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Working in a cold environment, feeling cold at work and chronic pain: A cross-sectional analysis of The Tromsø Study

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Abstract

Aim: The main aim of this study was to investigate if working in a cold environment and feeling cold at work are associated with chronic pain (i.e. lasting ≥3 months). We also aimed to describe the prevalence of other health complaints related to cold exposure.

Methods: We used data from the sixth survey (2007-2008) of the Tromsø Study. Analyses included 6533 men and women aged 30-67 years who were not retired, not receiving full-time disability benefits, and had no missing values. Associations between working in a cold environment, feeling cold at work, and self-reported chronic pain were examined with logistic regression adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity, and smoking.

Results: 779 participants reported working in a cold environment ≥25% of the time. This exposure was positively associated with pain at ≥3 sites (OR 1.57; 95% CI 1.23 to 2.01) and with neck, shoulder, and leg pain, but not with pain at 1-2 sites. Feeling cold sometimes or often at work was associated with pain at ≥3 sites (OR 1.58; 95% CI 1.22 to 2.07 and OR 3.90; 95% CI 2.04 to 7.45, respectively). Feeling cold often at work was significantly and positively associated with pain at all sites except the hand, foot, stomach, and head.

Conclusion: Working in a cold environment was significantly associated with chronic pain. The observed association was strongest for pain at musculoskeletal sites and for those who often felt cold at work.

Article Summary

Strengths and limitations of this study

- The study has a high response rate (65.7%) which increases the likelihood that it is a representative sample of the working population
- The observed associations in the present study are consistent for pain at multiple sites and at specific sites
- The healthy worker effect may cause an underestimation of the associations
- The results are to some extent vulnerable to residual confounding by other occupational risk factors

INTRODUCTION

By evolution, humans are not physiologically fit to live in cold environments. To survive in such environments, we must use different strategies, such as insulating clothing, houses, and heating, which protect us from low temperatures. However, these protective measures may not be sufficient, as there is an excess of deaths recorded during the winter season. This excess is only partly explained by seasonal diseases and thus indicates that even moderately cold temperatures induce a strain on the body and negatively affect health.[1]

Cold exposure can cause pain. Indeed, immersing one's hand in cold water is commonly used as a test of pain tolerance.[2] Exposure to a cold environment, at work or during leisure time, can cause one to experience acute pain. In Finland, the reported prevalence of musculoskeletal pain believed by respondents to be caused by cold exposure is as high as 30% for men and 27% for women.[3, 4] Cold exposure is also known to reduce both physical and cognitive performance.[5, 6] Cold temperatures may also have sub-acute effects. Working in a cold environment has been found to be associated with an increased prevalence of back, neck, and shoulder pain.[7-10] In addition, it has been suggested that working in a cold environment is related to respiratory, cardiovascular, and dermatological complaints and diseases.[11]

Factors that affect workers' thermal balance are contact with water or cold surfaces, humidity, air velocity, radiation, type of clothing, and the heat produced by executing the work.[12] A cold working environment is defined as an environment with an ambient temperature below 10° C.[13] However, the ambient air temperature might not be a good measure of a worker's heat loss. In a study of seafood-processing workers, no relationship was found between workers' reports of feeling cold and measured air velocity, air temperature at the feet, or air temperature 1.1 meters above the floor.[14] This indicates that actual cold exposure is difficult to measure. Some studies have circumvented this problem by using self-reported cold experience as a measure of cold exposure.[15, 16] Among workers in the food processing industry, self-reported experiences of cooling of the neck, shoulder, wrist, and lower back were associated with a self-reported disadvantage in daily routines due to pain at those sites.[15] In a study of seafood industry workers, feeling cold often at work was associated with musculoskeletal pain.[16] Feeling cold often at work has also been associated with an increased prevalence of symptoms from skin and airways.[14]

These previous studies mostly used musculoskeletal pain over the last 12 months as the outcome. This includes acute periods of pain within the past 12 months, but contributes no information about the duration of pain. Chronic pain, defined as pain lasting 3 months or longer, may be a better measure of the impact on quality of life and future work ability.[17, 18] However, there is a lack of studies on the association between cold exposure and chronic musculoskeletal pain or pain in other tissues. Therefore, the main aim of this study was to investigate if working in a cold environment and feeling cold at work are associated with chronic pain. We also aimed to describe the prevalence of other health complaints related to cold exposure.

METHODS

Participants

The Tromsø Study is a prospective cohort study performed in the municipality of Tromsø in Northern Norway. The study currently consists of seven surveys, with the first conducted in 1974 and the seventh in 2015-2016. Tromsø has a coastal climate; the outdoor temperature is below 10° C for a major part of the year and seldom falls below -10° C.[19] This study includes participants from the sixth survey of the Tromsø Study (Tromsø 6), which was carried out in 2007-2008 and encompassed physical examinations and extensive health questionnaires.[20] Of the 19,762 individuals invited to Tromso 6, 12,984 (65.7%) participated. The age of the participants ranged from 30 to 87 years. We excluded participants who were retired, were above retirement age (i.e. 67 years), on full-time disability benefits, and those with missing values. Thus, the final study population comprised 6,533 men and women (Figure 1). The Regional Committee of Research Ethics approved Tromsø 6 and this particular analysis.

Pain

Participants were asked if they had persistent pain lasting 3 months or more (yes/no) and if so, at which anatomical site the pain was situated. The alternatives were jaw, neck, back, shoulder, arm (including elbow), hand, hip, leg (including thigh, knee, and calves), foot (including ankle), head (including face), chest, stomach, genitals, skin, and other. Sites where participants reported pain were then counted, and participants were categorized as having: no pain, pain at 1-2 sites, and pain at ≥3 sites.

Cold exposure and cold-related health complaints

The Tromsø 6 questionnaire included the question "Do you work outdoors at least 25% of the time or in cold buildings (e.g. storage/industry buildings)?". Those who answered "Yes" were given an extra set of questions about working in a cold environment in the second questionnaire. Among those questions were "Do you feel cold at work?" (yes, often/yes, sometimes/no, never). Participants were also asked if they had experienced cold-related itching and/or rash (yes/no), and if they experienced any of the following cold-related symptoms while working in cold environments: breathing difficulties, wheezing, mucus secretion from the lungs, chest pain, arrythmia, circulatory disorders/disturbance in hands or feet, temporary impaired vision, temporary migraine, fingers turning white temporarily, and fingers turning blue/blue-red temporarily (yes/no). The questionnaire also contained questions on how working in a cold environment and cold-related symptoms affected participants' concentration, memory, finger sensitivity, finger dexterity, control of movement (for example, shivering), heavy physical work, or long-lasting physical work. The response alternatives where "reduced", "unchanged" and "improved"; improved and unchanged were combined due to few responses in the improved category.

Confounders

Possible confounders obtained from the questionnaires were age, sex, education, insomnia, physical activity at work, leisure time physical activity, and smoking. Body mass index (BMI) kwas calculated from weight and height measured at the examination. BMI was categorized into underweight/normal weight (<25 kg/m^2), overweight (≥25 kg/m^2 and <30 kg/m^2) and obese (≥30 kg/m^2) in the descriptive statistics, but it was included as a continuous variable in the regression analysis. Insomnia was assessed by the question "In the past 12 months, how often have you suffered from sleeplessness?" (never, or just a few times a year/1-3 times a month/approximately once a week/more than once a week). Physical activity at work was measured with the question "If you have paid or unpaid work, which statement describes your work best?" (mostly sedentary/requires a lot of walking/requires a lot of walking and lifting/heavy manual labor). Leisure time physical activity had four categories: sedentary, low, moderate, and hard. Sedentary was described as "reading, watching TV, or other sedentary activity", low as "walking, cycling, or other forms of exercise at least 4 hours per week", moderate as "recreational sports, heavy gardening for at least 4 hours per week", and hard as "hard training or sports competition, regularly several times per week". Smoking was categorized into current, former, and never smoker.

Statistics

Pearson chi-square was used to test differences in prevalence if all cells had n>5; Fisher's exact test was used if n≤5. T-test was used for age. Multivariable logistic regression was used to assess the association between working in a cold environment ≥25% of the time and self-reported pain. All statistical analyses were performed in Stata MP 15.

Patient and Public Involvement

There were no patient or public involvement in this particular sub study.

RESULTS

Participants

Among the 6,533 participants included in the study, 779 reported to work in a cold environment ≥25% of the time. These individuals were younger, were mostly men, had lower levels of education compared to the rest of the working population, and had a higher BMI. They were also more likely to have physically demanding work, have lower levels of leisure time physical activity and to be current or former smokers (Table 1).

