Multi-site musculoskeletal pain in mine workers exposed to cold environment

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Helge Ringberg, MK-10

Morten Skandfer og Kjell Ingemar Rödin

Arbeids- og miljømedisinsk avdeling, UNN

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ABSTRACT:

Objectives:

We aimed to examine the prevalence of musculoskeletal single- and multi-site pain and exposure factors from two high north mining populations. In addition, we aimed to analyze for possible associations between perceived cold and pain in single and multiple locations.

Methods:

This study follows a cross sectional epidemiological design. Data was collected by questionnaire among 254 miners from two open pit mines; Stjernøya, Norway and Aitik, Sweden. Gathered was data on musculoskeletal ailments and pain during the previous month and year across 9 locations, perceived whole-body cold during damp and dry cold, and additional covariates, adjustment factors and exposures. All data presented are accompanied by tables. In addition, binary logistic regression was used to analyze any associations between musculoskeletal pain and cold exposure.

Results:

Feeling cool or cold was reported by 13.3% of miners during damp cold and by 34.8% during dry cold. Single-region pain was reported by 18.6%, whereas pain in two, three or four regions affected 27.7%, 24.1% and 17.0%, respectively. When adjusting for covariates we found no significant association between cold exposure and the presence of single- or multi-site pain.

Conclusions:

Musculoskeletal pain, both single- and multi-site, is common among miners in the Barents region. Although miners are working in the low winter temperatures, most do not feel cold. No significant association was found between cold exposure and musculoskeletal pain. Further studies should investigate the epidemiology and ramifications of multi-site pain while also considering possible effects of cold.

WORKING PROCESS:

Work on this paper first started in January of 2014. I met with Morten Skandfer who was to become my main supervisor and Kjell Ingemar Rödin, my secondary supervisor. They presented me with the opportunity to use the data they, and the rest of the MineHealth group, had collected. My first task was to transcribe the data from the Norwegian questionnaire into an excel worksheet, this was done in cooperation with Ingeborg Steinholt. Initially the topic for the study was not strictly defined. The outcome was musculoskeletal pain, but we had not concluded on what exposures we were to investigate. After the data was transcribed I started scouring for publications on musculoskeletal pain, lower back pain, effects of whole-body vibration, operating heavy equipment, seasonal weather changes and more. Before long exam was approaching, and with it decreased spare time to continue work on this study. Progress was halted, and not resumed until March of 2015 when I had completed all obligatory internship during 5th year of medical school. In the meantime Morten had been intrigued by studies done on multi-site pain and realized that we had excellent data to conduct a study on multi-site pain and the effects of cold exposure. His enthusiasm spread onto me. We agreed on the subject presented here, and I set off to gather publications and references relevant for this study. I performed a structured search of PubMed with relevant search terms, constructing a digital library of literature using Thomson Reuters EndNote X7.3.1. Topics covered were cold exposure, mining, multi-site pain and general musculoskeletal research. A month later I had acquired sufficient knowledge, and a database of references, such that I could start the writing process. Using the data from the Swedish and Norwegian mines I used excel for dichotomization, prevalence calculations and calculation of crude odds ratios. Morten helped me do the regression analyses using SPSS. We met frequently during the last couple of months, discussing our findings and how they could be interpreted. Morten has been invaluable throughout the whole process of this study; as an overall mentor guiding this work in the right direction, right down to the details of how my wording could become more precise and correct. This work could not have been accomplished without the help of Morten as my supervisor. The final meeting between us, indicating the conclusion of this study, took place on 30.05.15.

INTRODUCTION:

Musculoskeletal pain is one of the most prevalent reported health complaints among people. In Norway roughly 75% of all adults will have musculoskeletal pain or discomfort in the course of a month. The economic implications are equally massive. In 2009, the total estimated cost of musculoskeletal disease in Norway was between 69 and 73 billion NOK (1). Even though most cases of musculoskeletal pain are minor and do not require treatment, it is still the most frequently used group of diagnoses for sickness absence. Through the fourth quarter of 2014, 33,1 % of all diagnoses used in sickness absence were musculoskeletal disease (2). That represents just over 2.6 million man-days (3). Musculoskeletal diseases can be grouped in various ways, one example would be by anatomical location. Another way is to group them into either overuse disorders, inflammatory disorders or degenerative disorders (4). Overuse disorders consist of disorders arising when muscles, tendons or joints are exposed to a level of stress over time that lies beyond their capacity to adapt. Inflammatory disorders are characterized by an inflammatory response that can result in the destruction of tissue. Degenerative disorders are the result of degenerative cell changes, which for various reasons have become a continuous process. Additionally injuries and accidents can lead to small lacerations affecting only the outer layers of the skin, to huge crush-injuries involving bones, joints, nerves, muscle and blood supply.

