

Occurrence of frostbite in the general population – work-related and individual factors

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Mäkinen TM, Jokelainen J, Näyhä S, Laatikainen T, Jousilahti P, Hassi J. Occurrence of frostbite in the general population – work-related and individual factors. *Scand J Work Environ Health*. 2009;35(5):384–393.

Objective To examine the occurrence of frostbite in the general population and the related risk factors.

Methods We analyzed two national FINRISK studies (1997 and 2002) and their cold sub-studies (N=2624 and N=6951, respectively), consisting of questionnaires administered to men and women aged 25–74 years.

Results A total of 697 frostbites were reported, 425 of which had occurred during the past year and 272 over a lifetime according to the respondents. The overall proportion of annually occurring *mild* frostbite was 12.9% (14.2% and 11.9% for men and women, respectively). The annual incidence of *severe* frostbite was 1.1% (1.6% and 0.6% for men and women, respectively). The cumulative lifetime incidence of severe frostbite was 10.6% (14.1% and 7.4% for men and women, respectively). Frostbite occurs more often in men than women and decreases in frequency over the age of 65. Most frostbite incidents were reported among occupational groups such as skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators, assemblers and technicians, and associate professionals. Work-related risk factors included employment in certain industries, high physical strain, and weekly cold exposure at work; however frostbite was also likely to occur during leisure time. Individual factors that increase frostbite risk are diabetes, white fingers in the cold, cardiac insufficiency, angina pectoris, stroke, depressive feelings, and heavy alcohol consumption.

Conclusions Work-related and individual risk factors should be taken into account when developing risk assessment and management strategies for preventing frostbite both at work and during leisure time.

Key terms cold exposure; cold injury; health; physical strain; population; occupation.

Frostbite is a tissue injury resulting from tissue cooling and subsequent freezing. A frostbite injury may be superficial, or extend to deeper layers of the skin and cause permanent tissue damage. Although fewer than one out of 10 000 people are admitted to hospital due to frostbite (1), other forms of frostbite are common in northern populations and may cause harmful sequelae. For example, over 60% of people sustaining a severe frostbite may suffer from different post-frostbite symptoms (2) while 43% reported decreased work ability (3). Furthermore, 13% of those with finger frostbite reported hypersensitivity to cold, pain, numbness, functional limitations, and decreased work ability (2). However,

the occurrence of frostbite in the general population is not well known. The available information is limited to conscripts (4), schoolchildren (5) and cases treated in hospital (6, 7). There are reports from specific occupational groups (8–10) but even then the information is insufficient (11).

Frostbite is preventable and, therefore, unacceptable from the viewpoint of public health and occupational safety. As exposure to cold is markedly high in Finland, especially among certain occupational groups (12), we have determined the occurrence of frostbite using two nationwide health surveys (national FINRISK studies). Our paper reports the annual and lifetime incidence

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of frostbite in the general population of Finland, with breakdowns by gender, age, occupational group, smoking habits, and alcohol consumption. The potential effect of physical strain was also considered, as people performing physically strenuous work are often exposed to environmental cold. Since pre-existing diseases may predispose individuals to frostbite, separate analyses were devoted to people suffering from various medical conditions.

Study population and methods

We obtained the data, on which our findings are based, from two independent national FINRISK studies conducted from January to April in both 1997 and 2002. In conjunction with these studies, participants completed a separate questionnaire on cold-related complaints.

In January 1997, the average temperature ranged from -4.1°C (Helsinki in southern Finland) to -13.7°C (Utsjoki in northern Finland). The average temperature in April of the same year was $+2.0^{\circ}\text{C}$ (Helsinki) and -6.6°C (Utsjoki). In 2002, the January average temperature ranged from -2.6°C (Helsinki) to -12.1°C (Utsjoki) and in April from $+7.0^{\circ}\text{C}$ (Helsinki) to $+3.4^{\circ}\text{C}$ (Utsjoki).

The 1997 national FINRISK study

The 1997 FINRISK study was carried out in five areas of Finland: (i) the county of North Karelia (ii), the county of Northern Savo (iii) the cities of Turku and Loimaa, as well as 11 other municipalities in South-West Finland, (iv) the cities of Helsinki and Vantaa, and (v) the province of Oulu (figure 1).

