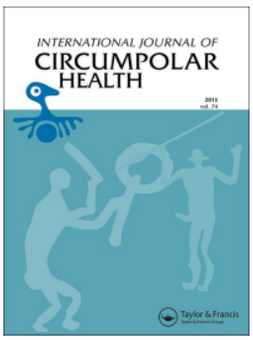

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A prospective study on local cold injuries in northern Sweden

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ABSTRACT

The study aimed to determine the prevalence and incidence proportion of local cold injuries in northern Sweden, and identify associated factors. It was based on prospective data from surveys in 2015 and 2021 sent to a population-based sample in northern Sweden. Multiple binary logistic regression was performed. The study included 5,017 subjects (response rate 44.4%). The prevalence of cold injuries in the hands was 11.4%, feet 12.6%, and face 19.9%, while the incidence proportion was 1.0%, 1.0%, and 0.9%, respectively. Male gender was associated with incident cold injuries in the hands (OR 1.69; 95% CI 1.31–1.28), feet (OR 1.34; 95% CI 1.04–1.73), and face (OR 1.53; 95% CI 1.15–2.03); mental stress with cold injuries in the hands (OR 1.55; 95% CI 1.16–2.05) and feet (OR 1.39; 95% CI 1.04–1.88); previous stroke with cold injuries in the hands (OR 2.64; 95% CI 1.09–6.40) and face (OR 3.09; 95% CI 1.26–7.56); and Raynaud's phenomenon with cold injuries in the hands (OR 2.48; 95% CI 1.80–3.41) and feet (OR 2.07; 95% CI 1.50–2.87). We conclude that male gender, mental stress, previous stroke, and Raynaud's phenomenon increased the probability of contracting local cold injuries.

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Cold exposure; cold injury; Sweden

Introduction

The environment in northern Sweden is characterised by a subarctic climate in which the winters are long and cold. In this environment, local cold injuries are very common. Cross-sectional data from one of our previous studies indicated that 7–30% of the population in northern Sweden were afflicted with local cold injuries, depending on the affected body part and gender [1]. Local cold injuries can result in long-lasting symptoms and functional limitations, which can affect the quality of life and work ability [2,3]. Effective treatments of such sequelae are largely lacking, but the injuries are preventable to a considerable degree.

Exposure to low ambient temperatures, cold surfaces, objects, and liquids may all individually or in combinations cause local cold injuries [4,5]. In an occupational setting, cold ambient temperatures have been defined as being 10°C or below [6]. External factors that contribute to increased cooling and risk for local cold injuries are windspeed, humidity, and radiation fluxes. Also, the duration of exposure affects the outcome [4,7]. Exposure to cold can occur during leisure time, working time, and while travelling in daily life [8]. Occupations that implicate extensive cold exposure include mining, military, forestry, agriculture, construction work, and tourism [1,8]. Also, indoor work such as that in the food industry may implicate cold exposure when handling fresh foodstuff and frozen goods [9,10]. Beyond occupational factors, individual factors such as gender, age, education, physical activity, and health status also modify the effects of cold exposure [9,11].

Local cold injuries are divided into freezing cold injuries and non-freezing cold injuries, depending on whether the injury developed at an ambient temperature below or above 0°C, respectively, and if freezing of tissue has occurred [7]. The most common parts of the body for local cold injuries to occur are the hands, feet, and face [12]. Sequelae associated with local cold injuries are sensory loss, hyperhidrosis, persistent skin colour changes, pain when exposed to cold, loss of proprioception, osteoarthritis, peeling of the skin, and secondary Raynaud's phenomenon (RP) [7,13]. The severity of immediate associated symptoms and later sequelae are partly dependent on the severity and depth of the injury [5]. Local cold injuries are categorised as superficial (which heal without loss of tissue) or deep (which result in loss of tissue) [14]. Superficial injuries are further classified as first or second-degree injuries. First-degree injuries are partial skin freezing (intradermal), and present with erythema, oedema, and hyperaemia; no blisters or necroses occur. Second-

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degree injuries are fully dermal and present with clear fluid-filled blisters, often within 24 hours from which the injury was contracted. Deep injuries are classified as third-degree or fourth-degree injuries. Third-degree injuries extend through the dermis and subcutaneous tissue and present with haemorrhagic blisters which proceed to black eschars. Fourth-degree injuries extend through the dermis, subcutaneous tissue, and underlying structures such as nerves, vessels, muscles, tendons, and bones. These injuries lead to necroses and gangrene and rarely present with blisters [5,15].