Multi-site pain is defined as a condition when pain exists at different places at the same time. Coggon et al. (5) suggests classifying multi-site pain by the number of anatomical sites affected, stating that pain affecting 6-10 anatomical sites differs importantly in its association with risk factors, than pain affecting 1-3 sites. They did not however, find that pain located at 6-10 sites differed qualitatively in its association with risk factors, than did pain affecting 1-3 sites. Another study (6) simply grouped anatomical sites into four zones, neck or shoulders, lower back, upper extremities and hips or lower extremities. They then analyzed how the number of painful zones changed the association with their study outcome. Multi-site pain is frequently encountered; a study of 3700 French workers found that two-thirds of the workers had pain in two or more anatomical sites, almost one-third had in four or more sites and 10% reported pain from six or more anatomical sites (7). Other reported prevalence for multi-site pain is 41% for two or more sites, 16% for four or more and 5% for six or more anatomical pain sites (5). In that study, however, the prevalence of multi-site pain, especially for six or more pain sites, was found to be much higher than could be expected, if assuming that the prevalence of pain at separate anatomical sites were independent of each other. Female sex, older age, somatization tendency and exposure to multiple physically stressing occupation activities are all associated risk factors for musculoskeletal pain. But a study of 12,000 adult workers found that pain in 6-10 anatomical areas, as opposed to just 1-3 anatomical areas, showed much stronger association with the listed risk factors (5). The same study also found that once participants had pain in one site, they were more likely to have pain at other sites as well, and that any laterally localized pain (i.e. knee, elbow, wrist etc.) was strongly associated with pain at the same contralateral location. A two-year prospective study found that high levels of adverse psychosocial factors at work, little to moderate amount of leisure-time physical activity, high physical workload and Body Mass Index (BMI) > 30, all predicted multi-site pain at the two-year follow-up (8). Preventive measures are imperative when discussing multi-site pain. Several studies have found that the number of pain sites and the occurrence of multi-site pain is very stable over time (8-11). The importance of multi-site pain is in part demonstrated with its effect on sickness absence. A study of almost 3,500 finish workers (12) found that an increase in the number of pain sites increased the risk of sickness absence. If workers had pain in all four pain sites (neck, upper limbs, lower back and lower limbs), they had a 4-fold risk of being classified as having high sickness absence, compared with workers without pain. This same study also emphasizes the importance of the number of pain sites, as it is a better predictor of sickness absence than age, smoking, sleep disorders, physical workload, BMI or self-reported diagnosed diseases. Haukka et al. (6) found that pain in multiple sites among 4,000 finish workers increases, not only the risk of poor physical work ability, but also the self-evaluated risk of poor future work ability. Furthermore, they found that those with multi-site pain planned to retire early compared to those without it. Similarly, Kamaleri et al. (13) found, through their 14-year study of 1300 Norwegian citizens, a dose-response relationship between increasing number of pain sites, from zero to ten, and increasing probability for a disability pension. Self-rated work ability decline has been found to be associated with the occurrence of multi-site pain in food industry workers (14).

Exposure to cold temperatures effect many aspects of occupational health and safety. Cold exposure has marked effects on human functioning. The ISO 15734 standard for work environment defines temperatures below +10 °C as an unfavorable condition with increased risk of negative effects on human function, increasing the risk of injuries and musculoskeletal symptoms (15). Through systematic review of a number of publications, Oksa et al. (16) showed that muscular performance was greatly affected by cooling. Endurance, force, power, velocity and coordination were all limited by lowered temperatures. Low temperatures can cause or worsen existing respiratory, musculoskeletal, cardiovascular or skin conditions (17). Working in cold temperatures increase the rates of both cold exposure injures, eg. frostbite, and slip and fall injuries (17-19). A study (19) analyzed 73,000 mining industry injuries gathered from seven US states over six years for associations with temperature and wind, and found an association between decreasing environmental temperatures and increasing slip and fall injuries. The strongest association was shown for temperatures below 1.6 °C.

The mining industry has traditionally involved vigorous manual labor, but is now an industry in great change. Through the last 25 years machines have increasingly taken over the physical workload. Miners now spend most of their hours operating machinery and some occasional heavy work. McPhee suggested that this new work pattern is more damaging because there is a reduced training effect (20). Additionally, the increased amount of time spent operating machinery brings about health problems following sedentary work in fixed positions, as well as exposure to “rough rides”. In a study of 3,500 miners in northern Russia, Skandfer et al. (21) found that lower back pain was strongly associated with cold working conditions, wet clothes and awkward postures, but not with exposure to whole-body vibration. As stated earlier, being exposed to multiple physically stressing occupational activities shows association with musculoskeletal symptoms and disease, particularly for multi-site pain. This, in combination with cold temperatures in northern Scandinavia and subsequent elevated risk for slip and fall injuries, puts the mining industry in northern Norway and Sweden at greater risk for musculoskeletal conditions. Therefore, we aimed to examine the occurrence of musculoskeletal single- and multi-site pain and exposure factors during mining north of the Arctic Circle. In addition, we aimed to analyze for possible associations between perceived cold and pain in single and multiple locations.

METHODS:

Context:

This study is an offspring from a European multinational collaboration concerning mining in the Barents region in the period 2011 – 2014. The project was named MineHealth (22). The overall aim of the Mine Health project was to provide long term sustainability of well-being health and work ability among workers in the mining industry by increased and updated knowledge on how to cope with the environment and to adopt preventive measures for working in the mining industry within the Barents region. Mines and researchers from Norway, Sweden, Russia and Finland participated in working towards the common goal of the project. Information concerning work exposure, personal factors and health outcomes for the miners were collected by on-site measurements in the mines’ working environment and through data collection by clinical examination and questionnaires. The latter formed the database used here. Self-reported health in occupational populations have been used in several studies (6-8, 21, 23, 24). Although the Mine Health study included information about mine workers' exposures and health in operational mines from four countries, some questionnaires were tailored to fit local and national conditions, so for the purpose of the study presented here, only the outline of datasets from Norway and Sweden were identical and thus possible to fuse into one. Thus, included in this study are the two mines located in Stjernøya, Norway and Aitik, Sweden.