The study population consisted of men and women aged 25–64 years. In addition, a sample of 65–74 year old women and men from North Karelia and Helsinki were included. From each area, a random sample of 250 25–64 year olds, stratified by gender and 10-year age groups, was selected from the national population register; an additional 250 women and 500 men aged 65–74 years from North Karelia and Helsinki were included. Of 11 500 people, a random sample of 4397 persons (40%) was selected for the cold sub-study, 60% (2624 persons) of whom returned the cold questionnaire.

The 2002 national FINRISK study

In addition to the five areas mentioned above, the 2002 survey included Lapland, the northernmost province of Finland. A random sample in the age range 25–64 years, stratified by sex and age, was drawn from each area; the age group 64–74 years was also included in Helsinki/Vantaa, North Karelia, and Lapland. The entire sample size was 13 437, but 3181 people selected randomly

from all areas – except Lapland – attended a dietary interview and were excluded from the cold sub-study. The cold questionnaire was sent out to the remaining 10 256 people, 6591 of whom (64%) replied.

The questionnaire

In the FINRISK questionnaire, each respondent was asked to indicate whether he/she had sustained a mild or severe (at least blister grade) frostbite during the past year, or a severe frostbite at any point during his/her lifetime (see appendix). As the question concerning the annual occurrence of severe frostbite was similar for 1997 and 2002, the data was pooled for the regression analyses regarding this particular question. The occurrence of mild frostbite and lifetime cumulative incidence of severe frostbite were derived from the 1997 data and analysed separately. The questionnaire asked for the location of the injury in 1997 and the number of frostbites in 2002, but these were omitted from our analysis.

The field of work in which the respondent was engaged for most of the year was classified into seven main categories, including pensioners and the unemployed, as detailed in the appendix. There was an

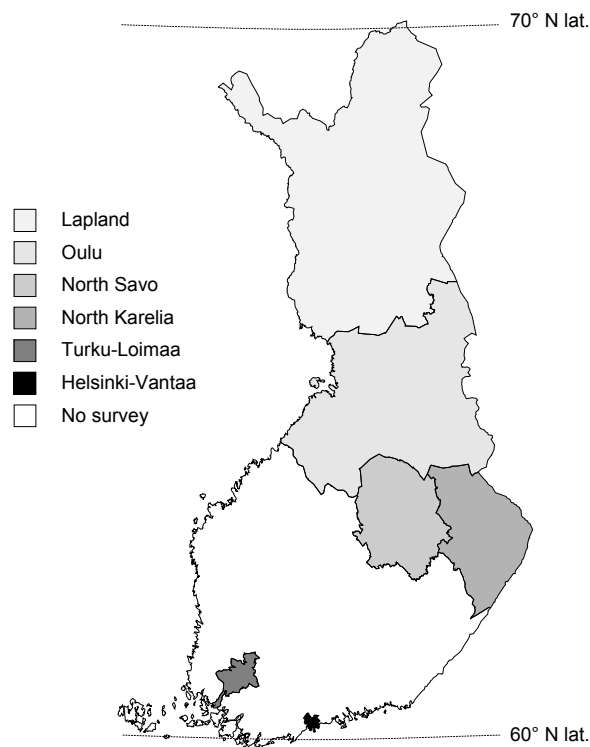


Figure 1. The areas studied in 1997 and 2002 (the area of Lapland was only included in 2002).

open-ended question on current occupation (or former occupation if the respondent was retired or unemployed), the answer to which was coded according to the International Standard Classification of Occupations (for European Union purposes, 1988 version). The questionnaire asked about the amount of physical strain separately for work, leisure time, and commuting to and from work.

Health-related questions inquired whether the respondent had suffered from any of the following diseases diagnosed or treated by a doctor during the past 12 months: elevated blood pressure or arterial hypertension, and cardiac insufficiency or chest pain upon exertion (angina pectoris). Respondents were also asked if they had ever been diagnosed with myocardial infarction, cerebral stroke, diabetes or glucose intolerance, or whether they had experienced depression or depressive feelings for at least two weeks during the past year. Finally, subjects were asked whether they suffered from episodic color changes (eg, fingers turn white in the cold).

The questionnaire measured alcohol consumption by asking how many bottles of beer (medium strong or strong) or cider, or how many portions of hard liquor or glasses of wine the respondent had consumed during the last seven days. The responses were converted to grams per week and classified as light, moderate, and heavy drinking: <230, 230–350 and >350 g/week, respectively, for men and <150, 150–210, >210 g/week, respectively, for women (13).

