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Musculoskeletal symptoms in cold exposed and non-cold exposed workers

Hugo Piedrahíta[a,b,*], Laura Punnett[c], Houshang Shahnavaz[d]

[a] Luleå University Technology, Industrial Ergonomics Department, Luleå, Sweden
[b] Universidad de Antioquia, Facultad Nacional de Salud Pública, Departamento de Salud Ocupacional, Medellín, Colombia
[c] University of Massachusetts Lowell, Department of Work Environment, Lowell, MA, USA
[d] CEDC, Center for Ergonomics of Developing Countries, Stockholm, Sweden

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Abstract

A cross-sectional epidemiologic study was carried out to explore the relationship between musculoskeletal symptoms and cold exposure in a large meat processing company in Colombia. All workers in the packing areas ($n=162$) were recruited: 50 workers from very cold areas (+2°C) and 112 workers from less severely exposed areas (range +8°C to +12°C). Thermal environmental conditions were measured in both areas. By Standardized Nordic Questionnaire, there was a high prevalence of musculoskeletal symptoms among the more exposed workers, especially for low back, neck and shoulders. The prevalence ratios for neck and low back symptoms interfering with usual work were 11.2 (95% CI 1.3–93.4) and 4.5 (95% CI 1.6–12.4), respectively. Job features that could not be addressed in this study included work shift (day versus night), adequacy of thermal protective clothing, type of contract with the company and psychosocial conditions at work. The association between cold exposure and musculoskeletal problems is plausible but the mechanism is still obscure and there is a need for further research, both experimental and epidemiologic (preferably cohort studies).

Relevance to industry

Industries that have environments with cold exposure might consider measures such as warm rooms for breaks and thermal protective clothing as part of a program to reduce the prevalence of workers' musculoskeletal symptoms.

Keywords: Cold exposure; Ergonomics; Environmental cold; Cross sectional study; Standardized Nordic Questionnaire for Musculoskeletal Symptoms

1. Introduction

The Bureau of Labor Statistics of United States (2002) indicated that the highest incidence rates of disorders associated with repeated trauma in

*Corresponding author. Facultad Nacional de Salud Pública, Universidad de Antioquia, Departamento de Salud Ocupacional, Carrera 62 No. 52-59, Medellín, Colombia.
E-mail address: hupilo@epm.net.co (H. Piedrahíta).

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private industries during 2000 affected meat packing plants; poultry slaughtering processing, and sausages; and other prepared meats with rates of 812.0, 374.0 and 274.2 cases by each 10,000 full-time workers respectively. These specific industries occupied the first, third and sixth place respectively between all private industries in this country. The workers in these three industries are permanently exposed to low air temperatures.

Cold exposure may result from low ambient air or water temperature or from wind-chill (Pienimäki, 2000). It may also be mediated through direct contact with cooled or frozen food products in cold stores and in the meat-processing industry. Hagberg et al. (1995) considered that cold may act in two ways to affect risk of musculoskeletal disorders: directly, by its effect on body tissue, and indirectly, from the possible problems caused by the personal protective equipment used to alleviate its effect. For example, wearing gloves increases the muscular load requirement for a given task. In addition, humidity in the environment and direct contact with cold water or wet products has been noted as potential contributors. Musculoskeletal disorders are widely acknowledged to have a multi-factorial origin (Bernard, 1997; Buckle and Devereux, 1999; National Research Council, 2001). Research on the relationship between musculoskeletal disorders (MSDs) and cold exposure is limited (Holmér, 1994). Several epidemiologic studies have shown that cold may be a risk factor for occurrence or aggravation of disorders of the low back (Chen et al., 1991; Wang et al., cited by Pienimäki, 2000; Hildebrandt et al., 2002; McGorry et al., 1998; and review by Jin et al., 2000); knee (Chen et al., 1991); shoulder (Chen et al., 1991; Pope et al., 1997; Niedhammer et al., 1998); and distal upper extremities (Chiang et al., 1990, 1993; Kurppa et al., 1991). However, only one of these was a cohort study, which concerned the incidence of tenosynovitis, peritendinitis and epicondylitis in a meat-processing factory (Kurppa et al., 1991). The unadjusted incidence of tenosynovitis/peritendinitis among female packers was higher than that of female sausage makers of the same age. The most notable difference between the working conditions of these two groups was the ambient temperature: $+8°C$ to $+10°C$ for packing versus $+20°C$ for sausage making.