The Stjernøya mine is operated by Sibelco Nordic, a subsidiary of Sibelco. The mine is on an island located at the mouth of the Alta fjord, approximately 30 kilometers north of Alta city. For reference, the island is slightly more than 400 kilometers north of the Arctic Circle. This is not an underground mine, but an open pit mine. This means the workers are exposed to the arctic climate in its entirety. The mine had at the time 101 workers. Due to regulations and considerations concerning the local reindeer Sami, the mine is not operational through most of May and June and three weeks during the reindeer migration in September. The excavated mineral is nepheline syenite, a mineral used extensively as a raw material in the glass and porcelain industry.

The Aitik mine is located roughly 15 kilometers southeast from the town of Gällivare, Sweden. This mine is also an open pit mine, one of Europe's largest mines of this type that excavate copper. There are approximately 700 employees at the mine, which is owned and run by Boliden Mineral, a subsidiary of Boliden AB. Although this mine is much farther south than Stjernøya mine, only 50 kilometers north of the Arctic Circle, it is much colder due to the fact that it is inland. The main product from the mine is copper, but also gold and silver are found in the excavated ore. Because both mines are open pit, the workers are constantly exposed to the arctic climate.

The mining operation can be simplified to involve blasting and/or excavation, transport and processing. Many different categories of workers are employed, including heavy machinery operators, drivers, blasters, foremen, electricians and even cafeteria personnel. The work bears similarities with large scale construction work.

Study design:

This study follows a cross-sectional design and is an observational study. This means that the data collected from the study population is collected at one specific point in time. The main advantage with the cross-sectional design is the possibility to include relatively large study populations at a limited cost. The Regional Committees for Medical and Health Research Ethics (REC) gave approval for the study on employees on Stjernøya, and a similar committee approved the study on employees in the Aitik mine.

Study population and enrolment:

From Stjernøya mine there were 101 people included in the study, roughly 90% of the total workforce. All 111 workers were invited, four chose not to participate, while seven did not meet. Of the 700 workers at Aitik, 160 had a work shift the day of the study. Of those 153 (96%) answered the questionnaire and were thus included in the study. The composition of workers on the different shifts were not qualitatively different and we expect no selection bias. The total study population was 254 workers. Participants were recruited by invitation to participate, distributed through the information channels provided by the companies' health safety and environment (HSE)-officers, supported by the workers' unions. The workers would also receive a health examination both as part of the study and as an extended routine annual health examination. Participation was voluntary and failure to participate did not disqualify for later examinations by the HSE-services or other benefits. They received normal pay through their participation time. Information was both written and oral, prior to and on the day of examination, and those participating signed an informed written consent. All personal information data were collected and stored with confidentiality, with names replaced by a code.

Data collection:

The questionnaire is adapted from an English validated questionnaire (25). Then translated to Norwegian and Swedish. The Norwegian questionnaire was proofed by piloting it on 10 randomly selected mine workers to discover possible sources of misinterpretation and clarify the phrasing. All participants had the option to request assistance in the odd event of confusion. Trained personnel would then, to the best of their abilities, resolve any issues.

For this study we used a questionnaire to collect all the data except height and weight which was measured as part of a medical examination. Section 1 of the questionnaire contained self-rated health and sleep, muscle and joint pain, skin irritation, respiratory ailments and stress. Muscle and joint pain was gathered for nine pain sites during the previous month and previous twelve months. Decreased work ability following pain in any of the nine sites was also collected for the previous month.

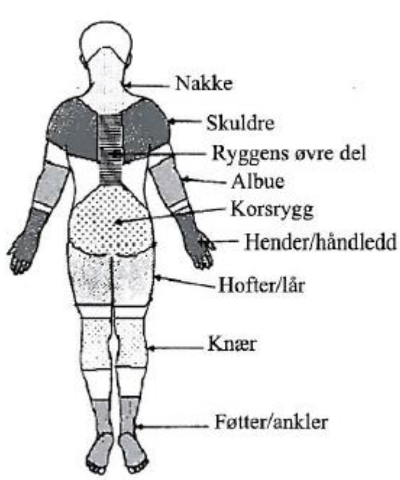
Section 2 included several questions on factors related to the working environment. Included were job title, previous working places, hours spent driving different vehicles (twelve options), exposure to vibrating hand tools and exposure to diesel exhaust or dust. Environmental conditions gathered included hours working outdoors or in non-heated buildings, exposure to wind and wet working clothes, and self-rated impact to various weather and cold conditions. The end of section 2 had questions regarding specific working positions, exposure to heavy lifting and kneeling or seated working position. Questions pertaining personal protective equipment (PPE) were gathered in section 3. This section gathered detailed information about PPE, including type of garment, layering of garments, problems with PPE and appropriate training for use and maintenance of PPE. Section 4 deals with personal data such as gender, housing, education, spare time activity, use of snuff or chewing tobacco and questions concerning several life aspects.

The Stjernøya mine was visited in November of 2013 by a team from the University Hospital North Norway (UNN), Department of Occupational and Environmental Medicine. Data from the Aitik mine was gathered in the spring of 2013 by a team from the Umeå University (UMU) Department of Public Health & Clinical Medicine Occupational and Environmental Medicine.

Dependent variable:

Musculoskeletal pain during the last month was the dependent variable. Presence of musculoskeletal pain was collected in the questionnaire by questions in the category named "muscle and joint pain". There was an illustration of the body (figure 1) from behind where each of the nine locations were indicated by shading and annotated arrows. Last month pain was measured by the question "Tick the intensity/level of any symptoms you have had during *the last month* (same figure as on the previous page)". Participants then had the option to tick "none", "mild", "moderate", "strong" or "very strong" for each of the depicted locations. The included anatomical sites include "neck", "one or both shoulders", "one or both elbows", "one or both wrists/hands", "upper part of the back", "lower part of the back (lumbar region)", "one or both hips", "one or both knees" and "one or both ankles/feet".