In Finland, where the climate is similar to that in Sweden, the overall annual incidence proportion of severe local cold injuries was 1.1% according to a longitudinal population-based study by Mäkinen et al. [16]. That study indicated that men were more likely to contract local cold injuries compared to women. Also, there were indications that cardiac insufficiency, angina pectoris, RP, diabetes mellitus, and high occupational cold exposure increased the probability of contracting local cold injuries, whereas smoking did not. In another study, Ervasti et al. reported that RP and smoking were associated with local cold injuries in men between 17–29 years in Finland [17]. Other previously reported risk factors include peripheral vascular disease, psychiatric disorders, as well as previous cold injuries [18].

Most of the previous studies on local cold injuries concern people in the armed forces or adventurers such as mountaineers, whereas studies concerning the general public are rare [16,19]. There are no previous Swedish prospective population-based studies on local cold injuries to date. Although the pathophysiology and external environmental factors that affect the development of local cold injuries are clearly understood, there is yet little known about which individual factors may precede or prevent the development. Cold injuries are preventable and considering the health effects and comprising consequences they may lead to, there is both medical and public interest to attain further knowledge on this topic.

The primary aim of our study was to determine the prevalence and annual incidence proportion of local cold injuries in northern Sweden. The secondary aim was to identify associated factors for incident local cold injuries in the hands, feet, and face.

Material and methods

Study design and setting

This prospective closed-cohort study was based on data from surveys sent out to a selection of men and women between 18 and 70 years living in northern Sweden who were randomly selected by Statistics Sweden. From February until May of 2015 (baseline), a first questionnaire was launched, including questions about occupation, exposure to cold, tobacco use, length, weight, current and previous diseases, and occurrence of local cold injuries in hands, feet, and face. If there was a reported local cold injury, the severity was to be graded into three stages. From March until April of 2021 (follow-up) a second questionnaire was sent out to the responders of the first one. This questionnaire included the same questions about local cold injuries as included in the first survey. If a local cold injury was reported during the study period, the year of occurrence and severity were advised to be stated. Only those who responded to both questionnaires (in 2015 and 2021) were included in the study. The study protocol was approved by the Regional Ethical Review Board situated at Umeå University (DNR 2014–286-31 M) and the Swedish Ethical Review Authority (DNR 2020–06707), and informed consent was obtained from all participants.

Variables

The social security number of the included participants was used to merge the data at baseline with the data at follow-up. Age at the baseline was categorised into quartiles before analysis. BMI was categorised according to clinical reference values for underweight, normal weight, and overweight [20]. The binary baseline variables gender, daily smoking, daily oral moist snuff use (a common form of tobacco use in Sweden), RP, diabetes mellitus, hypertension, angina pectoris, myocardial infarction, and stroke were included. Current occupation was assessed at baseline by participants answering the question "What is your primary employment/work?" in free-form text. The participants' answers were then classified according to the International Standard Classification of Occupations (ISCO) [21]. Mental stress was assessed at baseline by the participants answering the question "Have you experienced stress during the last month?", and answering "none/very little/some" was referred to as a negative response, while "quite a lot/very much" was considered a positive response. The extent of leisure-time and occupational cold exposure was graded by the study participants at baseline and follow-up by rating the statements "During work I am exposed to outdoor or cold environments" and "During leisure time I am exposed to outdoor or cold environments" on a numerical rating scale (NRS) from 1 to 10, where answer 1 implicated "I completely disagree" and 10 "I

fully agree". Additionally, a variable for the degree of the total extent of exposure to cold was created, by adding together occupational and leisure-time cold exposure, yielding a cumulative scale ranging from 2 to 20. Before analyses, the distribution of responses was divided into tertiles (NRS 1, 2 to 5, and 6 to 10 for occupational cold; NRS 1 to 4, 5 to 7, and 8 to 10 for leisure-time cold; and NRS 2 to 6, 7 to 10, and 11 to 20 for total cold exposure).