The remaining investigations of cold and MSDs have all been cross-sectional. Most of them also treated the exposure data as dichotomous, limiting the ability to make inferences about a dose-response relationship. In addition, several study populations had an association between cold exposure and other ergonomic job demands, either because of differences in the nature of the work; the effect of cold on work demands (e.g., frozen meat is more resistant to cutting); or the effect of extra thermal clothing on physical workload, body movements and postures of cold-exposed workers. Thus it remains unclear whether cold exposure is an independent risk factor or a co-factor in the development of chronic problems with muscles and joints (Lundqvist et al., 1990).

In regard to physiological mechanism, the evidence is also limited. With regard to the spine, Jumghanns (cited by Hildebrandt et al., 2002) stated that exposure to cold is unfavourable for the diffusion of fluid in the inter-vertebral disc when combined with heavy work and/or static posture. Most research involving the upper extremity has addressed the effects of cold on muscle, such as decreased voluntary strength capacity (Vincent and Tipton, 1986). Sundelin and Hagberg (1992) evaluated the effect of local cooling, caused by excessive drafts, on the myoelectric activity in shoulder and neck muscle in sedentary visual display unit work. They found that muscle activity in the cervical part of the descending trapezium and in the elevator scapulae changed during exposure to excessive airflow.

Oksa et al. (1995) found in a climatic chamber study that cooling ($+10°C$) decreased muscular performance, measured as mean IEMG activity in m. triceps brachii, especially with fast contraction velocities. Along with the decrement in performance, cooling slowed the function of the agonist muscle and decreased its IEMG-activity but increased the IEMG activity of the antagonist muscle. When either local or systemic cold exposure was combined with repetitive work, electromyographic (EMG) activity in the forearm muscles was higher for a given level of external work compared with the thermo-neutral condition (Oksa et al., 2002).

In light of these plausible physiological mechanisms and inconclusive epidemiology, this study explored the possible relationship between musculoskeletal disorders and cold exposure through a cross-sectional epidemiologic study comparing two groups of workers, exposed and non-exposed to cold, employed by a large meat-processing plant in Colombia.

2. Material and methods

2.1. General design and study population

This research was carried out in four meat-processing plants belonging to the largest meat-processing company in Colombia. This was a cross-sectional study whose base was all packing workers in the cities of Medellín, Bogotá, Barranquilla, and Pereira.

2.2. Study questionnaire

Participants completed a standardized questionnaire in Spanish on paid work time. One researcher (H.P.) explained the questionnaire to the workers in groups of ten. Worker's names remained anonymous. No company officer was present at any of the meetings with the workers. Participation in the research was voluntary.

The questionnaire included demographic items such as age, gender, and educational level as well as questions such as years on the job, hand dominance, and discomfort with cold draught. Questions about musculoskeletal symptoms were adopted from the Standardized Nordic Questionnaire (Kuorinka et al., 1987). The specific symptoms researched were pain, ache, or discomfort in specified body parts during the last year and during the last 7 days, as well as those that prevented the individual from doing his normal work. These items were translated into Spanish by the first author.

2.3. Job analysis and cold exposure

The packing job consisted of placing sausages in individual packages and then placing the packages in plastic baskets. Study participants were classified into two groups according to cold exposure. One group comprised subjects working in packing areas with a very low temperature, considered "exposed," while the other group worked in areas with a somewhat higher temperature and were labeled "non-exposed." The "exposed" and "non-exposed" workers performed very similar tasks.

The "Ergonomic Workplace Analysis" method developed by the Finnish Institute of Occupational Health (Ahonen et al., 1989) was used for job analysis.

For calculation of the metabolic heat production, three workers were selected for observation from each of the two exposure groups in each of the four plants. Each worker was evaluated for one hour while performing his or her usual job. The ISO 8996 standard, "Determination of metabolic heat production," was used to calculate the metabolic heat production in both groups. The INSHT (Instituto Nacional de Seguridad e Higiene en el Trabajo) in Spain has published a technical document (NTP 323) on the determination of metabolic heat production according to ISO 8996 (Nogareda et al., 1990). This method was used to estimate metabolic rates from tables by type of generic physical activity.

Ambient temperatures were measured in all plants in both the exposed and unexposed packing areas. Wet bulb temperature (°C), dry bulb temperature (°C), and WBGT (°C) were measured using a Quest 15 WBGT heat stress monitor. Air velocity (m/s) was measured by Alnor thermo anemometer and relative humidity (%) was measured by Air Quality Monitor AQ 5000 Pro. All equipments were calibrated before use. Two specific places were selected in each plant, both close to working areas. One place corresponded to exposed areas and the other one to non-exposed areas. The register of temperature was made every 15 min during three or four hours in each place selected in each plant. Environmental measurements of temperature were taken at three different levels from the floor: head (1.70 m), abdomen (1.10 m) and feet (0.10 m).