Figure 1:



12 month pain was measured by the question “Have you had physical ailments, such as pain, aches or discomfort, during the last 12 months? The figure depicts the different parts of the body. You decide in which body parts your symptoms are located”. Subjects then had the option to tick “no” or “yes” for each site.

Independent variables:

Exposure to cold and subsequent self-evaluated body temperature sensation is the independent variable. Exposure to cold was measured by the question “How are you usually affected by the following weather and cold conditions in your work?”. Then followed a row labeled “the whole-body feels:” where they could tick off either “warm”, “neutral”, “cool” or “cold” for both “mild or humid weather (temperature ca. -5 … +5 °C)” (damp cold) and “cold and dry weather (temperature ca. -20 … -10 °C)” (dry cold), respectively. A prerequisite for this question was given, stating “Question 2.13 should be answered only by those working outdoors (the whole day or parts of the day) during the winter. If you do not work outdoors, go to question 2.14”. Participants also had an option to tick off “temperatures below -10 °C do not occur”, and consequently defer from reporting any sensation for “cold and dry weather”.

Covariates and adjustment factors:

Covariates were chosen based on literature as potential causal factors, such as heavy lifting. Adjustment factors collected included age, gender, BMI and smoking. Additionally, exposures such as sleep quality and stress were gathered to be included in frequency tables only. Reasons for excluding them from the analysis is explained in the discussion.

Information on heavy lifting was collected with the question “How often during a normal work day: a) do you perform heavy lifting?”. Possible answers were “rarely/never”, “occasionally” or “often/always”. There was also a question b) and c) not worth mentioning in this study. Data was collected on age, gender, height, weight (the latter two used to calculate BMI) and self-reported smoking. Data on smoking was collected with the question “Do you smoke, or have you previously smoked?” (yes/no). Sleep quality was self-evaluated as either “very good”, “good”, “ok”, “bad” or “very bad” based the question, “How do you perceive your own sleep?”. Stress was first defined as “Stress implies a state where one feels tense in the body, restless, nervous, worried or unable to sleep because of an uneasy mind.”. Then data on the subjects self-rated stress were gathered with the question “Have you felt such stress the last month?”, to which subjects could choose “not at all”, “only slightly”, “to a certain degree”, “quite a lot” or “very much”.

Data analyses:

Last month pain was used for all analysis of association between pain and cold exposure. The ordinal variable, last month pain, was dichotomized with mild as the cut-off for the presence of pain during the last month. Furthermore, similarly to other studies (6) a pain variable consisting of five categories was constructed, from 0=no pain to 4=pain in all four regions. The regions were neck/shoulders comprising “neck”, “one or both shoulders” and “upper part of the back”, lower back comprising “lower part of the back (lumbar region)”, upper extremities comprising “one or both elbows” and “one or both wrists/hands”, and finally hips or lower extremities comprising “one or both hips”, “one or both knees” and “one or both ankles/feet”.

The independent variable, whole-body temperature feeling, was dichotomized so that cool and cold became cold, whereas warm and neutral became neutral. This was done for both damp and dry cold. Those dichotomized into the cold group were used as our exposed group, and those into the neutral group as our control. All those who did not answer questions on body temperature sensation, due to not working outdoors, were excluded from the analysis on association. However, they were included in many of the following descriptive tables as they still represent a big portion of the mining work force.

Furthermore, some of the covariates, adjustment factors and exposures were also dichotomized. Whether they performed heavy lifting or not was dichotomized to yes or no. Yes representing “occasionally” and “often/always” whereas “rarely/never” was labeled no. Age was grouped into five categories, <20, 20-29, 30-39, 40-49 and >49. BMI was calculated by dividing their measured weight in kilograms by the square of their measured height in meters. BMI was then grouped into above or below 30. Sleep quality was dichotomized to bad or good: bad if they answered “bad” or “very bad” and good for the other three options. Similarly to sleep quality, exposure to stress was also dichotomized so that “quite a lot” and “very much” were labeled yes and the other two answers became no.

Odds ratios (OR) were calculated independently as crude OR for possible associations between the outcome multi-site pain and the exposures damp cold, dry cold and heavy lifting. Binary logistic regression analysis was used to investigate associations between the dependent and independent variable, with covariates included in the analysis, hereafter called simply adjusted OR. Crude OR was calculated using Microsoft Excel 2013 (15.0.4719.1000) and controlled using IBM SPSS Statistics 22.0.0.0 (SPSS). Multiple logistic regression for adjusted OR were calculated using SPSS.

RESULTS:

The total number of participants in this study was 254, of those 101 were included from Stjernøya, Norway, while the remaining 153 from Aitik, Sweden. Of all the workers, 70.2% were men (62.8% in Aitik, 81.8% in Stjernøya). The average age was 40.6 years (standard deviation [SD] 12.0). Average BMI was 27.0 (SD 4.6) and 21.8% had a BMI greater than or equal to 30. In the study sample, 60.8% said they performed heavy lifting “occasionally” or “often/always”, 47.4% reported that they currently smoke, or had smoked in the past, 6.9% rated their sleep quality to bad or worse and 10.7% had “quite a lot” or “very much” stress. Data on background characteristics on the workers is shown in detail in table 1.

Table 1
Background characteristics of study population.