Cold injuries were self-reported and asked about using the following questions: "Have you ever sustained a cold injury to your hands/feet/face?", to which the study participants could answer yes or no. If they answered yes, they were asked to specify the year of first occurrence as well as the severity of the injury, using the following categories: "white spots", "blisters" or "blood-filled blisters". Incident cases of local cold injury were defined by no cold injury at baseline but with one or several injuries confirmed at follow-up. Subjects negating local cold injuries at both baseline and follow-up were considered healthy referents. All subjects with local cold injuries at baseline were excluded from further analyses. Additionally, a dichotomous composite variable for *any* local cold injury was created, which included all anatomical regions, where negating local cold injury in face, hands, and feet at baseline and confirming one or several at the follow-up was considered a positive response.

Statistical methods

Categorical variables were presented as numbers and valid percentages. The point-prevalence of local cold injuries was calculated as the number of positive responses divided by the total sample. The annual incidence proportion was calculated as the number of incident cases divided by subjects at risk (total sample minus subjects with symptoms at baseline) and number of years of follow-up. The associations between independent variables and incident local cold injuries were investigated using simple (univariable) and manual stepwise forward multiple binary logistic regression. Variables with a p value below 0.25 in simple analyses were included in the multiple models, and the procedures terminated when no variable reached a p value below 0.25 when added. The results were presented as odds ratios (OR) with 95% confidence intervals (95% CI). Statistical significance was set to a p value below 0.05. Statistical analyses were performed using IBM SPSS Statistics for Windows (Version 27, IBM Corporation, Armonk, NY, USA).

Results

Descriptive and outcome data

The first (baseline) questionnaire recruited 12,627 subjects and collected data through a postal survey. The second (follow-up) questionnaire in 2021, was sent out digitally (with one postal reminder) to all of those who had responded to the first one, after removing those who had died or moved from the study region, leaving 11,739 available subjects. If subjects were unable to respond digitally, they were given the option to respond using a postal survey. There were 5,208 responses to the second (follow-up) questionnaire in 2021, yielding a response rate of 44.4%. Due to 111 subjects with incorrect social security numbers and 80 multiple responses, 191 subjects were excluded, leaving 5,017 available for analysis. After excluding participants with local cold injury at baseline, the final study population regarding local cold injuries in hands, feet, and face consisted of 4,430, 4,358, and 3,555 subjects, respectively.

The prevalence of local cold injuries in the hands, feet, and face at follow-up was 568 (11.4%), 625 (12.6%), and 988 (19.9%) respectively. Also at follow-up, 259 participants reported a first occurrence of local cold injury during the study period in the hands, 249 participants in the feet, and 202 participants in the face. Additional baseline characteristics are presented in Table 1. Details on characteristics of incident local cold injuries are presented in Table 2, where the vast majority (88.3–93.9% depending on the localisation of affliction) graded their injuries as superficial (i.e. presenting with white spots). The annual incidence proportions of local cold injuries were 1.0% for the hands, 1.0% for the feet, 0.9% for the face, and 1.7% for any location.

Logistic regression analyses

Simple regression analyses are available in Supplemental material 1. In brief, incident cold injuries in the hands were associated with RP, daily snuff use, mental stress, stroke, and occupational cold exposure. For incident cold injuries in the feet there were associations with RP, mental stress, occupational cold exposure, leisure-time cold exposure, and age. Incident facial cold injuries were associated with occupational and leisure-time cold exposure, as well as age. Additionally, male gender was associated with higher point estimates for local cold injuries in all anatomical regions.

The complete multiple logistic regression models are shown in Table 3. For incident cold injuries in the hands, statistically significantly associated factors,

Table 1. Baseline characteristics of study participants, separated by local cold injury status at follow-up.