Table 1 Characteristics of the study population

	Working in a cold environment ≥25% of the time				
	No, n=5754		Yes, n=779		t/χ^2
	n	%	n	%	p-value
Age (years)*	49.9	8.8	48.8	8.7	<0.001
Sex					
Female	3178	55.2	143	18.4	
Male	2576	44.8	636	81.6	<0.001
Education					
Primary/secondary	727	12.6	262	33.6	
Technical school	1261	21.9	308	39.5	
High school	513	8.9	75	9.6	
College/university <4 years	1350	23.5	94	12.1	
College/university ≥4 years	1903	33.1	40	5.1	<0.001
Body mass index					
Under and normal weight (<25 kg/m²)	2233	38.8	205	26.3	
Overweight (≥25 and <30 kg/m²)	2494	43.3	406	52.1	
Obese (≥30 kg/m²)	1027	17.8	168	21.6	<0.001
Insomnia					
Never, or just a few times a year	3927	68.2	576	73.9	
1-3 times a month	1042	18.1	118	15.1	
Approximately once a week	365	6.3	42	5.4	
More than once a week	420	7.3	43	5.5	0.014
Physical activity at work					
Mostly sedentary work	3497	60.8	87	11.2	
Work that requires a lot of walking	1454	25.3	176	22.6	
Work that requires a lot of walking and lifting (n, %)	760	13.2	379	48.7	
Heavy manual labor	43	0.7	137	17.6	<0.001
Leisure time physical activity					
Sedentary	1081	18.8	186	23.9	
Low	3350	58.2	410	52.6	
Moderate	1176	20.4	174	22.3	

Hard	147	2.6	9	1.2	<0.001
Smoking					
Current	1111	19.3	211	27.1	
Former	2227	38.7	319	40.9	
Never	2416	42	249	32	<0.001

*Numbers are mean and standard deviation for age, otherwise n and %.

Out of the 779 workers who reported working in a cold environment ≥25% of the time, 92 never felt cold at work, 635 felt cold sometimes, and 52 felt cold often. The prevalence of chronic pain at different anatomical sites was higher in those who often or sometimes felt cold at work compared to those who never felt cold (Table 2).

Table 2 Prevalence of chronic pain in participants working in a cold environment <25% of the time and in those working ina cold environment ≥25% of the time by frequency of feeling cold

	Working in a cold environment <25% of the time n=5754		Frequency of feeling cold at work among those working in a cold environment ≥25% of the time n=779.					
Anatomical sites			Never, n=92		Sometimes, n=635		Often, n=52	
	n	%	n	%	n	%	n	%
1-2 sites	783	14	14	15	91	14	8	15
≥3 sites	904	16	7	8	128	20	21	40
Neck	765	13	8	9	106	17	18	35
Back	811	14	6	7	106	17	14	27
Shoulder	753	13	8	9	113	18	18	35
Arm	465	8	6	7	69	11	11	21
Hand	341	6	3	3	39	6	6	12
Hip	514	9	7	8	49	8	9	17
Leg	557	10	7	8	76	12	13	25
Foot	385	7	3	3	36	6	4	8
Head	318	6	0	0	32	5	7	14
Stomach	210	4	1	1	27	4	5	10

Multiple pain sites

Working in a cold environment ≥25% of the time was significantly associated with pain at ≥3 sites after adjustment (odds ratio [OR] 1.57; 95% confidence interval [CI] 1.23 to 2.01) (Table 3).

Table 3 Logistic regression analysis with pain at 1-2 or ≥3 sites and specific pain sites as outcomes

	Working in a cold environment <25% of the time n = 5754		Working in a cold environment ≥25% of the time n = 779						
				Adjusted for age and sex			Fully adjusted model*		
Anatomical sites	n	OR	n	OR	95% CI		OR	95% CI	
1-2 sites †	783	1	113	**1.15**	**0.92**	**1.44**	0.95	0.73	1.24
≥3 sites ‡	904	1	156	**2.02**	**1.64**	**2.48**	**1.57**	**1.23**	**2.01**
Neck	765	1	132	**1.78**	**1.44**	**2.20**	**1.46**	**1.13**	**1.89**
Back	811	1	126	**1.38**	**1.12**	**1.71**	1.18	0.91	1.52
Shoulder	753	1	139	**1.96**	**1.58**	**2.42**	**1.39**	**1.08**	**1.78**
Arm	465	1	86	**1.93**	**1.49**	**2.50**	1.34	0.98	1.83
Hand	341	1	48	**1.66**	**1.19**	**2.32**	1.16	0.79	1.71
Hip	514	1	65	**1.59**	**1.19**	**2.12**	1.26	0.90	1.75
Leg	557	1	96	**1.87**	**1.47**	**2.40**	**1.47**	**1.10**	**1.96**
Foot	385	1	43	1.16	0.83	1.63	0.80	0.54	1.19
Head	318	1	39	1.28	0.89	39	1.13	0.75	1.70
Stomach	210	1	33	1.42	0.96	33	1.30	0.82	2.04

* Adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity, and smoking

† Model does not include those with pain at ≥3 sites

‡ Model does not include those with pain at 1-2 sites

OR: odds ratio, CI: confidence interval.

However, in the fully-adjusted model, those who worked in a cold environment ≥25% of the time did not have higher odds for pain at 1-2 sites compared to those who worked in a cold environment <25% of the time. When those who worked in a cold environment ≥25% were divided into never, sometimes, and often feeling cold at work, both sometimes and often feeling cold was associated with pain at ≥3 sites (OR 1.58; 95% CI 1.22 to 2.07 and OR 3.90; 95% CI 2.04 to 7.45, respectively) (Figure 2).

Pain at specific sites

In the analysis with pain at specific sites as outcomes, the low number of participants who worked in a cold environment ≥25% with pain in the jaw (n=4), chest (n=10), skin (n=5), genitals (n=8), and other location (n=3) prevented separate analyses for these outcomes. When using pain at the remaining 10 sites as separate outcomes, working in cold environments ≥25% of the time was significantly associated with pain at all sites except the foot, head, and stomach in the model adjusted for age and sex (Table 3). Although those working in cold environments ≥25% of the time had higher odds for pain at all sites except the foot in the fully-adjusted model, only the associations for pain at the neck, shoulder, and leg were statistically significant (Table 3).

When those working in cold environments ≥25% of the time were divided by frequency of feeling cold, those who felt cold sometimes or often at work had significantly higher odds for pain at musculoskeletal sites compared to those working in a cold environment <25% of the time. In the model adjusted for age and sex, feeling cold often was significantly associated with head and stomach pain (Figure 2).

After adjusting for possible confounders, workers who felt cold often had higher odds for neck, shoulder, arm, leg, back, and hip pain compared to the group that worked in a cold environment <25% of the time (Figure 2). The strongest association was for neck pain (OR 3.05; 95% CI 1.64-5.66). Among those working in cold environments ≥25% of the time, the group that reported feeling cold sometimes at work had higher odds for neck, shoulder, and leg pain, with ORs between those who never felt cold and those who felt cold often at work (Figure 2). In the group working in cold environments ≥25% of the time, never feeling cold at work was not significantly associated with chronic pain at any specific site in either of the models.

Cold-related health complaints

Among those working in cold environments ≥25% of the time, 33% reported they had experienced circulatory disorders/disturbances in their hands or feet, 26% had their fingers turn white temporarily, and 19% had their fingers turn blue/blue-red temporarily (Supplementary table 1). The prevalence of participants who had itching or rash, temporary impaired vision, circulatory disorders/disturbances in their hands or feet, or fingers turning white or blue/blue-red fingers temporarily was higher among those who felt cold often compared to those who never felt cold at work. Over 60% of those working in cold environments ≥25% of the time experienced decreased finger sensitivity and dexterity. Many workers also reported reduced ability to control their movement (shivering), perform heavy physical work, and long-lasting physical work, with prevalences ranging from 23% to 31%. In addition, workers who felt cold often were more likely to report loss of performance in all domains except memory compared to those who never felt cold at work (Supplementary table 2).

DISCUSSION

Key results

In this study, working in a cold environment ≥25% of the time was associated with chronic pain (i.e. pain lasting ≥3 months) at the neck, shoulder, and leg, as well as pain at ≥3 sites, even after adjusting for age, sex, education, BMI, insomnia, physical activity at work, and leisure time physical activity. Those who felt cold often at work had significantly higher odds for pain at ≥3 sites and for pain at all specified sites except the hand, foot, head, and stomach. Feeling cold sometimes at work was associated with neck, shoulder, and leg pain. We found no significant differences in chronic pain between those who never felt cold when working in a cold environment ≥25% of the time and those who work in cold environment <25% of the time.