The company provided all packing workers with the following clothing for cold protection: jacket, insulated boots, insulated gloves, head protection, insulated trouser and insulated socks. The company's internal policy required that they use all of the thermal insulation provided. This clothing was examined visually and determined that it was uniform among all plants. All of these garments are made by local companies in Colombia and the manufacturers do not provide the *clo index* values for their products. Thus, in addition to computing the insulation value (clo units) required to maintain thermal equilibrium, the *clo index* provided by the clothing was estimated from tables (Holmér, 1999) according to the clothing thickness and body surface area coverage.

2.4. Statistical analysis

The Statistical Package for Social Sciences (SPSS) 8.0 for Windows was used for all statistical analyses. The prevalence ratio and corresponding 95% confidence interval (CI) were calculated to compare the prevalence of musculoskeletal symptoms between groups.

The test of normality was calculated for continuous covariates of interest (age, years on the job, hours per week, weight and height). To compare these variables between exposure groups, the Mann-Whitney test was used for age, years at the company, years on the job, hours per week and weight. The Student *t*-test was calculated for weight because this variable had a normal distribution (see Table 1).

Table 1
Test statistics: Mann-Whitney *U* and *t*-test for interested variables

	Mann-Whitney	*p*-value
Mann-Whitney U test statistic		
Age	1823.000	0.000*
Years at the company	1691.500	0.000*
Years on the job	1902.000	0.001*
Hours per week[a]	1582.000	0.000*
Height	2430.500	0.179
Weight		
t-test		
Weight	−0.940	0.379

*$p < 0.05$.
[a]Working hours per week according to Colombian legislation is 48.

3. Results

A total of 162 employees (100% of the target population) participated in the study. All workers were male. Some differences in demographic characteristics were found between the groups. In particular, the cold-exposed workers ($n = 50$) were younger, had less seniority in the present job, and worked more hours per week compared with the non-exposed group ($n = 112$) (Table 2). Further, most of the exposed group (92%) worked at night (shift 3, 10 pm to 6 am). There were no workers in the night shift working in unexposed areas. In addition, 90% of cold-exposed workers had an indirect contract with the company (by outsourcing), as opposed to 62.5% of those not exposed to cold.

The most important ergonomic conditions identified were highly repetitive movements with hands, low manual forces, and standing position all day. In both groups the estimated metabolic expenditure rate was moderate (155 W/m^2). The only micro-ergonomic difference was that the exposed group had a faster work pace.

Around 20 h of temperature measurements were developed for each worker. Differences among the environmental measurements at head, abdomen and foot level were very small (Table 3). The average dry bulb temperature in the "unexposed" areas was 11.6°C and in the exposed areas it was 2.4°C or about 9°C colder. In addition, humidity and especially air velocity were higher in the exposed areas.

According to the recommendations of Holmér (1999), the thermal insulation provided by the company was 1.19 Clo, including the T-shirt, underwear, and shirt usually worn by the workers. The clo index was calculated under the assumption that all workers used the clothing completely.

However, no workers used all the clothing provided, and there were important differences between the two groups in the usage of insulated garments. Usually the exposed group wore all issued clothing, whereas the unexposed group was much less likely to wear gloves, trousers and socks (Fig. 1).

The workers working at exposed areas reported more discomfort with cold draught than the non-exposed group, 62% and 52%, respectively.

Table 2
Descriptive data on the population studied, mean and standard deviation (SD): Cold-exposed workers at one Colombian meat-packing company ($n = 162$)

Variables	Exposed group ($n = 50$)		Non exposed group ($n = 112$)		p-value
	Mean (range)	(SD)	Mean (range)	(SD)	
Age	26 (18–45)	5.67	30.1 (19–60)	8	0.000*
Years on the job	1.4 (0.1–9)	1.67	3.6 (0.1–25)	4.45	0.001*
Years at the company	2 (0.1–14)	2.65	5.7 (0.1–25)	6.22	0.000*
Hours per week[a]	53.5 (48–72)	5.12	50.2 (48–65)	3.89	0.000*
Weight (kg)	70.9 (52–96)	8.1	69.6 (54–97)	8.1	0.379†
Height (cm)	172 (158–185)	5.7	171 (160–188)	6.1	0.179
Educational level[b]	4.64 (1–8)	4.64	4.34 (1–7)	1.16	

* Mann-Whitney U test statistic.
† Student t-test.
[a] The maximum number of work hours per week, according to Colombian legislation, is 48.
[b] (1 = incomplete primary school, 8 = complete secondary school).