	Any incident local cold injury	No incident local cold injury
Baseline variable	N (%)	N (%)
Gender		
Male	177 (55.1)	1188 (41.1)
Female	144 (44.9)	1705 (58.9)
Age (years)		
18–43	99 (30.8)	689 (23.8)
44–54	89 (27.7)	623 (21.5)
55–62	73 (22.7)	803 (27.8)
63–70	60 (18.7)	778 (26.9)
County of residence		
Norrbotten	79 (24.6)	646 (22.3)
Västerbotten	112 (34.9)	955 (33.0)
Västernorrland	73 (22.7)	786 (27.2)
Jämtland–Härjedalen	57 (18.7)	506 (17.5)
Daily smoking		
Yes	17 (5.3)	189 (6.6)
No	301 (94.7)	2691 (93.4)
Daily snuff use		
Yes	50 (15.8)	350 (12.2)
No	267 (84.2)	2526 (87.8)
Body mass index (kg/m^2)		
<18.5	2 (0.6)	24 (0.8)
18.5–25	131 (42.0)	1285 (45.0)
>25	179 (57.4)	1548 (54.2)
Raynaud's phenomenon		
Yes	36 (11.2)	272 (9.4)
No	285 (88.8)	2611 (90.6)
Mental stress		
Yes	74 (23.2)	525 (18.3)
No	245 (76.8)	2347 (81.7)
Stroke		
Yes	7 (2.2)	37 (1.3)
No	310 (97.8)	2816 (98.7)
Myocardial infarction		
Yes	5 (1.6)	53 (1.8)
No	314 (98.4)	2825 (98.2)
Occupation [a]		
Armed forces	1 (0.3)	5 (0.2)
Managers	15 (4.8)	139 (4.9)
Professionals	67 (21.5)	935 (33.0)
Clerical support workers	40 (12.8)	287 (10.1)
Service and sales workers	28 (9.0)	364 (12.9)
Skilled agriculture, forestry, and fishery workers	4 (1.3)	38 (1.3)
Crafts and related trade workers	20 (6.4)	132 (4.7)
Plant and machine operators and assemblers	25 (8.0)	143 (5.1)
Elementary occupations	8 (2.6)	61 (2.2)
Sick leave	7 (2.2)	32 (1.1)
Self-employed	7 (2.2)	51 (1.8)
Parental leave	2 (0.6)	10 (0.4)
Unemployed	8 (2.6)	45 (1.6)
Students	12 (3.8)	106 (3.7)
Retired	32 (10.3)	483 (17.1)

Subjects with cold injuries at baseline are omitted
[a]According to the International Standard Classification of Occupations (ISCO) 2008

added in the following order, were RP (OR 2.92; 95% CI 2.08–4.09), male gender (OR 1.82; 95% CI 1.37–2.41), mental stress (OR 1.73; 95% CI 1.28–2.33), and stroke (OR 2.64; 95% CI 1.09–6.40). For cold injuries in the feet, statistically significant factors were RP (OR 2.22; 95% CI 1.58–3.12), age in the third quartile (OR 0.55; 95% CI 0.37–0.81) and fourth quartile (OR 0.57; 95% CI 0.48–0.85), male gender (OR 1.40; 95% CI 1.10–1.85), mental stress (OR 1.39; 95% CI 1.02–1.90), and occupational cold exposure in the second quartile (OR 1.48; 95% CI 1.00–2.18). For facial cold injuries, the statistically significant factors included leisure-time cold exposure in the third tertile (OR 1.75; 95% CI 1.23–2.47), age in the third quartile (OR 0.62; 95% CI 0.41–0.94) and fourth quartile (OR 0.55; 95% CI 0.34–0.87), male gender (OR 1.56; 95% CI 1.15–2.12), stroke (OR 3.09; 95% CI 1.26–7.56), and mental stress (OR 1.44; 95% CI 1.01–2.03). Finally, in the multiple model for local cold injuries in any anatomical region, the remaining statistically significant factors were male gender (OR 1.84; 95% CI 1.44–

Table 2. Details on incident local cold injuries at follow-up, separated by anatomical region of affliction.