The ORs for chronic musculoskeletal pain in the present study were lower than estimates for musculoskeletal pain during the last 12 months from studies of slaughterhouse and seafood industry workers.[15, 16] Interestingly, in the fully-adjusted model, we found no association between working in a cold environment ≥25% of the time and hand and foot pain, although these body parts are the most susceptible to cooling. If cooling of local tissue is the mechanism for a higher prevalence of chronic pain, one could assume that body parts most exposed to cold would be at a higher risk for pain. The results for hand and foot in the present study do not support such an assumption. However, this observation is in contrast to other studies that found associations between a cold environment or an experience of cooling of the wrist and pain in the wrist, hand, and forearm.[7, 15, 21] The difference between earlier findings and the present study might be due to a different etiology and pathology for chronic musculoskeletal pain and 12-month pain prevalence. Different study populations and cold exposures could also contribute to the contradictory results.

Feeling cold is a subjective experience and contains little or no information about the actual environment, such as ambient temperature, humidity, and air velocity. However, ambient temperature could also be a poor measure of cold exposure. A study of seafood industry workers could not establish a simple relationship between thermal environmental factors and the prevalence of workers feeling cold. The same study also found that working in relatively high temperatures (>12° C) led to low finger temperatures and a major drop in foot temperature.[14] Thermal comfort and sensation seem to be closely connected to both average skin temperature and rectal temperature.[22] Although subjective, feeling cold might be a better indication of the environment's effect on the body than ambient air temperature. In the present study, the higher prevalence of several cold-related complaints and the higher prevalence of impaired performance among those who felt cold often, support this notion.

The general health status of a person might also influence to what degree they feel cold. Individuals with diagnosed musculoskeletal disorders are more prone to report cold-related musculoskeletal pain [23], and male slaughterhouse workers with chronic pain had more complaints about indoor climate, including complaints about temperatures that were too low and draughts, when compared to those without pain.[24] Chronic pain could also influence the perception of feeling cold. The design of the present study is not adequate to address the direction of the observed association.

Few plausible causal mechanisms between cold exposure and musculoskeletal pain, chronic or not, have been suggested. Studies have found that cooling induces physiological responses, such as a change in electromyography, poorer energy-efficiency, and increased muscle activity.[25-27] However, a relationship between altered electromyography, increased muscle activity, and subsequent chronic pain has not been satisfactorily established. A cross-sectional study of slaughterhouse workers found that a lower pressure pain threshold was associated with more complaints about the indoor climate.[24] A possible explanation for the observed association between chronic pain and frequency of feeling cold in the present study could be that persons who felt cold have a lower pain threshold than those who did not. Future research should explore whether this is genetic, or if thermal stimuli could contribute to a sensitization process.

The prevalence of cold-related respiratory and cardiovascular health complaints in the present study are similar to those found in a population sample aged 25-74 years in Finland.[4] However, the prevalence of circulatory disorders/disturbances in the hands or feet, and fingers turning white or blue/blue-red temporarily was higher among participants who worked in a cold environment ≥25 of the time in the present study.

Strengths and limitations

In our study, participants who worked in a cold environment ≥25 of the time had generally low education and executed a lot of heavy physical work, both of which have been identified as risk factors for musculoskeletal pain; [28-30] adjusting for these confounders attenuated the associations in the present study. Workers exposed to cold are also exposed to several other occupational risk factors that can be associated with poor health, and physical activity at work is not a satisfactory measure of these risk factors.[31] Consequently, the results are to some extent vulnerable to residual confounding.

Our results could also be influenced by the healthy-worker effect.[32] Feeling cold is uncomfortable, and individuals negatively affected by a cold environment might change their occupation or workplace to avoid getting cold. The remaining employees exposed to cold may therefore be the ones that are the least negatively affected by the cold. Additionally, chronic pain can contribute to selection bias by having a different impact in different occupations. There is a social gradient in disability benefits, and physical work has been found to increase the risk for disability pension, even after adjustment for health status.[33] Thus, the effect estimates may be underestimated.

The high response rate (65.7 %) of Tromsø 6 is a major strength and increases the likelihood that the findings are representative of the general population. Nevertheless, non-participants in Tromsø 6 tend to have lower education than participants;[20] therefore we cannot rule out that the prevalence of cold-exposed workers was higher among non-participants. Additionally, some of the occupations in which workers are typically exposed to cold environments have a high number of migrant workers, a group not invited to participate in The Tromsø Study. As an example, in 2008 in Norway, approximately 12% of workers in the construction industry were migrant workers.[34] These aspects may have led to selection bias and thus an underestimation of the proportion of workers exposed to a cold environment. How this selection bias affects the association between feeling cold and musculoskeletal pain or cold-related health complaints is not known.

A clear limitation of the study is the low number of participants who reported feeling cold often or never, resulting in large CIs. Also, there were few female participants working in a cold environment ≥25% of the time (n=123), which prevented any useful analysis stratified by sex. There are sex differences in types of work, prevalence of cold discomfort or cooling [15], and in the prevalence of musculoskeletal pain.[30] The association between working in cold environment and musculoskeletal pain is likely different by sex.

The observed associations in the present study are consistent for pain at multiple sites and at specific sites. Although not all the effect estimates were significant, the direction of the associations was consistent, with increased pain reporting with increasing experience of cold at work, at all sites except the hip. This consistency and the high effect estimates indicate that the observed associations are robust, and that additional adjustment for occupational risk factors would not explain all associations.

Even though Tromsø is situated at 69°N, the climate is relatively mild due to the Gulf Stream. There are also several factors other than ambient air temperature that can affect a worker's thermal balance, e.g. amount of protective clothing. At work, individual differences in heat loss, and protection and adaptations such as behavioral responses, adjusting clothing, or increasing physical activity, are very difficult to measure and would vary throughout a workday. The heat loss of one worker in a cold environment may be the same as that of another in a moderately cold environment if not properly protected. Thus, we believe the results of the present study are not specific to our study population, but relevant to others working in cold environments, whether they are indoors or outdoors.

Conclusion

Working in a cold environment ≥25% of the time was associated with chronic pain at ≥3 sites, and with neck, shoulder, and leg pain. Those who worked in a cold environment and felt cold often at work had higher odds for neck, shoulder, arm, back, hip, and leg pain compared to those who worked in a cold environment <25 % of the time. Working in a cold environment ≥25% of the time and never feeling cold was not associated with pain at any site. Organizing work and workplaces in a way that ensures thermal balance for workers might reduce the risk of chronic pain.

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FIGURE LEGENDS

Figure 1 Flow chart presenting number of subjects invited to Tromsø 6, those who participated in Tromsø 6, and those excluded and included in the present analysis.

Figure 2 Odds ratios with 95% confidence intervals for chronic pain. Working in a cold environment ≥25% of the time and feeling cold never, sometimes, or often compared to those working in a cold environment <25% of the time

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Contributors

EHF, ACH and MS designed the study. EHF conducted the data analysis and wrote the manuscript with the assistance of ACH and MS. All authors contributed to the interpretation and read and approved the final manuscript. CSN and AS contributed to the data acquisition of questions regarding pain from the 6th survey of the Tromsø study.

Collaborators

Lisbeth Aasmoe contributed to the data acquisition of questions regarding work in the cold from the 6th survey of the Tromsø study.