Smoking was also covered in the questionnaire. Based on structured questions, the respondents were classified as: (i) current smokers (ie, those who had smoked regularly for at least one year and had smoked during the previous month), (ii) ex-smokers (ie, those who had smoked regularly, but had quit <0.5 years before the survey), (iii) ex-smokers (ie, those who had smoked regularly, but quit at least >0.5 years before the

survey), and (iv) non-smokers (ie, those who had never smoked regularly).

Statistical analyses

The occurrence of frostbite was measured as: (i) lifetime cumulative incidence of severe frostbite (ie, the proportion of respondents who had sustained at least one such frostbite during their lifetime), and (ii) annual incidence of severe and mild frostbite (ie, the proportion of respondents who had sustained at least one such frostbite during the past year). The results were expressed as crude incidence proportions and odds ratios (OR), adjusted for gender and age (in 10-year classes) together with their 95% confidence intervals (95% CI). We performed statistical analyses using the SAS system version 9.1 for Windows (SAS Institute, Cary, NC, USA) and set significance at $P < 0.05$.

Results

Incidence of frostbite by age

Out of a total of 13 713 respondents in the two surveys, 697 (5.1%) had sustained at least some kind of a frostbite. The overall incidence during the past year was 12.9% for *mild* frostbite (FINRISK 1997) and 1.1% for *severe* frostbite (FINRISK 1997 and 2002 combined). In addition, the amount of respondents who reported having a severe frostbite during their lifetime was 10.6% (FINRISK 1997). All types of frostbite were more common in men than women, except in the age group 25–34 where the gender ratio was reversed (table 1). The annual incidence of mild frostbite decreased consistently with age, while no age trend was seen for the annual

Table 1. Self-reported occurrence of mild (superficial) and severe (blister grade or more severe) frostbite during the past year and over a lifetime for men and women by age.

Age	Mild frostbite (FINRISK 1997)				Severe frostbite (FINRISK 1997)				Severe frostbite (FINRISK 2002)				Severe frostbite, lifetime cumulative occurrence (FINRISK 1997)			
	Men		Women		Men		Women		Men		Women		Men		Women	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
25–34 years	223	18.4	280	23.9	221	3.2	280	1.8	522	1.2	705	0.1	223	10.8	282	4.3
35–44 years	261	14.9	292	11.0	259	1.5	291	1.4	603	1.7	737	0.8	261	10.0	293	7.5
45–54 years	284	15.5	320	9.1	284	2.8	320	0.0	658	1.1	740	0.8	287	15.7	319	7.2
55–64 years	310	11.9	336	8.3	309	1.6	339	1.2	753	1.3	791	0.5	311	19.6	340	10.9
65–74 years	139	8.6	130	3.1	140	2.1	131	0.8	479	0.6	464	0.7	141	12.1	135	5.2
Total	1217	14.2	1358	11.8	1213	2.2	1361	1.0	3015	1.2	3437	0.6	1223	14.1	1369	7.4

incidence of severe frostbite. The amount of respondents who reported having a severe frostbite during their lifetime increased cumulatively up to those aged 55–64 years, but declined thereafter. Severe frostbiting decreased from 1997 to 2002 (from 2.2% to 1.2% in men and 1.2% to 0.6% in women).

Incidence of frostbite by industry and occupational group

The incidence of frostbite showed a difference among trade and occupational groups (table 2). However, it should be noted that the observed frostbiting could have occurred both during work, as well as leisure time. Of those men reporting a mild frostbite during the previous year, 28% were engaged in agriculture, forestry, stock-raising or related work, 24% were students, 17% were unemployed, and 10% were pensioners. For women reporting similar frostbite, the figures were students: 29%; agriculture/forestry-related workers: 16%; and pensioners: only 5%. Similar differences were seen for severe frostbite, with unemployed men or men engaged in agriculture/forestry-related work showing a relatively high incidence (3%). For women with severe frostbite, only agriculture/forestry-related work was pronounced, but the absolute differences were small. The occurrence of frostbite over a lifetime was also relatively high in both male and female agriculture/forestry-related workers, pensioners, and the unemployed.