	Anatomical region			
	Hands	Feet	Face	Any
Variable	N (%)	N (%)	N (%)	N (%)
Severity of local cold injury				
White spots	184 (93.9)	158 (88.3)	176 (93.6)	291 (89.5)
Blisters	12 (6.1)	19 (10.6)	12 (6.4)	32 (9.8)
Blood-filled blisters	0 (0.0)	2 (1.1)	0 (0.0)	2 (0.6)
Year of the first occurrence [a]				
2015	6 (19.4)	6 (21.4)	8 (15.7)	20 (18.2)
2016	6 (19.4)	4 (14.3)	14 (27.5)	24 (21.8)
2017	1 (3.2)	3 (10.7)	3 (5.9)	7 (6.4)
2018	6 (19.4)	3 (10.7)	10 (19.6)	19 (17.3)
2019	2 (6.5)	5 (17.9)	1 (2.0)	8 (7.3)
2020	6 (19.4)	3 (10.7)	8 (15.7)	17 (15.5)
2021	4 (12.9)	4 (14.2)	7 (13.7)	15 (13.6)

[a]The results are affected by a large proportion of missing data, and valid percentages are presented

Table 3. Manual stepwise forward multiple logistic regression between baseline variables and incident local cold injuries.

	Anatomical region			
	Hands	Feet	Face	Any
Baseline variable	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Raynaud's phenomenon				
Yes	**2.92 (2.08–4.09)***	**2.22 (1.58–3.12)***		
No	1 (–)	1 (–)		
Gender				
Male	**1.82 (1.37–2.41)***	**1.40 (1.10–1.85)***	**1.56 (1.15–2.12)***	**1.84 (1.44–2.36)***
Female	1 (–)	1 (–)	1 (–)	1 (–)
Mental stress				
Yes	**1.73 (1.28–2.33)***	**1.39 (1.02–1.90)***	**1.44 (1.01–2.03)***	**1.45 (1.08–1.94)***
No	1 (–)	1 (–)	1 (–)	1 (–)
Stroke				
Yes	**2.64 (1.09–6.40)***		**3.09 (1.26–7.56)***	1.77 (0.73–4.34)
No	1 (–)		1 (–)	
Age (years)				
18–43	1 (–)	1 (–)	1 (–)	1 (–)
44–54	0.91 (0.64–1.29)	1.10 (0.77–1.50)	1.10 (0.76–1.60)	1.03 (0.75–1.40)
55–62	0.76 (0.53–1.09)	**0.55 (0.37–0.81)***	**0.62 (0.41–0.94)***	**0.63 (0.45–0.88)***
63–70	0.71 (0.47–1.05)	**0.57 (0.48–0.85)***	**0.55 (0.34–0.87)***	**0.54 (0.38–0.78)***
Occupational cold exposure				
1st tertile	1 (–)	1 (–)	1 (–)	
2nd tertile	1.37 (0.94–2.00)	**1.48 (1.00–2.18)***	1.42 (0.92–2.19)	
3rd tertile	1.09 (0.80–1.48)	1.18 (0.86–1.61)	1.26 (0.90–1.78)	
Total cold exposure [a]				
1st tertile				1 (–)
2nd tertile				**1.46 (1.09–1.96)***
3rd tertile				**1.69 (1.26–2.29)***
Leisure-time cold exposure				
1st tertile		1 (–)	1 (–)	
2nd tertile		1.19 (0.85–1.67)	1.44 (0.98–2.11)	
3rd tertile		1.27 (0.93–1.73)	**1.75 (1.23–2.47)***	
Daily snuff use				
Yes	1.27 (0.89–1.79)			
No	1 (–)			
Myocardial infarction				
Yes	0.39 (0.09–1.64)			
No	1 (–)			

[a]Cumulative measure of occupational and leisure-time cold exposure
*Bold values indicate OR with significant 95% confidence intervals

2.36), age in the third quartile (OR 0.63; 95% CI 0.45–0.88) and fourth quartile (OR 0.54; 95% CI 0.38–0.78), total cold exposure in the second tertile (OR 1.46; 95% CI 1.09–1.96) and third tertile (OR 1.69; 95% CI 1.26–2.29), and mental stress (OR 1.45; 95% CI 1.08–1.94).

Analyses regarding associations between occupational titles and incident local cold injuries are presented in Table 4, where "clerical and support workers" was set as unexposed reference group. Incident cold injuries in the hands were not statistically significantly associated with

Table 4. Simple logistic regression between occupational group and incident local cold injuries.