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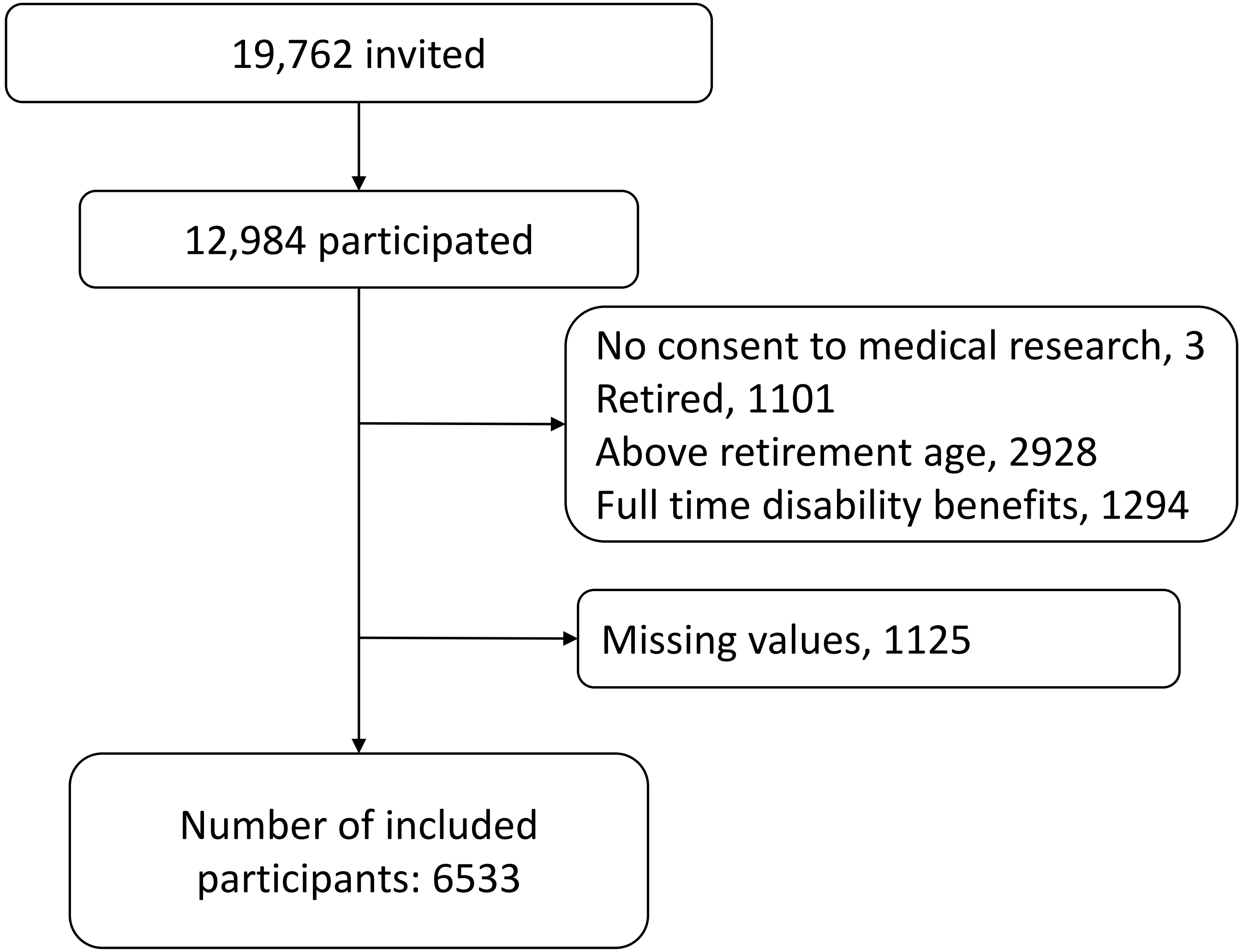
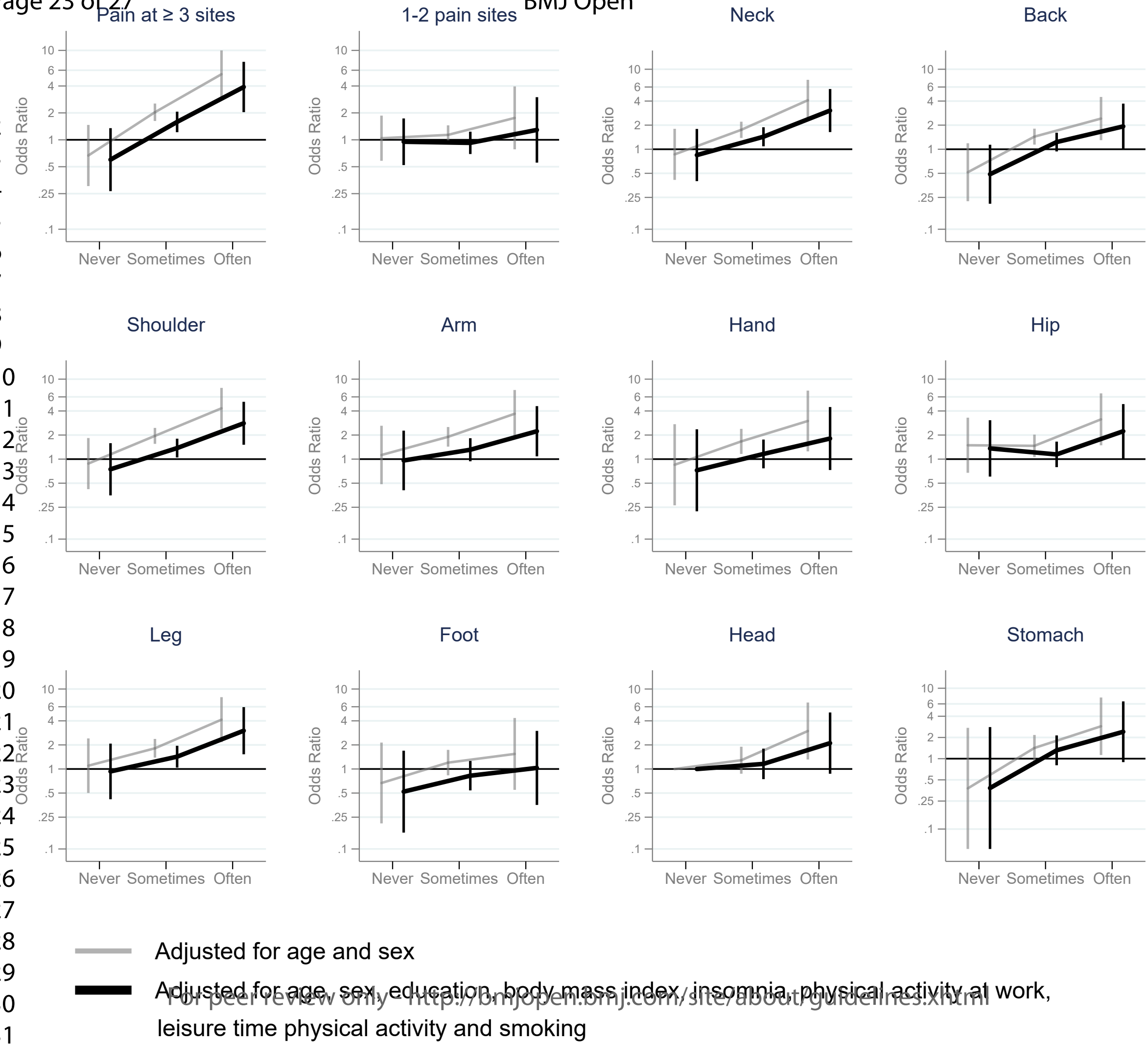
Competing interests: None declared

Data sharing: All data are available by applying to The Tromsø Study http://tromsoundersokelsen.uit.no/tromso/


19,762 invited
12,984 participated
No consent to medical research, 3
Retired, 1101
Above retirement age, 2928
Full time disability benefits, 1294
Missing values, 1125
Number of included participants: 6533


Pain at ≥ 3 sites
1-2 pain sites
Neck
Back
Shoulder
Arm
Hand
Hip
Leg
Foot
Head
Stomach
Odds Ratio
10
6
4
2
1
.5
.25
.1
Never
Sometimes
Often
Adjusted for age and sex
Adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity and smoking

Supplementary table 1 Cold-related health complaints during or after exposure to a cold environment

		Working in a cold environment ≥25% of the time								
		Total		Never feeling cold		Feeling cold sometimes		Feeling cold often		χ^2/Fischer exact
		n	%	n	%	n	%	n	%	*P*
Itching or rash	Yes	103	15	4	5	88	15	11	23	
	Total	698		78		573		47		0.008
Breathing difficulties	Yes	69	10	3	4	59	11	7	16	
	Total	666		72		549		45		0.091
Wheezing	Yes	38	6	4	6	30	6	4	9	
	Total	656		72		540		44		0.536
Mucus secretion from the lungs	Yes	35	5	2	3	29	5	4	9	
	Total	655		72		539		44		0.366
Chest pain	Yes	27	4	2	3	21	4	1	2	
	Total	753		71		544		42		1
Arrythmia	Yes	10	2	1	1	8	2	1	2	
	Total	661		72		545		44		0.665
Circulatory disorders/ disturbance in hands or feet	Yes	214	33	10	14	178	33	26	59	
	Total	658		72		542		44		<0.001
Temporary impaired vision	Yes	12	2	0	0	8	2	4	9	
	Total	660		72		544		44		0.007
Temporary migraine	Yes	22	3	1	1	17	3	4	9	
	Total	659		71		543		45		0.072
Fingers turning white temporarily	Yes	174	26	9	13	146	27	19	43	
	Total	658		72		542		44		0.001
Fingers turning blue/ blue-red temporarily	Yes	118	19	3	4	105	20	10	24	
	Total	634		70		523		41		0.001