	Workers included in analyses due to outdoor work, n = 151		Workers excluded from analyses due to no outdoor work, n = 254	
	N	**%**	**N**	**%**
Age (years)				
<20	2	1	2	1
20-29	36	24	59	23
30-39	35	23	54	21
40-49	34	23	67	26
>49	42	28	70	28
Female (gender)	32	21	75	30
BMI > 30	31	21	55	22
Smoking (past or present)	70	46	119	47
Heavy lifting (occasionally or often/always)	105	70	149	59
Sleep problems (bad or very bad)	11	7	17	7
Stress (quite a lot or very much)	18	12	27	11

* Missing not shown

Concerning exposure to cold, 151 subjects reported data on whole-body temperature sensation during winter temperatures between -5 °C and +5 °C (damp cold), while 135 reported equivalent data for temperatures between -10 °C and -20 °C (dry cold). Damp and dry cold are not mutually exclusive. All participants who reported dry cold, also reported damp cold, reflecting perceived temperature throughout all of winter. In percent of the total study population (254), the response rates for damp and dry cold equal 59.4% and 53.1%, respectively. Of those exposed to damp cold the average temperature sensation, where value 2 is neutral, was 1.97 (SD 0.6), and for dry cold the average was 2.36 (SD 0.7), for both temperatures the median was 2, or neutral. More detailed data on the self-evaluated whole-body temperature feeling following cold exposure is shown in table 2.

Table 2

Perceived whole-body temperature sensation as reported by those exposed to cold during outdoor work.

Cold quality	1) Warm n(%)	2) Neutral n(%)	3) Cool n(%)	4) Cold n(%)	Total n(%)	No outdoor work n(%)*
Damp cold	27(17.9)	104(68.9)	17(11.3)	3(2.0)	151(100)	103(40.6)
Dry cold	8(5.9)	80(59.3)	38(28.1)	9(6.7)	135(100)	119(46.9)

*% of total study population (254)

The median reported level of pain last month was 1 (no pain) except for locations neck, shoulder and lower back where the median was 2 (mild). For pain level mild or worse the most frequently reported site was for lower back (63.6%) followed by neck (52.2%), shoulder (55.2%), knee (37.4%) and upper back (33.1%). Every fourth reported mild or worse pain in the wrist or hand (26.4%) and hip (25.6%). The least frequently reported locations for this pain level were elbow (15.8%) and ankle or foot (15.8%). Mild or worse pain during the previous month in any of the nine pain sites was reported by 227 participants (89.4%). Similarly, 228 (89.8%) participants reported pain or discomfort during the previous year at any of the same nine sites. In depth information on the distribution and prevalence of pain across the different pain sites for the previous month is presented in table 3, and for the previous year in table 4. As shown from the tables, the prevalence of no pain for last month and last year are similar for most anatomical locations.

Table 3

Prevalence of reported intensity of pain or discomfort in different locations during the previous month

	Anatomical Location								
Pain last month	Neck n(%)	Shoulder n(%)	Elbow n(%)	Wrist or hand n(%)	Upper back n(%)	Lower back n(%)	Hip n(%)	Knee n(%)	Ankle or foot n(%)
1) None	107(42.1)	111(43.7)	202(79.5)	181(71.3)	164(64.6)	91(35.8)	183(72.0)	154(60.6)	208(81.9)
2) Mild	53(20.9)	58(22.8)	16(6.3)	30(11.8)	28(11.0)	56(22.0)	26(10.2)	33(13.0)	16(6.3)
3) Moderate	68(26.8)	56(22.0)	16(6.3)	29(11.4)	39(15.4)	75(29.5)	24(9.4)	41(16.1)	19(7.5)
4) Strong	18(7.1)	20(7.9)	5(2.0)	4(1.6)	11(4.3)	26(10.2)	11(4.3)	15(5.9)	3(1.2)
5) Very Strong	2(0.8)	3(1.2)	1(0.4)	2(0.8)	3(1.2)	2(0.8)	2(0.8)	3(1.2)	1(0.4)
Missing	6(2.4)	6(2.4)	14(5.5)	8(3.1)	9(3.5)	4(1.6)	8(3.1)	8(3.1)	7(2.8)
Total	254	254	254	254	254	254	254	254	254

Table 4

Prevalence of reported intensity of pain or discomfort in different locations during the last 12 months

Pain last month	Anatomical Location								
	Neck n(%)	Shoulder n(%)	Elbow n(%)	Wrist or hand n(%)	Upper back n(%)	Lower back n(%)	Hip n(%)	Knee n(%)	Ankle or foot n(%)
1) None	103(40.6)	111(43.7)	194(76.4)	172(67.7)	160(63.0)	83(32.7)	178(70.1)	149(58.7)	201(79.1)
2) Pain	141(55.5)	128(50.4)	36(14.2)	66(26.0)	78(30.7)	164(64.6)	61(24.0)	92(36.2)	40(15.7)
3) Missing	10(3.9)	15(5.9)	24(9.4)	16(6.3)	16(6.3)	7(2.8)	15(5.9)	13(5.1)	13(5.1)
Total	254	254	254	254	254	254	254	254	254

Because most of the generated pain regions comprise several of the pain sites, their prevalence increase. This is the case for all except lower back region which is only comprised of the site lower back. The most prevalent pain regions were Neck/shoulder and Lower back. Table 5 details data collected on reported pain across the different regions, and the number of missing.