Severe frostbite during the past year was further classified by the detailed occupation categories available in the 2002 survey. The proportion of severe frostbite was 18.4% and actually the same in four occupational groups

[data not shown (individual occupations in parentheses)]: (i) skilled agricultural and forestry workers (reindeer herder, housewife, agriculture/forest worker); (ii) craft and related trades workers (institutional assembler, electrical assembler, assembler, construction worker, painter, carpenter, vehicle painter, asphalt worker); (iii) plant and machine operators, and assemblers (felling machine operator, excavation vehicle operator, forestry vehicle operator, sewing machine entrepreneur, ferry operator, factory worker, machine operator, driver); and (iv) technicians and associated professionals (psychiatric nurse, foreman, special advisor [forestry], product group expert, forest industry technician, physiotherapist, physical education instructor, building contractor, client advisor).

Work-related risk factors

For students and agriculture/forestry-related workers, the age- and gender-adjusted odds ratio (OR) for sustaining a mild frostbite were twice as high as that of office workers. The adjusted OR for severe frostbite during the past year was even higher for those involved in agriculture/forestry-related work, pensioners, and the unemployed; severe lifetime frostbite was also elevated for the same groups (table 3). Physical strain at work was associated with mild frostbite and severe lifetime frostbite, while no such association was found regarding physical strain during leisure time. Physical strain while commuting that lasted at most 1 hour/day showed marginally elevated OR compared with those reporting no strain, mainly for mild frostbite and severe lifetime frostbite, but no such association was seen for

Table 2. Self-reported occurrence of mild (superficial) and severe (blister grade or more severe) frostbite during the past year and over a lifetime for men and women by trade.

Trade	Mild frostbite (FINRISK 1997)				Severe frostbite (FINRISK 1997 and 2002)				Severe frostbite, lifetime occurrence (FINRISK 1997)			
	Men		Women		Men		Women		Men		Women	
	N	%	N	%	N	%	N	%	N	%	N	%
Agriculture ^a	80	27.5	61	16.4	238	3.4	165	1.2	80	20.0	61	11.5
Industry ^b	258	14.7	63	4.8	952	1.5	210	1.0	259	10.8	63	3.2
Office ^c	381	12.9	643	13.2	1409	1.3	2464	0.5	383	11.7	645	6.4
Student ^d	25	24.0	51	29.4	25	12.0	51	7.8
Housewife	.	.	102	14.7	.	.	288	0.4	.	.	102	4.9
Pensioner	317	9.8	297	5.4	1123	1.3	1068	0.8	321	17.4	305	10.5
Unemployed	140	17.1	130	12.3	321	3.4	365	0.8	140	15.7	131	7.6
Total	1201	14.2	1341	11.9	4043	1.6	4560	0.6	1210	14.1	1358	7.4

^a Comprises agriculture, forestry, stock raising and related occupations.

^b Comprises factory work, mining, construction work or related occupations.

^c Comprises office, service, mental work (planning, management, administration or related occupations).

^d Severe frostbite occurring during the previous year was not reported in students.

Table 3. Self-reported occurrence of mild (superficial) and severe (blister grade or more severe) frostbite during the past year and over a lifetime for men and women by work-related factors. (Ref = Reference group)