Supplementary table 2 Influence of cold environment and cold-related health complaints on work performance, by frequency of feeling cold

	Working in a cold environment ≥25% of the time								
	Total		Never feeling cold		Feeling cold sometimes		Feeling cold often		χ^2 / Fischer exact
	n	%	n	%	n	%	n	%	p
Concentration									
Reduced	86	12	3	4	73	12	10	20	
Total	726		80		597		49		0.01
Memory									
Reduced	17	2	2	3	11	2	4	8	
Total	722		80		593		49		0.033
Finger sensitivity									
Reduced	502	68	44	54	416	68	42	84	
Total	743		81		612		50		0.002
Finger dexterity									
Reduced	469	64	39	48	392	65	38	76	
Total	736		81		605		50		0.002
Control of movement									
Reduced	210	29	15	18	172	29	23	48	
Total	722		82		592		48		0.002
Heavy physical work									
Reduced	173	24	10	13	141	24	22	46	
Total	721		79		594		48		<0.001
Long-lasting physical work									
Reduced	226	31	9	11	190	32	27	56	
Total	719		79		592		48		<0.001

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7*
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6, Fig 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9 tab 1
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	10 Table 2

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(*b*) Report category boundaries when continuous variables were categorized	7, tab 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Working in a cold environment, feeling cold at work and chronic pain: A cross-sectional analysis of The Tromsø Study

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Working in a cold environment, feeling cold at work and chronic pain: A cross-sectional analysis of The Tromsø Study

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Word count: 3320

Key words: Chronic pain, cold environment

Abstract

Aim: The aim of this study was to investigate if working in a cold environment and feeling cold at work are associated with chronic pain (i.e. lasting ≥3 months).

Methods: We used data from the sixth survey (2007-2008) of the Tromsø Study. Analyses included 6533 men and women aged 30-67 years who were not retired, not receiving full-time disability benefits, and had no missing values. Associations between working in a cold environment, feeling cold at work, and self-reported chronic pain were examined with logistic regression adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity, and smoking.

Results: 779 participants reported working in a cold environment ≥25% of the time. This exposure was positively associated with pain at ≥3 sites (OR 1.57; 95% CI 1.23 to 2.01) and with neck, shoulder, and leg pain, but not with pain at 1-2 sites. Feeling cold sometimes or often at work was associated with pain at ≥3 sites (OR 1.58; 95% CI 1.22 to 2.07 and OR 3.90; 95% CI 2.04 to 7.45, respectively). Feeling cold often at work was significantly and positively associated with pain at all sites except the hand, foot, stomach, and head.

Conclusion: Working in a cold environment was significantly associated with chronic pain. The observed association was strongest for pain at musculoskeletal sites and for those who often felt cold at work.

Article Summary

Strengths and limitations of this study

- The study has a high response rate (65.7%) which increases the likelihood that it is a representative sample of the working population
- The observed associations in the present study are consistent for pain at multiple sites and at specific sites
- The healthy worker effect may cause an underestimation of the associations
- The results are to some extent vulnerable to residual confounding by other occupational risk factors

INTRODUCTION

By evolution, humans are not physiologically fit to live in cold environments. To survive in such environments, we must use different strategies, such as insulating clothing, houses, and heating, which protect us from low temperatures. However, these protective measures may not be sufficient, as there is an excess of deaths recorded during the winter season. This excess is only partly explained by seasonal diseases and thus indicates that even moderately cold temperatures induce a strain on the body and negatively affect health.[1]

Cold exposure can cause pain. Indeed, immersing one's hand in cold water is commonly used as a test of pain tolerance.[2] Exposure to a cold environment, at work or during leisure time, can cause one to experience acute pain. In Finland, the reported prevalence of musculoskeletal pain believed by respondents to be caused by cold exposure is as high as 30% for men and 27% for women.[3, 4] Cold exposure is also known to reduce both physical and cognitive performance.[5, 6] Cold temperatures may also have sub-acute effects. Working in a cold environment has been found to be associated with an increased prevalence of back, neck, and shoulder pain.[7-10] In addition, it has been suggested that working in a cold environment is related to respiratory, cardiovascular, and dermatological complaints and diseases.[11]

Factors that affect workers' thermal balance are contact with water or cold surfaces, humidity, air velocity, radiation, type of clothing, and the heat produced by executing the work.[12] A cold working environment is defined as an environment with an ambient temperature below 10° C.[13] However, the ambient air temperature might not be a good measure of a worker's heat loss. In a study of seafood-processing workers, no relationship was found between workers' reports of feeling cold and measured air velocity, air temperature at the feet, or air temperature 1.1 meters above the floor.[14] This indicates that actual cold exposure is difficult to measure. Some studies have circumvented this problem by using self-reported cold experience as a measure of cold exposure.[15, 16] Among workers in the food processing industry, self-reported experiences of cooling of the neck, shoulder, wrist, and lower back were associated with a self-reported disadvantage in daily routines due to pain at those sites.[15] In a study of seafood industry workers, feeling cold often at work was associated with musculoskeletal pain.[16] Feeling cold often at work has also been associated with an increased prevalence of symptoms from skin and airways.[14]

These previous studies mostly used 12-months prevalence, i.e. musculoskeletal pain over the last 12 months, as the outcome. This includes acute periods of pain within the past 12 months, but contributes no information about the duration of pain. Chronic pain, defined as pain lasting 3 months or longer, may be a better measure of the impact on quality of life and future work ability.[17, 18] However, there is a lack of studies on the association between cold exposure and chronic musculoskeletal pain or pain in other tissues. Therefore, the main aim of this study was to investigate if working in a cold environment and feeling cold at work are associated with chronic pain. We hypothesize that exposure to a cold work environment increases the prevalence of chronic pain.

METHODS

Participants

The Tromsø Study is a prospective cohort study performed in the municipality of Tromsø in Northern Norway. The study currently consists of seven surveys, with the first conducted in 1974 and the seventh in 2015-2016. Tromsø has a coastal climate; the outdoor temperature is below 10° C for a major part of the year and seldom falls below -10° C.[19] This study includes participants from the sixth survey of the Tromsø Study (Tromsø 6), which was carried out in 2007-2008 and encompassed physical examinations and extensive health questionnaires.[20] Of the 19,762 individuals invited to Tromsø 6, 12,984 (65.7%) participated. The age of the participants ranged from 30 to 87 years. We excluded participants who were retired, were above retirement age (i.e. 67 years), on full-time disability benefits, and those with missing values. Thus, the final study population comprised 6,533 men and women (Figure 1). The Regional Committee of Research Ethics approved Tromsø 6 and this particular analysis.

Pain

Participants were asked "Do you have persistent or recurrent pain lasting 3 months or more" (Yes/No), and if so, at which anatomical site the pain was situated. The alternatives were jaw, neck, back, shoulder, arm (including elbow), hand, hip, leg (including thigh, knee, and calves), foot (including ankle), head (including face), chest, stomach, genitals, skin, and other. Sites where participants reported pain were then counted, and participants were categorized as having: no pain, pain at 1-2 sites, and pain at ≥3 sites.

Cold exposure

The Tromsø 6 questionnaire included the question "Do you work outdoors at least 25% of the time or in cold buildings (e.g. storage/industry buildings)?". Only those who answered "Yes" were given an extra set of questions about working in a cold environment in the second questionnaire. Among those questions were "Do you feel cold at work?" (yes, often/yes, sometimes/no, never).

Confounders

Possible confounders obtained from the questionnaires were age, sex, education, insomnia, physical activity at work, leisure time physical activity, and smoking. Body mass index (BMI) was calculated from weight and height measured at the examination. BMI was categorized into underweight/normal weight (<25 kg/m^2), overweight (≥25 kg/m^2 and <30 kg/m^2) and obese (≥30 kg/m^2) in the descriptive statistics, but it was included as a continuous variable in the regression analysis. Insomnia was assessed by the question "In the past 12 months, how often have you suffered from sleeplessness?" (never, or just a few times a year/1-3 times a month/approximately once a week/more than once a week). Physical activity at work was measured with the question "If you have paid or unpaid work, which statement describes your work best?" (mostly sedentary/requires a lot of walking/requires a lot of walking and lifting/heavy manual labor). Leisure time physical activity had four categories: sedentary, low, moderate, and hard. Sedentary was described as "reading, watching TV, or other sedentary activity", low as "walking, cycling, or other forms of exercise at least 4 hours per week", moderate as "recreational sports, heavy gardening for at least 4 hours per week", and hard as "hard training or sports competition, regularly several times per week". Smoking was categorized into current, former, and never smoker.