Table 5

Prevalence of reported intensity of pain or discomfort in different regions during the last month

Pain Last Month	Anatomical Region			
	Neck / Shoulders n(%)	Upper extremities n(%)	Lower back n(%)	Hips / Lower extremities n(%)
None	67(26.4)	167(65.7)	91(35.8)	119(46.9)
Pain	184(72.4)	80(31.5)	159(62.6)	130(51.2)
Missing	3(1.2)	7(2.8)	4(1.6)	5(2.0)
Total	254	254	254	254

The prevalence and distribution of multi-site pain is shown in table 6. Among all workers, it was more common to have pain in more than one region than not. Only 31.2% had one or no painful regions. The average number of pain zones, from no pain to four, was 2.14 (standard deviation 1.3).

Table 6

Number of concurrent (last month) pain regions, i.e. multi-site pain

# Painful zones	0	1	2	3	4
n	32	47	70	61	43
%	12.6%	18.6%	27.7%	24.1%	17.0%

N=253, 1 missing.

ORs were calculated in the analysis for association between exposures and multi-site pain. Crude OR, i.e. including single exposures and not adjusted for covariates, showed significant association between damp cold and four pain regions at a significance level of 0.05 (5%) with OR 3.0 (95% CI 1.1 to 8.1). When adjusting for covariates, the significance was lost, but there remained an association between damp cold and four pain regions at OR 2.5 (95% CI 0.6 to 10.1). Damp cold displayed no association with absence of pain or pain in one to three pain regions. Dry cold showed an association in the crude analysis for both three and four pain regions as outcome. For pain in four regions the crude OR for dry cold was significant at OR 2.7 (95% CI 1.1 to 6.4), but not significant in the adjusted analysis with OR 2.4

(95% CI 0.8 to 7.0). For three pain regions there was no significant association with dry cold; crude OR 1.3 (95% CI 0.5 to 3.2) and adjusted OR 1.3 (95% CI 0.5 to 3.4). Heavy lifting showed no significant association with multi-site pain. There was however a non-significant association with four pain sites. All data regarding the performed association calculations and included workers are presented in table 7.

Table 7

Adjusted risk of last month single- or multi-site pain by heavy lifting, perceived exposure to damp and dry cold compared to non-exposed, with crude and adjusted odds ratios (OR)

Number of pain sites	Type of exposure		Crude		Adjusted*	
	Number of references	Number of cases	OR	95% CI	OR	95% CI
	Damp cold					
0	129	22	0.6	0.1 to 2.9	0.6	0.1 to 3.2
1	127	24	0.6	0.1 to 2.5	0.6	0.1 to 5.8
2	109	42	0.6	0.2 to 1.9	0.8	0.2 to 3.3
3	120	31	1.0	0.3 to 3.1	0.9	0.2 to 3.8
4	119	32	3.0	1.1 to 8.1	2.5	0.6 to 10.1
	Dry cold					
0	113	22	0.9	0.3 to 2.3	1.1	0.4 to 3.2
1	112	23	0.2	0.1 to 0.8	0.3	0.1 to 1.1
2	96	39	0.9	0.4 to 2.0	0.8	0.3 to 2.1
3	110	25	1.3	0.5 to 3.2	1.3	0.5 to 3.4
4	109	26	2.7	1.1 to 6.4	2.4	0.8 to 7.0
	Heavy lifting					
0	129	22	2.2	0.7 to 6.8	1.6	0.5 to 5.4
1	127	24	0.7	0.3 to 1.7	0.6	0.2 to 1.8
2	109	42	0.8	0.4 to 1.8	0.9	0.4 to 2.3
3	120	31	0.9	0.4 to 2.1	0.7	0.3 to 1.9
4	119	32	1.2	0.5 to 2.7	1.5	0.5 to 4.5

* Adjusted for age, gender, BMI and smoking.

DISCUSSION:

In the crude analysis, both dry and damp cold were significantly associated with pain in four sites. When adjusting, we found no association between exposure to damp or dry cold and the presence of single- or multi-site pain. Additionally, as no multiple-testing correction has been performed, the odds ratios from such analysis are likely to show even less association than those reported. However, when considering the presence of concurrent pain, from one to four pain regions, indications of a slight dose-response relationship can be found. For damp cold the adjusted OR increases from 0.6, 0.8, 0.9 to 2.5 for one to four concurrent pain regions, respectively. A similar relationship is found for exposure to dry cold and concurrent pain regions, with OR increasing from 0.3, 0.8, 1.3 to 2.4.

Our conclusions are based on a data set formed by combing data collected at two separate mines, located in two different countries. We chose to do this in order to obtain a larger study population. The work environment and the populations of mine workers at the two sites were assumed to be very much alike; being located in the same high north region and in societies sharing ethnic and socioeconomic characteristics. However, when presenting results from the pooled database, we have disregarded possible differences between those two work locations.

One quandary in the study was how to relevantly measure exposure to cold in this complex working situation. Perceived versus measured temperature provide different approaches, as does skin and outdoor temperature. The miners working outdoors have many layers of garment separating them from the cold outdoor atmospheric temperatures. For personal clothing there are many variations that alter the true exposure to cold. Different types of garment isolate to different degrees. The number of garments, the layering, how they are worn and on what body parts all add to the complexity. While mining previously was a predominately manual work, present miners mostly operate machinery, such as drill-platforms, excavators, dozers, trucks and tractors. These machines have a driver cabin which is heated, reducing the exposure to cold. Most machine operators and drivers are not constantly inside the cabin, they often have to exit the cabin to perform various others tasks, thus exposing themselves to low ambient temperatures. In this diverse and complex real-life situation, can exposure to cold be objectively measured? Our answer is no. One option is to simply ignore all aforementioned factors complicating the actual exposure to cold, make the exposed group miners in a Barents mining operation, and the control group a different mine located in warmer regions. Merely stating that although the exposure to cold is complex and multi-factorial, the exposed group will be more exposed to cold than the control. One major problem with this approach is whether or not the two populations can be compared, or if the cultural and genetic differences (i.e. covariates) make them incomparable. Another alternative is to measure exposure to cold by use of objective measures for temperature, e.g. thermistors located on different skin locations. One main culprit with that is skin temperature is not only affected by the exterior environment. The skin is the most important organ in regulating core body temperatures, and any excess heat, e.g. from increased physical activity, will increased skin temperature (26). Consequently, activity level would be a significant confounder. Another disadvantage with using skin temperature as a measure of exposure to cold is the challenging practical aspect of fitting workers with thermistors to wear through a given period of time.