	Mild frostbite (FINRISK 1997)				Severe frostbite (FINRISK 1997 and 2002)				Severe frostbite, lifetime cumulative (FINRISK 1997)			
	N	%	Adjusted OR ^a	95% CI	N	%	Adjusted OR ^a	95% CI	N	%	Adjusted OR ^a	95% CI
Trade												
Office ^b	1024	13.1	Ref	..	3752	0.7	Ref	..	1028	8.4	Ref	..
Agriculture ^c	141	22.7	1.9	1.2–3.0	431	2.3	3.1	1.5–6.4	141	16.3	1.9	1.1–3.1
Industry ^d	321	12.8	0.9	0.6–1.3	1144	1.3	1.4	0.7–2.8	322	9.3	0.8	0.5–1.3
Student	76	27.6	1.9	1.1–3.3	285	0.4	0.4	0.1–3.2	76	9.2	1.5	0.6–3.5
Housewife	104	14.4	1.1	0.6–2.0	310	0.3	0.5	0.1–4.0	104	5.8	1.0	0.4–2.4
Pensioner	614	7.7	0.8	0.5–1.3	2231	1.1	2.3	1.1–4.8	626	14.1	1.7	1.1–2.5
Unemployed	270	14.8	1.2	0.8–1.7	724	2.2	3.1	1.7–5.9	271	11.8	1.3	0.8–2.0
Physical strain at work												
None	1399	11.0	Ref	..	4659	0.9	Ref	..	1406	10.2	Ref	..
Light	547	15.7	1.3	1.0–1.7	1988	0.8	0.9	0.5–1.6	549	9.5	1.1	0.8–1.6
Moderate	426	12.7	1.0	0.7–1.4	1507	2.1	2.2	1.3–3.6	8427	11.5	1.2	0.8–1.7
Heavy	118	27.1	2.3	1.5–3.6	459	1.5	1.3	0.6–3.1	120	18.3	1.8	1.1–3.1
Physical strain during leisure time												
None	561	12.7	Ref	..	2027	1.0	Ref	..	565	9.9	Ref	..
Little	1439	11.6	1.0	0.7–1.3	4871	0.9	0.9	0.6–1.6	1448	10.8	1.0	0.7–1.4
Moderate	494	16.6	1.2	0.9–1.7	1844	1.6	1.5	0.9–2.7	494	11.3	1.2	0.8–1.7
Often	27	22.2	1.4	0.5–3.7	91	0.0	–	–	27	3.7	0.3	0.0–2.4
Physical strain while commuting												
None	1432	11.4	Ref	..	5142	1.1	Ref	..	1445	10.8	Ref	..
<15 min/day	319	15.7	1.3	0.9–1.9	1133	0.9	0.8	0.4–1.5	318	10.1	1.0	0.6–1.5
15–30 min/day	348	16.1	1.4	1.0–2.0	1144	1.0	0.9	0.5–1.8	349	9.7	1.0	0.7–1.5
30–44 min/day	199	15.1	1.4	0.9–2.1	663	1.4	1.5	0.7–3.0	200	11.0	1.3	0.8–2.1
45–59 min/day	72	20.8	2.1	1.2–3.9	255	1.2	1.3	0.4–4.1	73	15.1	1.8	0.9–3.6
>1 hour/day	91	8.8	0.8	0.4–1.7	280	1.8	1.8	0.7–4.7	90	6.7	0.6	0.3–1.4
Reported weekly cold exposure^e												
At work												
<1 hour/week	–	–	–	..	1564	0.6	Ref	–	–	–	–	..
1–10 hours/week	–	–	–	..	893	1.2	1.9	0.8–4.6	–	–	–	..
>10 hours/week	–	–	–	..	550	2.0	2.9	1.1–7.3	–	–	–	..
Total												
<1 hour/week	–	–	–	..	135	0.7	Ref	–	–	–	–	..
1–10 hours/week	–	–	–	..	3883	0.6	0.8	0.1–5.9	–	–	–	..
>10 hours/week	–	–	–	..	2143	1.2	1.6	0.2–11.6	–	–	–	..

^a Adjusted by age and gender.^b Office, service, mental work (planning, management, administration or related occupations).^c Agriculture, forestry, stock raising and related occupations.^d Factory work, mining, construction work or related occupations.^e Includes only FINRISK 2002 data.

commuting times >1 hour/day. Severe frostbite during the past year was three times as common in those reporting a weekly exposure time to cold of >10 hours compared with those reporting of <1 hour/week.

Individual risk factors

The respondents who had been diagnosed with cardiac insufficiency, angina pectoris, white fingers, diabetes or glucose intolerance, or who often felt depressed showed

2–3 higher OR for severe frostbite during the past year than those with no such conditions, the trend being similar – but weaker – for severe lifetime frostbite (table 4). The OR for mild frostbite during the past year were significantly elevated for white fingers and depression, but not for other medical conditions. The OR for heavy alcohol consumption was marginally elevated compared with light consumption, but in the year 2002 separately the OR was 4.3 (95% CI 1.6–11.5). Smoking was not associated with any type of frostbite with any certainty.