Statistics

Pearson chi-square was used to test differences in prevalence if all cells had n>5; Fisher's exact test was used if n≤5. T-test was used for age. Multivariable logistic regression was used to assess the association between working in a cold environment ≥25% of the time and self-reported pain. All statistical analyses were performed in Stata MP 15.

Patient and Public Involvement

There were no patient or public involvement in this particular sub-study.

RESULTS

Participants

Among the 6,533 participants included in the study, 779 reported to work in a cold environment ≥25% of the time. These individuals were younger, were mostly men, had lower levels of education compared to the rest of the working population, and had a higher BMI. They were also more likely to have physically demanding work, have lower levels of leisure time physical activity and to be current or former smokers (Table 1).

Table 1 Characteristics of the study population

	Working in a cold environment ≥25% of the time				
	No, n=5754		Yes, n=779		t/χ^2
	n	%	n	%	p-value
Age (years)*	49.9	8.8	48.8	8.7	<0.001
Sex					
Female	3178	55.2	143	18.4	
Male	2576	44.8	636	81.6	<0.001
Education					
Primary/secondary	727	12.6	262	33.6	
Technical school	1261	21.9	308	39.5	
High school	513	8.9	75	9.6	
College/university <4 years	1350	23.5	94	12.1	
College/university ≥4 years	1903	33.1	40	5.1	<0.001
Body mass index					
Under and normal weight (<25 kg/m^2)	2233	38.8	205	26.3	
Overweight (≥25 and <30 kg/m^2)	2494	43.3	406	52.1	
Obese (≥30 kg/m^2)	1027	17.8	168	21.6	<0.001
Insomnia					
Never, or just a few times a year	3927	68.2	576	73.9	
1-3 times a month	1042	18.1	118	15.1	
Approximately once a week	365	6.3	42	5.4	
More than once a week	420	7.3	43	5.5	0.014
Physical activity at work					
Mostly sedentary work	3497	60.8	87	11.2	
Work that requires a lot of walking	1454	25.3	176	22.6	
Work that requires a lot of walking and lifting (n, %)	760	13.2	379	48.7	
Heavy manual labor	43	0.7	137	17.6	<0.001
Leisure time physical activity					
Sedentary	1081	18.8	186	23.9	
Low	3350	58.2	410	52.6	
Moderate	1176	20.4	174	22.3	

Hard	147	2.6	9	1.2	<0.001
Smoking					
Current	1111	19.3	211	27.1	
Former	2227	38.7	319	40.9	
Never	2416	42	249	32	<0.001

*Numbers are mean and standard deviation for age, otherwise n and %.

Out of the 779 workers who reported working in a cold environment ≥25% of the time, 92 never felt cold at work, 635 felt cold sometimes, and 52 felt cold often. The prevalence of chronic pain at different anatomical sites was higher in those who often or sometimes felt cold at work compared to those who never felt cold (Table 2).

Table 2 Prevalence of chronic pain in participants working in a cold environment <25% of the time and in those working ina cold environment ≥25% of the time by frequency of feeling cold

	Working in a cold environment <25% of the time n=5754		Frequency of feeling cold at work among those working in a cold environment ≥25% of the time n=779.					
Anatomical sites			Never, n=92		Sometimes, n=635		Often, n=52	
	n	%	n	%	n	%	n	%
1-2 sites	783	14	14	15	91	14	8	15
≥3 sites	904	16	7	8	128	20	21	40
Neck	765	13	8	9	106	17	18	35
Back	811	14	6	7	106	17	14	27
Shoulder	753	13	8	9	113	18	18	35
Arm	465	8	6	7	69	11	11	21
Hand	341	6	3	3	39	6	6	12
Hip	514	9	7	8	49	8	9	17
Leg	557	10	7	8	76	12	13	25
Foot	385	7	3	3	36	6	4	8
Head	318	6	0	0	32	5	7	14
Stomach	210	4	1	1	27	4	5	10

Multiple pain sites

Working in a cold environment ≥25% of the time was significantly associated with pain at ≥3 sites after adjustment (odds ratio [OR] 1.57; 95% confidence interval [CI] 1.23 to 2.01) (Table 3).

Table 3 Logistic regression analysis with pain at 1-2 or ≥3 sites and specific pain sites as outcomes

	Working in a cold environment <25% of the time n = 5754	Working in a cold environment ≥25% of the time n = 779						
	Reference		Adjusted for age and sex			Fully adjusted model*		
Anatomical sites	n	n	OR	95% CI		OR	95% CI	
1-2 sites †	783	113	**1.15**	**0.92**	**1.44**	0.95	0.73	1.24
≥3 sites ‡	904	156	**2.02**	**1.64**	**2.48**	**1.57**	**1.23**	**2.01**
Neck	765	132	**1.78**	**1.44**	**2.20**	**1.46**	**1.13**	**1.89**
Back	811	126	**1.38**	**1.12**	**1.71**	1.18	0.91	1.52
Shoulder	753	139	**1.96**	**1.58**	**2.42**	**1.39**	**1.08**	**1.78**
Arm	465	86	**1.93**	**1.49**	**2.50**	1.34	0.98	1.83
Hand	341	48	**1.66**	**1.19**	**2.32**	1.16	0.79	1.71
Hip	514	65	**1.59**	**1.19**	**2.12**	1.26	0.90	1.75
Leg	557	96	**1.87**	**1.47**	**2.40**	**1.47**	**1.10**	**1.96**
Foot	385	43	1.16	0.83	1.63	0.80	0.54	1.19
Head	318	39	1.28	0.89	39	1.13	0.75	1.70
Stomach	210	33	1.42	0.96	33	1.30	0.82	2.04

* Adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity, and smoking

† Model does not include those with pain at ≥3 sites

‡ Model does not include those with pain at 1-2 sites

OR: odds ratio, CI: confidence interval.

However, in the fully-adjusted model, those who worked in a cold environment ≥25% of the time did not have higher odds for pain at 1-2 sites compared to those who worked in a cold environment <25% of the time. When those who worked in a cold environment ≥25% were divided by frequency of feeling cold, feeling cold sometimes and often was associated with pain at ≥3 sites (OR 1.58; 95% CI 1.22 to 2.07 and OR 3.90; 95% CI 2.04 to 7.45, respectively) (Figure 2).

Pain at specific sites

In the analysis with pain at specific sites as outcomes, the low number of participants who worked in a cold environment ≥25% with pain in the jaw (n=4), chest (n=10), skin (n=5), genitals (n=8), and other location (n=3) prevented separate analyses for these outcomes. When using pain at the remaining 10 sites as separate outcomes, working in cold environments ≥25% of the time was significantly associated with pain at all sites except the foot, head, and stomach in the model adjusted for age and sex (Table 3). Although those working in cold environments ≥25% of the time had higher odds for pain at all sites except the foot in the fully-adjusted model, only the associations for pain at the neck, shoulder, and leg were statistically significant (Table 3).

When those working in cold environments ≥25% of the time were divided by frequency of feeling cold, those who felt cold sometimes or often at work had significantly higher odds for pain at most musculoskeletal sites compared to those working in a cold environment <25% of the time. In the model adjusted for age and sex, feeling cold often was significantly associated with head and stomach pain (Figure 2).

After adjusting for possible confounders, only pain from musculoskeletal pain sites remained significant; workers who felt cold often had higher odds for neck, shoulder, arm, leg, back, and hip pain compared to the group that worked in a cold environment <25% of the time (Figure 2). The strongest association was for neck pain (OR 3.05; 95% CI 1.64-5.66). Among those working in cold environments ≥25% of the time, the group that reported feeling cold sometimes at work had higher odds for neck, shoulder, and leg pain, with ORs between those who never felt cold and those who felt cold often at work (Figure 2). In the group working in cold environments ≥25% of the time, never feeling cold at work was not significantly associated with chronic pain at any specific site in either of the models.