	Anatomical region			
	Hands	Feet	Face	Any
Baseline occupation	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Clerical support workers	1 (–)	1 (–)	1 (–)	1 (–)
Managers	1.24 (0.63–2.43)	**2.58 (1.23–5.42)***	0.59 (0.25–1.41)	1.11 (0.57–2.14)
Professionals	1.04 (0.65–1.67)	**2.09 (1.16–3.77)***	0.84 (0.51–1.36)	1.17 (0.76–1.82)
Service and sales workers	1.09 (0.63–1.90)	1.89 (0.98–3.66)	0.89 (0.50–1.59)	1.01 (0.60–1.70)
Skilled agriculture, forestry and fishery workers	0.98 (0.29–3.38)	**3.20 (1.09–9.36)***	0.28 (0.04–2.12)	1.08 (0.36–3.24)
Crafts and related trade workers	1.39 (0.71–2.72)	1.88 (0.84–4.20)	1.25 (0.63–2.50)	1.55 (0.84–2.86)
Plant and machine operators and assemblers	1.53 (0.82–2.84)	**2.16 (1.03–4.52)***	1.62 (0.86–3.03)	**1.79 (1.01–3.19)***
Elementary occupations	0.89 (0.30–2.63)	**2.72 (1.05–7.03)***	0.19 (0.03–1.44)	1.34 (0.58–3.09)
Sick leave	1.24 (0.36–4.28)	2.14 (0.59–7.81)	0.74 (0.17–3.28)	2.24 (0.91–5.54)
Parental leave	–	4.39 (0.90–21.31)	–	2.05 (0.43–9.82)
Unemployed	2.14 (0.88–5.20)	1.42 (0.39–5.11)	0.98 (0.33–2.95)	1.82 (0.78–4.25)
Students	0.66 (0.25–1.77)	0.94 (0.30–2.92)	1.26 (0.60–2.66)	1.16 (0.57–2.37)
Retired	0.84 (0.48–1.46)	1.24 (0.63–2.44)	**0.41 (0.21–0.78)***	0.68 (0.40–1.15)
Self–employed	1.49 (0.62–3.69)	**2.96 (1.19–7.36)***	0.98 (0.33–2.95)	1.41 (0.58–3.39)
Armed forces	1.97 (0.24–16.189)	**6.14 (1.22–30.88)***	–	2.05 (0.23–18.17)

*Bold values indicate odds ratios with significant 95% confidence intervals

any of the occupations. For incident cold injuries in the feet, the highest point estimates were found among armed forces workers (OR 6.14; 95% CI 1.22–30.88),), skilled agriculture, forestry, and fishery workers (OR 3.20; 95% CI 1.09–9.36), and self-employed (OR 2.96; 95% CI 1.19–7.36). For facial injuries, there was an inverse relation among retired subjects (OR 0.41; 95% CI 0.21–0.78).

Discussion

Main findings

A novel finding of our study was that mental stress was statistically significantly associated with incident cold injuries in both the hands and feet. Also, RP was associated with incident cold injuries in the hands and feet. Male gender increased the probability of contracting cold injuries regardless of anatomical location, while older age seemed to be a general protective factor.

Interpretation

There was an association between RP and incident cold injuries in the hands and feet with a roughly two-fold OR compared to those who did not suffer from RP. This corresponds with previous studies by Mäkinen et al. and Ervasti et al. [16,17], although the latter also reported a statistically significant higher point estimate for cold injuries in the head for those with RP. The plausible mechanism for an increased probability of contracting local cold injuries among subjects with RP is the impaired thermoregulation and delayed rewarming it causes [22] after the distinct constriction of the blood vessels in the digits of the hands and feet [23,24]. Additionally, cold-induced vasodilation, which is presumed to prevent local cold injuries through a periodical increase in cutaneous blood flow in feet and hands with subsequent tissue rewarming [7,25], is thought to be less active in those suffering from RP [26], thus worsening the effects of cold exposure. Lower point estimates for cold injuries in feet, face, and any anatomical region were found for those at an older age when compared to those at a younger age. This however does not necessarily indicate that older age is a protective factor per se. Rather, the findings in our study may be explained by the fact that older people, in general, could be more risk conscious and avoid outdoor exposures to a greater extent. This is supported by a previous report by the Swedish Work environment Authority [27], reporting that the amount of cold exposure at work decreases with age. The mechanism for mental stress being associated with incident local cold injuries could be an activation of the sympathetic nervous system, which results in peripheral vasoconstriction with subsequent reduction in perfusion of peripheral tissues [28,29]. Furthermore, a reduced flow-mediated dilatation of arteries in healthy subjects when exposed to mental stress has been reported, indicating that stress for only a short period might result in vascular endothelial dysfunction lasting for hours [30]. Additionally, there are indications that RP, except being triggered by cold exposure, also is triggered by emotional stress [24,31], and this could further increase the risk of being afflicted with local cold injuries.

