was vibration exposure for 0-500 hours per year among the subjects with CPWF.

**DISCUSSION**

**Occurrence**

Information on the life-time occurrence of frostbite in civilian populations is somewhat limited. Our results suggest that frostbite is a common cold injury, even among young healthy men in an average circumpolar civilian population, since the life-time cumulative occurrence prior to military service was 44%. Factors related to life-style that have been earlier reported to increase the life-time occurrence of frostbite, such as alcohol abuse, other harmful substances, or the presence of psychiatric disorders, (14,15) could not have affected the present result, as respondents who were prone to these effects were excluded in advance from military service (and therefore would never have received this questionnaire). From the life-time frostbite occurrence, the estimated annual experience of frostbite obtained here was 2.2%, or more, which is close to the incidence of frostbite (2.3%) documented in hospital by the same subjects later, during their military service (16). Annual incidence rates reported earlier for frostbite suffered in peacetime military activities include figures of 3.1% (18) and 2.4% (12). Our results showed that the head area was more prone to frostbite than the extremities, the difference probably being due to inferior protection of the facial area (17). Consistent with the observations of Cattermole (18), superficial frostbite was often located in the head area, whereas the deep frostbite usually occurred in the extremities.
Risk of frostbite

In order to minimize heat loss and conserve the body core temperature, the circulation in the peripheral parts of the body is reduced in the cold (19) and, conversely, peripheral vasoconstriction ceases and the circulation returns to its initial level once cold exposure is over. Subjects with especially pronounced vasoconstriction, e.g. those with Raynaud’s phenomenon, exhibit occasional whitening of the skin on the fingers during cold exposure (20). The present results show that this CPWF increases the risk of frostbite. Indeed, it has been shown that thermal conditions in the peripheral tissues are altered in the presence of certain idiopathic circulatory disturbances: i.e. persons with primary Raynaud’s phenomenon have lower finger temperatures than healthy persons during whole-body cooling (21) and also show a decreased rate of surface temperature rise upon re-warming (22). Cold-induced vasoconstriction, especially in the fingers, may temporarily disappear upon severe cooling, due to cold-induced vasodilatation (23). The temperature of the skin increases during the vasodilatation phase, which thus serves to prevent freezing injury (11). Moreover, the constriction and dilatation phases may alternate, which is often referred to as the "Hunting Phenomenon" (24). Persons with an absence of the hunting phenomenon, representing about 15-20% of the average population, are more likely to have pale hands in the cold and are more prone to frostbite than those who experience alternating constriction and dilatation phases.

Circulatory disturbances may also arise from external stress factors. The use of vibrating tools may cause hypersensitivity to cold, probably via damage to the vasoregulatory structures, especially during the vasodilatation phase of cold adaptation (25, 26). We found that exposure to hand vibration was a risk factor for frostbite at both levels of exposure that we followed. The risk is still seen at lower levels of exposure than those reported by Virokannas and Anttonen (27).

The results also suggest that smoking is a risk factor for frostbite. Absorbed nicotine elevates plasma catecholamine levels, whilst other constituents of the smoke reduce the synthesis of nitric oxide, an important vasodilator and also impairs endotelium-dependent skin vasorelaxation (28). Smoking also potentiates
thrombosis, by increasing fibrinogen concentrations and platelet activity (28), thus hindering blood flow, an effect which becomes accentuated in constricted vessels.

In conclusion, the present results shown that there is high occurrence of frostbite among young healthy individuals, which should be noted by the health care personnel in northern countries. It has been reported that individual risk factors for frostbite, including both physiological and exposure factors, affect the peripheral circulation and, consequently, the thermal balance of superficial tissues (for a review, see 13). It is beyond the scope of this article, however, to assess the critical limit for each exposure factor.

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