DISCUSSION

Key results

In this study, working in a cold environment ≥25% of the time was associated with chronic pain (i.e. pain lasting ≥3 months) at the neck, shoulder, and leg, as well as pain at ≥3 sites, even after adjusting for age, sex, education, BMI, insomnia, physical activity at work, and leisure time physical activity. Those who felt cold often at work had significantly higher odds for pain at ≥3 sites and for pain at all specified sites except the hand, foot, head, and stomach. Feeling cold sometimes at work was significantly associated with neck, shoulder, and leg pain. We found no significant differences in chronic pain between those who never felt cold when working in a cold environment ≥25% of the time and those who work in cold environment <25% of the time.

There are many different etiologies of pain and we do not have sufficient information to appropriately identify the origin of the pain.[21] Additionally, we have no information on whether the reported pain was present at all times or only when exposed to cold environment. Nevertheless, the ORs for chronic pain at musculoskeletal locations in the present study were lower than estimates for musculoskeletal pain during the last 12 months from studies of slaughterhouse and seafood industry workers.[15, 16] Interestingly, in the fully-adjusted model, we found no association between working in a cold environment ≥25% of the time and hand and foot pain. These are the body parts that are most susceptible to cooling. If cooling of local tissue is the mechanism for a higher prevalence of chronic pain, one could assume that body parts most exposed to cold would be at a higher risk for pain. The results for hand and foot in the present study do not support such an assumption. However, this observation is in contrast to other studies that found associations between a cold environment or an experience of cooling of the wrist and pain in the wrist, hand, and forearm.[7, 15, 22] The difference between earlier findings and the present study might be due to a different etiology and pathology for chronic musculoskeletal pain and 12-month pain prevalence. Different study populations and cold exposures could also contribute to the contradictory results.

Feeling cold is a subjective experience and contains little or no information about the actual environment, such as ambient temperature, humidity, and air velocity. However, ambient temperature could also be a poor measure of cold exposure. A study of seafood industry workers could not establish a simple relationship between thermal environmental factors and the prevalence of workers feeling cold. The same study also found that working in relatively high temperatures (>12° C) led to low finger temperatures and a major drop in foot temperature.[14] Thermal comfort and sensation seem to be closely connected to both average skin temperature and rectal temperature.[23] Although subjective, feeling cold might be a better indication of the environment's effect on the body than ambient air temperature.

The general health status of a person might also influence to what degree they feel cold. Individuals with already existing diseases are more prone to report cold-related musculoskeletal pain [24], and male slaughterhouse workers with chronic pain had more complaints about indoor climate, including complaints about temperatures that were too low and draughts, when compared to those without pain.[25] Chronic pain could also influence the perception of feeling cold. The design of the present study is not adequate to address the direction of the observed association.

Few plausible causal mechanisms between cold exposure and musculoskeletal pain, chronic or not, have been suggested. Studies have found that cooling induces acute physiological alterations in the musculoskeletal and neural system. There seems to be a dose-response relationship between the temperature in the muscle and muscle power, and the contraction velocity decreases with decreasing temperature. Further, there is an increased activation of the antagonist muscles indicating a reduced motor control. [26-28] Another study reports an enhanced fatigue in the muscles when performing repetitive work in a cold environment.[29]These alterations points in the direction that cold exposure increases the strain on the musculoskeletal apparatus . Repeated exposure to a cold environment can also have a long-term effect in the form of habituation or acclimatization. Habituation is described as a reduction in shivering, vasoconstriction stress response and cold sensation. Additionally, different acclimatization processes like lowering core temperature, increasing the metabolic rate and increasing vasoconstriction or sub-cutaneous fat have been reported.[30] However, a relationship between these altered acute and long-term physiological responses, and subsequent chronic pain has not been satisfactorily established. A cross-sectional study of slaughterhouse workers found that a lower pressure pain threshold was associated with more complaints about the indoor climate.[25] A possible explanation for the observed association between chronic pain and frequency of feeling cold in the present study could be that persons who felt cold have a lower pain threshold than those who did not. Future research should explore whether this is genetic, or if thermal stimuli could contribute to a sensitization process.

Strengths and limitations

In our study, participants who worked in a cold environment ≥25 of the time had generally low education and executed a lot of heavy physical work, both of which have been identified as risk factors for musculoskeletal pain; [31-33] adjusting for these confounders attenuated the associations in the present study. Workers exposed to cold are also exposed to several other occupational risk factors that can be associated with poor health, and physical activity at work is not a satisfactory measure of these risk factors.[34] Consequently, the results are to some extent vulnerable to residual confounding.

There are a number of clinical conditions that could be a cause of pain, or increase the risk of chronic pain.[21] As these conditions could be unevenly distributed, they could confound the observed association. Our results could also be influenced by the healthy-worker effect.[35] Feeling cold is uncomfortable, and individuals negatively affected by a cold environment might change their occupation or workplace to avoid getting cold. The remaining employees exposed to cold may therefore be the ones that are the least negatively affected by the cold. Additionally, chronic pain can contribute to selection bias by having a different impact in different occupations. There is a social gradient in disability benefits, and physical work has been found to increase the risk for disability pension, even after adjustment for health status.[36] Thus, the effect estimates may be underestimated.

The high response rate (65.7 %) of Tromsø 6 is a major strength and increases the likelihood that the findings are representative of the general population. Nevertheless, non-participants in Tromsø 6 tend to have lower education than participants;[20] therefore we cannot rule out that the prevalence of cold-exposed workers was higher among non-participants. Additionally, some of the occupations in which workers are typically exposed to cold environments have a high number of migrant workers, a group not invited to participate in The Tromsø Study. As an example, in 2008 in Norway, approximately 12% of workers in the construction industry were migrant workers.[37] These aspects may have led to selection bias and thus an underestimation of the proportion of workers exposed to a cold environment. How this selection bias affects the association between feeling cold and musculoskeletal pain or cold-related health complaints is not known.

A clear limitation of the study is the low number of participants who reported feeling cold often or never, resulting in large CIs. Also, there were few female participants working in a cold environment ≥25% of the time (n=123), which prevented any useful analysis stratified by sex. There are sex differences in types of work, prevalence of cold discomfort or cooling [15], and in the prevalence of musculoskeletal pain.[33] The association between working in cold environment and musculoskeletal pain is likely different by sex.

The observed associations in the present study are consistent for pain at multiple sites and at specific sites. Although not all the effect estimates were significant, the direction of the associations was consistent, with increased pain reporting with increasing experience of cold at work, at all sites except the hip. This consistency and the high effect estimates indicate that the observed associations are robust, and that additional adjustment for occupational risk factors would not explain all associations.

Even though Tromsø is situated at 69°N, the climate is relatively mild due to the Gulf Stream. There are also several factors other than ambient air temperature that can affect a worker's thermal balance, e.g. amount of protective clothing. At work, individual differences in heat loss, and protection and adaptations such as behavioral responses, adjusting clothing, or increasing physical activity, are very difficult to measure and would vary throughout a workday. The heat loss of one worker in a cold environment may be the same as that of another in a moderately cold environment if not properly protected. Thus, we believe the results of the present study are not specific to our study population, but relevant to others working in cold environments, whether they are indoors or outdoors.

Conclusion

Working in a cold environment ≥25% of the time was associated with chronic pain at ≥3 sites, and with neck, shoulder, and leg pain. Those who worked in a cold environment and felt cold often at work had higher odds for neck, shoulder, arm, back, hip, and leg pain compared to those who worked in a cold environment <25 % of the time. Working in a cold environment ≥25% of the time and never feeling cold was not associated with pain at any site. Organizing work and workplaces in a way that ensures thermal balance for workers might reduce the risk of chronic pain.

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FIGURE LEGENDS

Figure 1 Flow chart presenting number of subjects invited to Tromsø 6, those who participated in Tromsø 6, and those excluded and included in the present analysis.

Figure 2 Odds ratios with 95% confidence intervals for chronic pain. Working in a cold environment ≥25% of the time and feeling cold never, sometimes, or often compared to those working in a cold environment <25% of the time

Acknowledgments

Contributors

EHF, ACH and MS designed the study. EHF conducted the data analysis and wrote the manuscript with the assistance of ACH and MS. TB assisted in the analysis. All authors contributed to the interpretation and revised the manuscript. CSN and AS contributed to the data acquisition of questions regarding pain from the 6th survey of the Tromsø study. All authors read and approved the final manuscript.

Collaborators

Lisbeth Aasmoe contributed to the data acquisition of questions regarding work in the cold from the 6th survey of the Tromsø study.