Since cardiovascular diseases might lead to reduced blood flow to cutaneous and subcutaneous tissues, as could diabetes mellitus, it was presumed that these diseases would increase the probability of local cold injuries [23]. Indeed, we found an association between previous stroke and incident cold injuries in the hands. However, there was no significant association between hypertension, angina pectoris, myocardial infarction, or

diabetes mellitus in relation to incident local cold injuries. This is to some extent in concordance with what Mäkinen et al. previously reported, although they found an association between severe local cold injuries among those suffering from angina pectoris and diabetes mellitus [16]. The reason for our study not being able to show a statistically significant association could be that it was insufficiently statistically powered, since there were very few subjects reporting other cardiovascular disease than mere hypertension. There was also a presumption that smoking would increase the risk for incident local cold injuries since the substances of tobacco smoke cause impaired peripheral circulation through oxidative stress, endothelial damage, and intravasal inflammation with atherogenesis. Further, nicotine, either being administered by inhalation of cigarette smoke or by snuff use, causes haemodynamic stress with cutaneous vascular constriction in the peripheral tissues, resulting in reduced peripheral blood flow (29). However, in our study, smoking did not implicate any significant association with incident cold injuries in any of the investigated anatomical regions. This is in concordance with the findings by Mäkinen et al. [16]. However, Ervasti et al. reported a statistically significantly association between smoking and local cold injuries [17]. Their variable for smoking was categorised by the extent of smoking rather than whether being a smoker or not, as in our study. Therefore, since the extent of smoking might differ considerably among participants having affirmed it, complementary analyses were made in our study to investigate whether the extent of smoking influenced the outcome, but no such associations were found (data not shown). The hypothesis of the impact of snuff use on local cold injuries was the same as that of the impact of smoking, but a larger effect was expected since the concentration of nicotine in the blood can be kept at a higher level and for a longer period when using snuff compared to smoking cigarettes [32]. In the present study, Tthere was a statistically significant association between snuff use and incident cold injuries in the hands in simple analyses, but not in the multiple model. This suggests that snuff use was not a major predictor of incident local cold injuries.

Previous studies have shown that men tend to be exposed to ambient cold at work to a larger extent than women [1,27]. This could be attributed to the observed higher probability for incident local cold injuries among those of the male gender in our study. Also, similar observations were made by Mäkinen et al., although they observed the opposite in the ages between 25–34 years [16]. Even though a high amount of body fat is thought to have insulating properties [23], there was no protective effect of high BMI in our study. One plausible explanation is that the adipose tissue is distributed more centrally and does not result in increased insulation of the most peripheral parts of the body, such as hands, feet, as nose. For instance, ample body fat may prevent hypothermia but does not have an effect on local cooling of the head [33]. Further, the hands have a large surface area in relation to the volume and observations in a previous study supported no correlation between body fat mass and heat loss in the hands when immersed in cold water [34]. However, the relation between body composition and cold-related health effects is a topic for further study.