Table 4. Self-reported occurrence of mild (superficial) and severe (blister grade or more severe) frostbite during the past year and over a lifetime for men and women by individual risk factor. (Ref = Reference group)

	Mild frostbite (FINRISK 1997)				Severe frostbite (FINRISK 1997 and 2002)				Severe frostbite, lifetime (FINRISK 1997)			
	N	%	Adjusted OR ^a	95% CI	N	%	Adjusted OR ^a	95% CI	N	%	Adjusted OR ^a	95% CI
Acute myocardial infarction												
Yes	71	7.0	0.7	0.3–1.8	258	1.6	1.5	0.5–4.3	74	13.5	1.0	0.5–2.0
No	325	13.0	Ref	..	8702	1.0	Ref	..	2510	10.4	Ref	..
Stroke												
Yes	6	9.2	0.9	0.4–2.1	193	2.1	2.0	0.7–5.7	68	10.3	0.7	0.3–1.6
No	2499	13.0	Ref	..	8760	1.0	Ref	..	2513	10.6	Ref	..
Hypertension												
Yes	501	10.8	1.0	0.7–1.4	1792	0.9	0.9	0.5–1.6	506	13.2	1.2	0.9–1.6
No	2039	13.4	Ref	..	7102	1.0	Ref	..	2050	9.8	Ref	..
Cardiac insufficiency												
Yes	75	12.0	1.4	0.7–2.9	272	2.6	3.3	1.4–7.5	79	15.2	1.3	0.7–2.5
No	2448	12.9	Ref	..	8604	1.0	Ref	..	2459	10.2	Ref	..
Angina pectoris												
Yes	112	12.5	1.5	0.8–2.6	406	2.0	2.4	1.1–5.3	116	14.7	1.2	0.7–2.2
No	2415	12.8	Ref	..	8478	1.0	Ref	..	2428	10.2	Ref	..
White fingers in cold												
Yes	690	24.8	3.8	3.0–4.9	2051	1.9	2.4	1.6–3.6	696	15.5	2.1	1.6–2.8
No	1885	8.6	Ref	..	6976	0.9	Ref	..	1896	8.8	Ref	..
Diabetes												
Yes	95	8.4	0.8	0.4–1.6	23	311	2.6	1.1–5.7	10.3	2417	1.4	0.8–2.5
Glucose intolerance	49	6.1	0.5	0.2–1.7	174	2.3	2.8	1.0–7.9	51	17.7	1.6	0.7–3.3
No	2404	13.3	Ref	..	1.0	8374	Ref	..	15.5	97	Ref	..
Feeling depressed												
Often	121	18.2	1.9	1.2–3.1	415	2.2	2.4	1.2–5.0	123	13.0	1.6	0.9–2.9
Sometimes	1052	14.4	1.3	1.0–1.7	3184	1.0	1.1	0.7–1.7	1058	11.6	1.4	1.1–1.8
Not at all	1382	11.4	Ref	..	5319	1.0	Ref	..	1389	9.5	Ref	..
Use of alcohol												
Light	2206	12.56	Ref	..	7244	1.0	Ref	..	2220	10.45	Ref	..
Moderate	137	13.87	1.0	0.6–1.7	1168	1.0	0.8	0.4–1.5	137	10.95	1.0	0.6–1.7
Heavy	48	20.83	1.9	0.9–3.9	259	2.7	2.1	0.9–4.6	48	6.25	0.5	0.1–1.5
Smoking												
1. No	1377	13.2	Ref	..	4720	0.9	Ref	..	1383	9.3	Ref	..
2. Quit >1/2 years ago	523	10.9	0.8	0.6–1.2	1874	1.2	1.1	0.6–1.8	527	14.8	1.3	0.9–1.8
3. Quit <1/2 years ago	48	14.6	0.9	0.4–2.1	150	0.7	0.6	0.1–4.3	48	10.4	1.1	0.4–2.8
4. Current smoker	608	13.8	0.9	0.7–1.3	2197	1.3	1.1	0.7–1.8	612	10.1	1.0	0.7–1.3

^a Adjusted for age and gender.

Discussion

Occurrence of frostbite in the population

The annual incidence of 13% and 1% for mild and severe frostbite, respectively, and 11% for severe lifetime frostbite are the first published estimates based on an entire general population aged 25–74 years. The occurrence of frostbite was greater in occupational groups such as skilled agriculture and fishery workers, craft and related trades workers, plant and machine operators, assemblers and technicians, and associate professionals.

Frostbite risk was also higher in certain industries and for physically strenuous work or individuals suffering from cardiovascular conditions, diabetes, white fingers, or depressed mood. Frostbite risk generally was associated with male gender and alcohol consumption; the risk of mild frostbite was associated with young age, while the effect of smoking was not confirmed.