The physiology and psychology of feeling cold is complex. Feeling cold does not always imply being cold. An example would be when one feels cold during a fever when the core body temperature is increasing. Feeling cold, at least in the hands and feet, may be a hereditary trait and is often reported more commonly by women (27), this could be a possible confounder. Cold intolerance, defined as an abnormal sensitivity to cold environment or cold temperatures, can be a symptom of somatic disease, including anemia, anorexia nervosa and hypothyroidism to mention some (28). Rapid decreases in temperature as opposed to a slow and steady decreases, give a greater sensation of cold. This is a trait of the cold thermoreceptors that play an integral role in thermoception. They have a constant rate of firing at any given temperature inside their operational temperature range, thus giving off an indication of the current absolute temperature. They are however much more sensitive to changes in temperature than to absolute temperature. A 0.2 °C change in temperature is sufficient to cause a marked change in impulse frequency (29). Research on Norwegian seafood industry workers concluded that the prevalence of feeling cold may be a useful exposure estimate in moderate cold exposure situations (30). Thus, when choosing the wording for the questionnaire, feeling cold was considered a feasible way to collect data on cold exposure in the complex setting that is the real-world mining workplace.

We dichotomized the four-scale rating of whole-body cold sensation to two values, cold or neutral. The scale consisted of warm, neutral, cool and cold. The biggest distinction lies between neutral and cool, to a much lesser extent between the other alternatives. A small portion (2%) of those answering how they felt during dry cold (<-10 °C - >-20 °C) also answered that temperatures below -10 °C did not occur. We chose to include their data on dry cold, as we found it more likely that the invalid answer was in fact that there were no temperatures below -10 °C. The reason for this is that reporting how you feel during dry cold requires more though than wrongly ticking off “temperatures below -10 °C do not occur”.

The decision to include only subjects working outdoors during the winter is to only analyze the effects of temperature ranges below +5 °C, which are unlikely to occur during most indoor work. It could be argued that all indoor workers, i.e. not exposed to cold, could serve as our control group. This would however result in excessive weakening of any possible associations as we in fact did not know whether or not they strictly weren’t exposed to cold. If they in fact were exposed to cold, we would not know how they felt during such exposure, and consequently whether to group them as exposed or not.

In our study sample multi-site pain was most prevalent, 68.8% had two or more pain regions. This is higher than in other studies also categorizing pain into four pain regions, where prevalence of multi-site pain ranged from 33% - 54% (6, 11, 12, 24, 31). This can in part be explained by the high physical demands inherent to the mining profession. Physical demands in modern day mining are not sufficiently frequent to result in a positive training effect (20). We found similarities between the reported prevalence of pain for the previous month and for the previous year. However, one would assume that with an increased time span, reported prevalence would increase. In a systematic literature review of the prevalence of neck pain it was stated, “Generally and as expected, the ranges increase with longer prevalence periods” (32). This was also the case in a literature review of musculoskeletal disorders in Norway, where the longer the time-span, the higher the prevalence (33). The question is then why this is not seen in our data material. The explanation may be that this is a special trait of our study population, or a result of some systematic reporting bias. We are unable to determine the magnitude of a possible recall or reporting bias. The prevalence of musculoskeletal pain is comparably high in view of other studies, also for single site ailments: for lower back, 64.6% reported to have pain the past 12 months, whereas Skandfer et al found 51% in a Russian mining population exposed to cold ambient temperatures (21). For neck we found 55.5% prevalence for last month pain, whereas a literature review found prevalence ranging from 15.4% to 41.1%, with a mean of 23.3% (32). Shoulder pain in the previous 12 months was reported by 50.4% in our study population, whereas a prevalence of 36% was reported from a study of a French working population (7). However the prevalence of knee pain in our mining population (36.3%) is comparable with that of a study of adult German citizens (34). It seems that for most of the single site ailments this study reports somewhat higher prevalence ratios. As mentioned this may be due to the strenuousness of mining. Though, it may also be due to the phrasing of the questions, and hence a qualitative difference in what respondents in fact are reporting in this study versus others.

Dichotomizing and the choice of cut offs also contribute to how results are presented: we could have dichotomized last-month pain differently, setting the cut-off at moderate instead of mild. Similarly, for twelve month pain the phrasing was “physical ailments, such as pain, aches or discomfort”. Aches and discomfort weaken the concept of pain, and may be interpreted differently in populations in different countries. Setting mild as the cut-off for pain and including wording such as discomfort, increases the probability of identifying those with ailments. I.e. the sensitivity of our study will increase, but the specificity will decrease. We acknowledge the consequences of those decisions, but given the size of our study sample we consider our cut-offs and phrasing appropriate.

Last month pain, as opposed to last year pain, was used for all analysis of association between pain and cold exposure. The reasoning for this is that the likelihood of reported pain being truly multi-site, i.e. present concurrently, is inversely proportional to the question’s time span, at least theoretically. This is a strength of this study compared to some other research whose question time-spans have been longer (7-9).