The collected data regarding details on incident local cold injuries was incomplete and therefore the results were difficult to interpret. However, superficial injuries (i.e. injuries presenting with white spots) clearly seemed to make up the majority of the incident local cold injures regarding both the extremities and face. This is in concordance with what Ervasti et al. observed [17]. The number of participants having responded to the question in which year they had their first occurrence of local cold injury was very low in our study, and this limits what conclusions can be made. Finally, several occupational groups showed associations with incident cold injuries in the feet, whereas none of the occupations were associated with incident cold injuries in the hands. Hands and arms, when compared to feet and legs, are more mobile and adaptable. Muscles in motion have increased blood flow and metabolic rate [5]; thus, hands rather than the feet might be easier to keep warm during working time. Also, for outdoor work, contact cold exposure between the feet and ground may be substantial during the winter season. Finally, workers are often able to change cold and wet gloves, but rarely shoes [35]. Generally, occupations implicating a large extent of working time spent outdoors were associated with incident local cold injuries. In addition, we have previously reported that managers, professionals and self-employed were not among those being highly exposed to ambient cold at work, but rather reported a high ambient cold exposure during leisure time [1], and this could attribute to these occupational groups being associated with an increased probability for incident local cold injuries in our study despite a low self-reported cold exposure at work. Data on occupation was collected at baseline and there was no information about current work at the time of cold injury or job change during the follow-up period. Some of the highly cold-exposed occupational groups also included very few subjects (i.e. armed forces), which

makes the odds ratio estimates more uncertain. Therefore, the analyses on occupation only give a rough estimate of potential associations between work and local cold injuries.

Limitations and strengths

There were a considerably smaller number of participants finally being included in our study in 2021 (N = 5,017) when compared to the initial number of participants in 2015 (N = 12,627). Therefore, there is a concern about sampling bias, where subjects with local cold injuries may have been more eager to participate in the follow-up survey. We lacked data on socioeconomic parameters, which could potentially have been important confounders. Another potential bias is that subjects with local cold injuries at baseline were excluded from analyses, without any consideration to whether they also had reported any new incidents at follow-up. This means that the number of incident local cold injuries may actually have been higher than reported. The diagnosis of local cold injury was self-reported without being verified by a clinician. Among the general public, there might be a lack of knowledge about local cold injuries, which might implicate that there were misjudgements regarding the diagnosis. Subjects may either have reported a local cold injury when not having been afflicted with one or vice versa, but a random effect cannot be assumed. Also, this could explain the low number of participants having responded to the questions regarding the severity of local cold injuries, since this might have been too difficult to determine without medical training. There were surprisingly weak associations between cold exposure and incident local cold injuries, and this raises concern about the validity of these exposure variables. The reason for occupational cold exposure tending towards a higher probability for incident local cold injuries in comparison to that of leisure-time cold exposure, could be that during working-time outdoor exposure is more mandatory and there is usually a lower ability to adjust the ambient circumstances to the individuals' needs and comfort [36]. Finally, there were many statistical tests performed, which increases the risk of type 1-error. Taken together, the methodological concerns imply that the results of our study should merely be considered as hypothesis-generating, to be evaluated by future confirmatory studies.

A strength of our study was that it was population-based with the selection of participants being randomised by Statistics Sweden, thus minimising the risk of selection bias. Also, the distribution among women and men was rather even. To the authors' knowledge, this is the first prospective study based on the Swedish population and the study sample was large. Both the baseline and follow-up questionnaires were sent out during the same winter period, making it easier for the participants to recall the circumstances during winter time. Further, the questionnaires were comprehensive, enabling the participants to give extensive and detailed information, thus creating ample data and opportunities to investigate a large number of potential associated factors.

Implications

The results of our study offer some support of the notion that having certain occupations increase the probability of contracting local cold injuries, although these results need to be confirmed by future studies of other design. Swedish legislation does not regulate to what extent workers can be exposed to ambient cold conditions during outdoor work. There is an ISO standard (15743:2008) that thoroughly describes how employers and occupational health care services can perform technical and medical risk assessments of cold work [6]. This standard has been officially adopted in Sweden, but the implementation is generally lacking in working life. Since our study shows that occupational outdoor cold exposure is related to incident cold injuries to some extent, there appears to be a need for more preventive measures. One group that could deserve special interest in occupational risk assessments are subjects with RP, since they seem especially prone to contract local cold injuries.

Conclusions

The prevalence of local cold injuries ranged from 11 to 20% while the annual incidence proportion was between 0.9% and 1.0%. Male gender, mental stress, previous stroke, and suffering from Raynaud's phenomenon increased the probability of incident local cold injuries. High age appeared to be a protective factor.

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Author contributions

KM reviewed the literature, prepared the data, performed statistical analyses and wrote the manuscript. AS conceived the study, participated in data collection as well as critical review of the manuscript. Both authors read and approved the final version of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

Source data can be made available upon personal request.

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