The higher incidence of frostbite in men is in accordance with previous findings (14, 15) and can be explained by men's longer exposure to cold, both at work and during leisure time (12), and the higher prevalence of chronic diseases and alcohol use among men,

making them more susceptible to frostbite. Additionally, unemployment and lower education increase cold exposure (12) and can affect frostbite risk in men. The high occurrence of mild frostbite among the youngest respondents can be attributed to young people engaging more in recreational outdoor activities (12). Deficient skills and experience among young people regarding cold protection may provide a further explanation. The decline of frostbite incidence with advancing age could be due to increased morbidity and impaired functional capacity, thus limiting opportunities for outdoor activities among the elderly who are sick.

Frostbite by industry and occupational group

Work in cold conditions involves potential adverse effects ranging from unpleasant sensations to performance degradation, impaired health, and, at its worst, cold injuries (16, 17). Although the majority of the Finnish population is employed in indoor occupations, 57% of men are exposed to cold at work for >10 hours/week (12); we have shown a three-fold increase of severe frostbite at exposure times of >10 hours/week.

Frostbite was most common among people working in agriculture, forestry, stock raising or related work where the weekly working time in the cold is long, (ie, eight hours more than office work) (12). Another study based on insurance statistics also reported an elevated incidence of frostbite in agricultural workers (8). The relatively high incidence of frostbite among students, pensioners, and the unemployed may be related to the long time spent in the cold during leisure time (12). Also, the occurrence of frostbite among office workers suggests that these had occurred during non-working time. Age-related physiological changes, which impair thermoregulation and lower heat production capacity (18, 19), as well as the morbidity mentioned above are likely to increase frostbites among pensioners.

The specific occupational groups where frostbite occurred frequently were: skilled agricultural and fishery workers; craft and related trades workers; plant and machine operators, assemblers, and technicians; and associated professionals. Individual occupations within these categories could not be analyzed separately, but a relevant finding in the literature was the high occurrence of frostbite (annual incidence 22%) among reindeer herders, especially in conjunction with snowmobile driving (9). Sinks et al (8) reported an increased number of cold-weather injuries in connection with vehicle breakdown, which could help us understand the high occurrence of frostbite among machine operators. While frostbite is commonly reported among military personnel (3, 20–22), our study was unable to repeat this finding due to the insufficient size of this occupational group in our sample.

Individual risk factors

A novel finding was the association of cardiac insufficiency and angina pectoris with severe frostbite. Cold exposure places strain on the heart and circulatory function, and results in vasoconstriction and increased blood pressure, which increases the work load on the heart and requires higher oxygen demand (23). Reports on frostbite in people suffering a heart condition do not exist, but the impaired circulation among people with failing hearts would obviously predispose them to frostbite. An additional explanation is offered by concomitant diabetes mellitus (present in about one out of ten people with cardiac insufficiency) which should predispose individuals to frostbite due to diabetic neuropathies and altered thermoregulation. The blood flow in the lower extremities (24) as well as capillary blood flow (25) is lower in diabetics, and the cold-induced vasoconstriction is impaired (26). We found an elevated risk for severe frostbite in diabetics, but cannot attribute this to diabetes alone, since approximately three out of four respondents also had a cardiovascular disease.

Episodic color changes in the fingers in the cold, here associated with an increased risk of frostbite, are often related to Raynaud's phenomenon (27). Patients with Raynaud's phenomenon have lowered blood flow during cold exposure (28), delayed onset of cold-induced vasodilatation (29) and delayed recovery of blood flow after cooling (30), which decreases protection from cooling. Experience from reindeer herders (9) and young men in Finland (4) also points to an increased risk of frostbite among people with white finger syndrome.

No population-based survey has previously reported an increased risk of frostbite in people with depressive mood or a diagnosed mental depression, although small hospital studies suggest that psychiatric disease plays a role in frostbite (31–33). In our sample, frostbite risk increased with depressive mood, and could be related to high risk behavior, or some co-morbid condition.

Alcohol consumption has been shown to increase the risk of frostbite (7, 31), which is in line with our findings. Smokers have impaired microcirculation (34) and could be expected to have an increased risk for frostbite, but actual findings in the literature are contradictory. In Finland, young smoking men showed an increased risk (4), but reindeer herders did not (9), which is in accordance with the present study. There is a possibility that smoking may even enhance cold-induced vasodilatation and protect against frostbite (35).