The prevalence of musculoskeletal symptoms according to the Standardized Nordic Questionnaire was highest for the low back and neck (Tables 4 and 5). Prevalence during the last year was higher in the exposed group than in the non-exposed group for all body parts, except for elbows (Table 4). The highest prevalence ratios were for the hip/thigh (but very unstable), neck, shoulder, and wrist/hand.

The exposed group also had a higher prevalence of musculoskeletal problems that prevented the worker from doing his normal work (Table 5). The highest prevalence ratios were for the neck (also very unstable), low back, and shoulder.

4. Discussion

The results of this cross-sectional study of meat-processing workers showed that neck, shoulders and low back symptoms were more common among the more severely cold-exposed workers than among less exposed workers. The low back region was the most affected both by any symptoms in the last year and by those preventing workers from doing their normal work. Symptoms were significantly elevated for the neck, shoulders, low back and hips/thighs. Musculoskeletal problems that prevented workers from doing their normal work also showed significant increases in the neck and low back.

Among potential weaknesses of this study was its cross-sectional design, meaning that it could not confirm a causal relationship and reliance on self-report for determination of MSD symptoms. Questionnaires have been used by several authors to identify the relationship between musculoskeletal disorders and cold exposure (Chen et al., 1991; Pope et al., 1997; Niedhammer et al., 1998). The reliability of the questionnaire used in this research, the Standardized Nordic Questionnaire, has been demonstrated (Kuorinka et al., 1987). We could not evaluate the potential for differential error between the more and less exposed groups. However, it may be relevant that the prevalences of low back symptoms in the more and less severely cold-exposed groups (48% and 20%, respectively) were similar to those reported by Chen et al. (1991) and Jin et al. (2000) for workers exposed to similar temperature ranges.

For the definition of cold exposure, several classifications have been used by different authors (Chen et al., 1991; Wang et al. and Diang et al. cited by Pienimäki, 2000; Niedhammer et al., 1998; Kurppa et al., 1991; Chiang et al., 1990; Pope et al., 1997; Griefahn, 1997; Viikari-Juntura, 1983). In this research the classification to cold exposure used was –2°C to +2°C, equivalent to the conditions studied by Diang cited by Pienimäki

Table 3
Results of environmental measurements (means and ranges) in four Colombian meat-packing plants

	Head level		Abdomen level		Feet level		Average	
	Exp[a]	Unexp[b]	Exp	Unexp	Exp	Unexp	Exp	Unexp
Wet bulb Temperature (°C)	2.1 (0–2.5)	9.7 (7.1–12.7)	2.1 (0–4.4)	9.5 (6.6–12.3)	1.9 (0–4.6)	9.1 (6–11.4)	2.0 (0–4.6)	9.4 (6–12.7)
Dry bulb Temperature (°C)	2.5 (1.6–3.2)	11.8 (9–15.4)	2.5 (0.5–5.4)	11.8 (8.9–15.4)	2.3 (0.5–5.3)	11.3 (8.1–13.4)	2.4 (0.5–5.4)	11.6 (8.1–15.4)
Globe Temperature (°C)	2.8 (2.6–3.1)	12.4 (9.9–15.7)	2.8 (1.2–5.9)	12.6 (9.6–15.8)	2.7 (1.3–5.8)	11.9 (8.9–14.7)	2.8 (1.2–5.9)	12.3 (8.9–15.8)
WBGT (Int) (°C)	2.3 (1.9–3.3)	10.85 (8–13.5)	2.3 (0–4.8)	10.5 (7.5–13.2)	2.1 (0–5.0)	10 (6.9–12.1)	2.2 (0–5.0)	10.3 (6.9–13.5)
Humidity (%)							88.6 (68.7–94.1)	69.1 (53.7–76.8)
Air velocity (m/s)	0.45 (0.2–0.9)	0.12 (0.07–0.23)	0.41 (0.15–0.6)	0.12 (0.07–0.23)	0.36 (0.2–0.5)	0.16 (0.1–0.35)	0.41 (0.15–0.9)	0.14 (0.07–0.35)

[a] Exposed areas.
[b] Unexposed areas.