Heavy lifting was reported by 59% of the workers, this is comparable with another study on a mining population where 57.4% performed heavy lifting (21). No significant association was found between heavy lifting and the absence of pain, or occurrence of pain in one to four pain regions. In fact, as shown in table 7, there was a greater association between heavy lifting and absence of pain than between heavy lifting and pain at one to four pain regions. One of the pain regions used in this study was lower back pain. The absence of a significant association between heavy lifting and lower back pain in our study is supported by a recent review on the effects of occupational heavy lifting and lower back pain, concluding that a causal relationship between them cannot be established (35). Still, heavy lifting is widely considered as an established risk factor for lower back pain, supported by a meta-analysis demonstrating a significant association between the annual incidence of lower back pain and the intensity and frequency of lifting (36).

Several of the variables, both the dependent and independent variable, and many of the covariates, were dichotomized. The general disadvantage with this is that raw data is replaced by synthesized entities. An ordinal variable has several data points that can be ordered. But because it is an ordinal variable and not an interval one, the distance between each point on the ordinal scale is not constant. Consequently, there will hopefully be a greater distance between two set points than between any of the other points on the scale. If the cut-off for dichotomization is set between those two points, then dichotomization of the ordinal value will amplify the contrast in the data, instead of skewing it. Another more important consideration is; what is the appropriate amount of detail in an answer for any given question? Ultimately, the essence for our analysis were whether or not there was pain, not the intensity of pain. Similarly, the essence in cold exposure was whether or not subjects had been exposed to cold, yes or no. Also, because of the size of our study sample, we chose to amplify any contrast within the reported answers. We believe we achieved this without skewing the data.

Some possible covariates were left out from either or both of the descriptive or analytical aspect of this study. These include sleep problems, stress, work positions, rheumatic disease and education. All these factors were included in the questionnaire and are thus present in our complete data material. Education was not included as there were discrepancies in how the question was interpreted and reported between the populations in the countries. Rheumatic disease affected so few subjects that its incorporation into the study was not justified. We chose not to include work positions since the study outcome was pain in defined regions, whereas work positions were reported with relevance isolated to specific sites, thus considered unfit for the analysis. Both sleep quality and stress showed erroneous reporting and were consequently excluded from the analysis part of this study. E.g. for stress there was a disproportionate correlation towards four pain regions that annihilated any other possible associations. This correlation between stress and four pain regions was nonexistent for three pain regions. We interpreted this as being a random error of unknown cause. A similar abnormality was found between sleep quality and three pain regions, i.e. a spurious correlation.

No calculation of statistical power was performed prior to this study. Statistical power is the ability of a study to demonstrate an association or effect if one exists. This is influenced by factors such as the frequency of the condition under study, the magnitude of the effect, the study design, and sample size (37). The absence of associations in our study may be due the sample size, but we are unable to determine this.

Other methodological weaknesses in this study may include different types of bias or design flaws. Bias is defined as systematic deviation of results or inferences from truth or processes leading to such deviation. This can result from an error in the conception and design of a study—or in the analysis, publication, interpretation, collection, reporting, or review of data—leading to results or conclusions that are systematically (as opposed to randomly) different from truth (37). Several types of bias are worth discussing here. Information bias, defined as "A flaw in measuring exposure, covariate, or outcome variables that results in different quality (accuracy) of information between comparison groups" (37), is unlikely to have occurred in our study as we did not know at the time data was collected which subjects would be in either the exposed or control group. Response bias, defined as "Systematic error due to differences in characteristics between those who volunteer, choose, or accept to take part in a study and those who do not" (37), might exist, but to an negligible extent as response rates were over 90% for both locations. Selection bias, defined as "Bias in the estimated association or effect of an exposure on an outcome that arises from the procedures used to select individuals into the study or the analysis" (37), should be insignificant in terms of internal validity towards open-pit miners. However external validity might be biased, we find it reasonable to assume that there is a selection of individuals, sharing some traits, who become miners. There is an unfathomable amount of unmeasurable confounders between a selection of miners and a random selection of the population, hence caution should be taken before suggesting external validity. Recall bias, defined as "Systematic error due to differences in accuracy or completeness of recall to memory of past events or experiences" (37), might have played a role in the correlation seen between prevalences for last-month pain and last-year pain. Reporting bias, defined as "Selective revelation or suppression of information" (37), might have had an effect through respondent fatigue. When the survey task, i.e. the questionnaire length, increases the quality of the provided data may begin to deteriorate. Called respondent fatigue, this might have caused a reporting bias towards the later sections of the questionnaire. We don't know if this is the case or not, but measures were implemented to counter this effect. The workers were taken out from their regular work and brought to a heated, well lit room, where they were given coffee and snacks. Feedback from the participants was generally positive.

Another limitation is the choice of cross-sectional study design. The dependent and independent variable are measured concurrently. Consequently the true temporal order between them cannot be established.

Lessons learned from this study that can be brought forward in the case of similar future research is that researchers should strive for a larger study sample. Ideally estimates on statistical power should be performed to determine the suitable size of a study sample for the effects investigated in this research.

CONCLUSION:

Musculoskeletal pain, both single- and multi-site, is common among miners in the Barents region. Although miners are working in the low winter temperatures, most do not feel cold. We found no significant associations between feeling cold during cold exposure and the presence of musculoskeletal pain. Research on multi-site pain is limited, but our study adds to an increasing amount of data confirming the need to increase recognition and investigation of multi-site pain, and any possible effects of cold exposure.

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