Strengths and limitations

The strengths of our study included the representativeness of the sample, good geographical coverage, and relatively minor socioeconomic variations throughout

the country. The obtained results are applicable to the subarctic regions with comparable socioeconomic conditions. A limitation was that frostbite could not be directly linked with work because the detailed conditions in which the frostbite occurred were not assessed and the separation of work and non-work exposure was consequently not possible. However, additional information on work conditions, such as work-related physical strain and the time spent in the cold, supported our findings that occupational factors are associated with frostbite. Furthermore, the majority of the people surveyed were employed. Nevertheless, it is also probable that some of the reported frostbites occurred during leisure time. Another limitation of the study was the considerable drop-out which could cause some bias in the conclusions, as it is uncertain whether the risk of frostbite for the non-participants differed from the study population. Finally, a further limitation of the study was that self-reported outdoor exposure was assessed in a retrospective manner reflecting the average situation of the past winter. This may have resulted in inaccuracies (memory bias) especially in older age groups and when estimating lifetime cumulative incidence of frostbite.

Concluding remarks

Frostbite is a tissue injury which is not acceptable from a public health or occupational safety perspective. It may cause functional limitations and, for example, absence from work due to sick leave or hospitalization. Our results indicated that frostbite is a problem among the working-age population, especially in certain occupational and industrial groups. Work-related factors, such as the degree of physical strain and the reported amount of cold exposure at work affect frostbite risk. However, it is likely that frostbite also occurs also during leisure time. Our findings provide new knowledge on the work-related and individual risk factors of frostbite and may be used for appropriate cold risk management. These should be targeted both at work, as well as leisure time activities.

Acknowledgements

The study was financially supported by the Finnish Work Environment Fund. Jouko Remes from the Finnish Institute of Occupational Health is acknowledged for his work in analyzing the FINRISK 1997 data.

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Received for publication: 26 January 2009

Appendix

1997 and 2002 FINRISK questions

Frostbites

1. During the last year, have you experienced a mild frostbite which has caused hardening and whitening of the skin, but no blister formation? If the reply is yes, please indicate the location of the injury (hands, feet and face/ears separately) (FINRISK 1997)
2. During the last year, have you experienced a frostbite which involves the formation of blisters, or is associated with ulcers or tissue necrosis? (FINRISK 1997 and FINRISK 2002, data pooled)
3. Have you ever during your lifetime experienced a frostbite which involves the formation of blisters, or is associated with ulcers or tissue necrosis? (FINRISK 1997).

Trade and occupational groups

What type of work are you engaged in during most of the year?

1. Agriculture (agriculture, stock raising, forestry, and related occupations)
2. Industry (factory work, mining, construction work or related work)
3. Office work (office, services, mental work [planning, management, administration or related work])
4. Student
5. Housewife
6. Pensioner
7. Unemployed

What is your occupation? Answers were categorized according to the International Standard Classification of Occupations

1. Legislators, senior officials and managers
2. Professionals
3. Technicians and associate professionals
4. Clerks
5. Service and care workers, and shop and market sales workers
6. Skilled agricultural and fishery workers
7. Craft and related trades workers
8. Plant and machine operators and assemblers
9. Elementary occupations
10. Armed forces

Physical strain and exercise

How physically strenuous is your work?

1. My work mainly comprises sitting, and I do not walk much at work
2. I walk at work quite often, but do not have to lift or carry heavy items
3. I often have to walk and lift items at work, or climb stairs or walk uphill frequently
4. The work involves heavy physical strain with lifting or carrying heavy items, digging, shoveling or hacking frequently

How much do you move and strain yourself physically during your leisure time?

1. I read, watch TV and perform tasks where I do not move around much, and which are not physically strenuous
2. I walk, cycle or move at least 4 hours a week. This includes walking, fishing or hunting, light gardening work, but not commuting.
3. I am engaged in fitness training such as running, jogging, skiing, gymnastics, swimming, ball games, or I do gardening involving heavy physical activity, or associated activities for at least 3 hours a week.
4. I am engaged in competitive training several times a week, such as running, orienteering, skiing, swimming, ball games or other sports activities involving heavy physical strain.

While commuting, for how many minutes a day do you walk or cycle, or travel in some other way demanding physical exercise?

1. Not at all
2. Less than 15 minutes
3. 15–29 minutes
4. 30–44 minutes
5. 45–49 minutes
6. More than one hour