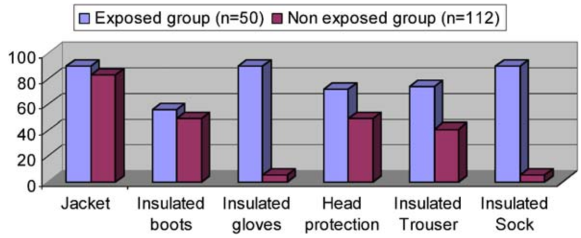

Fig. 1. Percentage of workers wearing thermal insulation clothing during working-hours, by exposure status.

(2000) as "Ice Stores." The temperature range between +8°C to +12°C was here defined as non-exposed to cold. However, these latter temperatures are also well below the normal ambient range. Of note, Oksa et al. (1995) found decrements in muscle function precisely in this exposure range. Thus comparison available for study was limited and the lack of a truly unexposed group may represent another weakness of this study. The true physiologic exposure would also have been modified by the thermal properties of the clothing worn by workers, which differed somewhat between the two exposure groups. Since the unexposed group was less likely to wear all of the insulated clothing, the effective temperature difference between the two groups may have been less than the ambient temperatures suggest.

The fact that the more cold-exposed workers were predominantly on night shift could have some influence (potential confounding) on the results, because the physical and physiological changes that produce the circadian rhythm could have some influence over the functional capacity or vulnerability of the musculoskeletal system.

The type of contract with the company is important because when workers have an indirect contract it is possible that they work more hours per week (as was true in this case) or accept more strenuous activities. Either of these considerations could possibly increase the stress on the musculoskeletal system. Less secure employment might also have affected their willingness to report symptoms, which would have led to under-reporting in the exposed group.

Unfortunately, in the population available for study here, night work and indirect contract—two

Table 4
Prevalence of musculoskeletal symptoms during last year (ache, pain, discomfort) in specified body regions

Body parts	Exposed group ($n=50$)		Non-exposed group ($n=112$)		Prevalence ratio (CI)
	No.	%	No.	%	
Neck	18	36	12	11	3.36 (1.75–6.44)*
Shoulders	12	24	7	6	3.84 (1.61–9.17)*
Elbows	2	4	4	13	1.12 (0.21–5.92)
Wrist/hands	14	28	14	11	2.57 (1.28–5.14)*
Upper back	13	26	13	12	2.24 (1.12–4.48)
Lower back	24	48	22	20	2.24 (1.52–3.92)*
Hips/thighs[a]	6	12	1	1	13.44 (1.66–108.8)*
Knees	6	12	10	9	1.34 (0.52–3.45)
Ankle/feet	5	10	6	5	1.87 (0.60–5.83)

*$p<0.05$.
[a] For this body part there were six cases in the exposed group and only one case in the non-exposed group.

Table 5
Prevalence of musculoskeletal symptoms that prevented workers from doing their normal work

	Exposed group ($n=50$)		Non-exposed group ($n=112$)		Prevalence ratio (CI)
	No.	%	No.	%	
Neck	5	10	1	1	11.2 (1.34–93.4)*
Shoulders	4	8	2	2	4.48 (0.85–23.6)
Elbows	1	2	1	1	2.24 (0.14–35.1)
Wrist/Hands	4	8	4	4	2.24 (0.58–8.6)
Upper back	2	4	2	2	2.24 (0.32–15.45)
Lower back	10	20	5	5	4.48 (1.61–12.4)*
Hips/thighs[a]	1	2	0	0	(undefined)
Knees	2	4	3	3	1.49 (0.26–8.66)
Ankle/feet	1	2	1	1	2.24 (0.14–35.1)

*$p<0.05$.
[a] For this body part the cases were 1 in exposed group and 0 in non-exposed group.

important sources of psychosocial stress—were so highly correlated with cold exposure that their separate associations could not be analyzed in this research. Two other factors whose effects could not be distinguished from ambient temperature were air velocity, which has a relationship with subjective discomfort to cold draughts, and the ergonomic consequences of wearing heavier clothing (Niedhammer et al., 1998).

In summary, intensity of cold exposure had a clear relationship with the prevalence of musculoskeletal symptoms, especially for neck, shoulders and lower back. The more and less exposed groups in this study had similar ergonomic conditions but some important differences in demographic and employment conditions. However, the evaluation of cold exposure as an etiologic or contributing factor for musculoskeletal symptoms is difficult. While there is evidence that cold affects muscle function, such processes could either potentiate the effects of ergonomics exposures or could result in subclinical symptoms becoming manifest. Few extant occupational health surveillance systems recognize cold as a primary risk factor. The lack of experimental and prospective field studies, and uncertainty about the precise pathophysiology mechanisms involved in the development of musculoskeletal disorders, limit our ability to definitively identify cold exposure as a causative factor; the need for further research is apparent.

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