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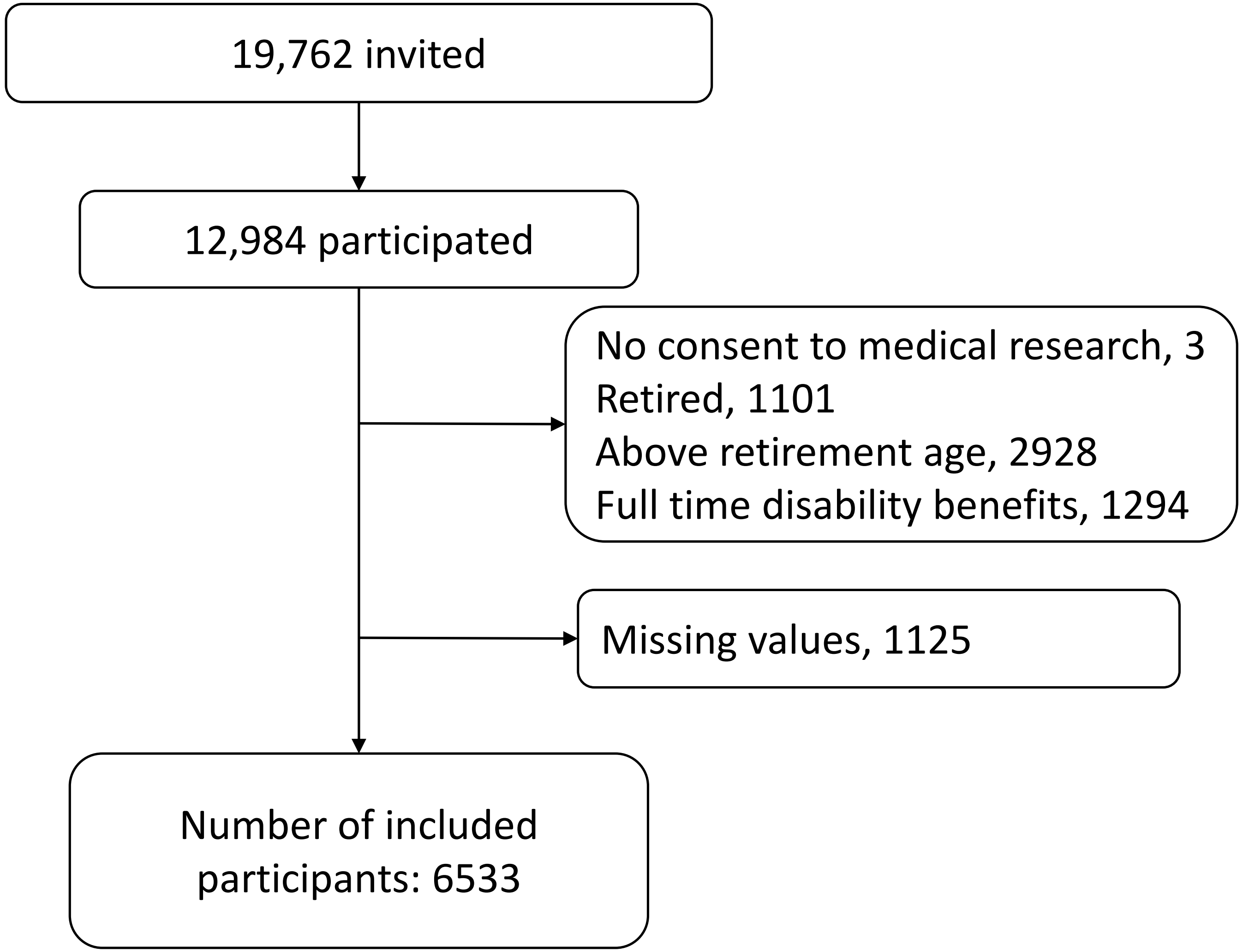
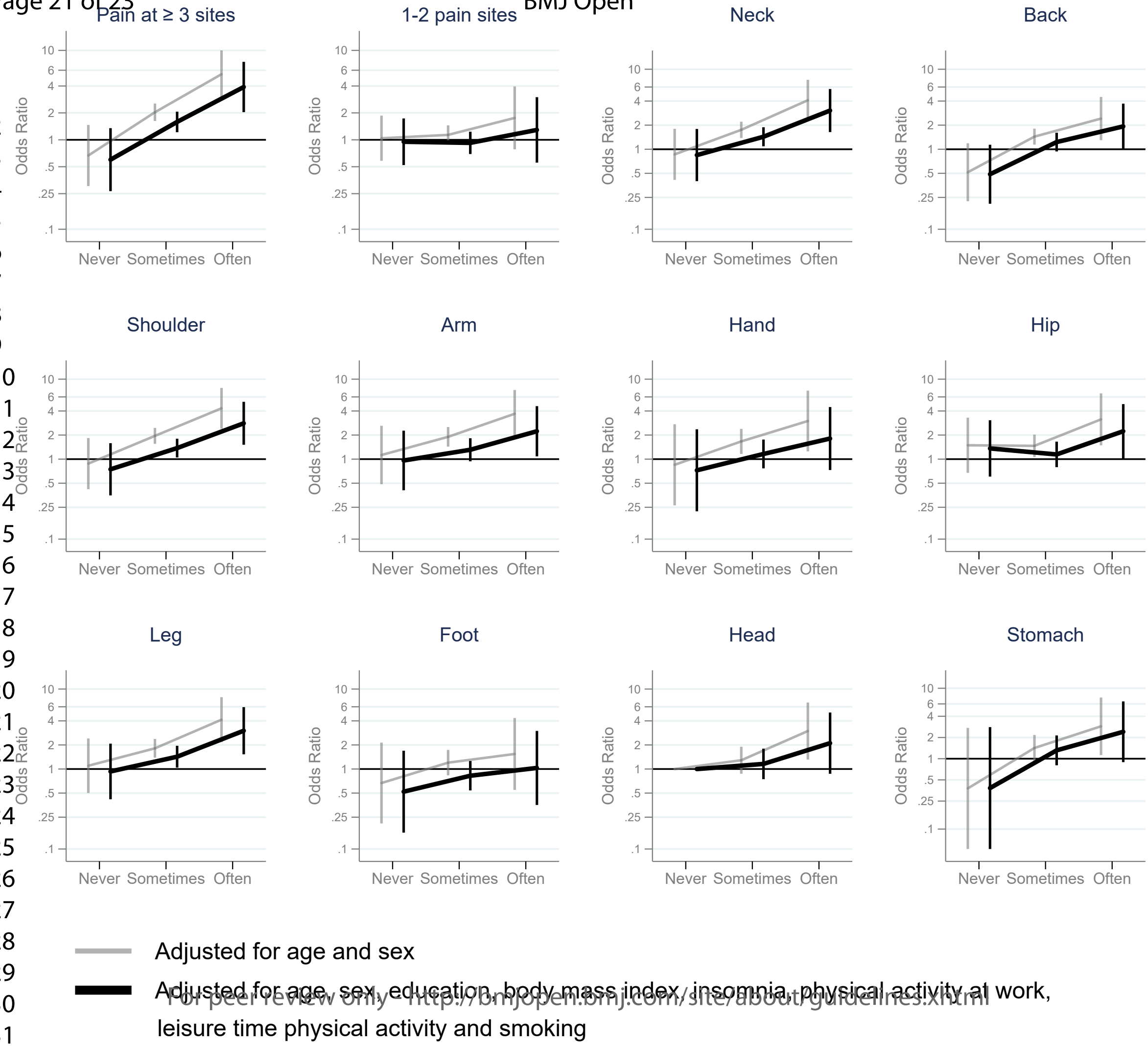
Competing interests: None declared

Data sharing: All data are available by applying to The Tromsø Study

http://tromsoundersokelsen.uit.no/tromso/


19,762 invited
12,984 participated
No consent to medical research, 3
Retired, 1101
Above retirement age, 2928
Full time disability benefits, 1294
Missing values, 1125
Number of included participants: 6533


Pain at ≥ 3 sites
1-2 pain sites
Neck
Back
Shoulder
Arm
Hand
Hip
Leg
Foot
Head
Stomach
Odds Ratio
10
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1
.5
.25
.1
Never
Sometimes
Often
Adjusted for age and sex
Adjusted for age, sex, education, body mass index, insomnia, physical activity at work, leisure time physical activity and smoking

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7*
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	6, Fig 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9 tab 1
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	10 Table 2

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(*b*) Report category boundaries when continuous variables were categorized	7, tab 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.