

# Prevalence of cold-related symptoms among Thai chicken meat industry workers: association with workplace temperature and thermal insulation of clothing

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**Abstract:** This study determined the association of cold-related symptoms with workplace temperature and thermal insulation of clothing among Thai chicken industry workers. Three hundred workers were interviewed regarding cold-related symptoms, which were regressed on worksite temperature and protective clothing. In total, 80% of workers reported respiratory symptoms; 23%, cardiac symptoms; 62%, circulation disturbances; 42%, thirst; 56%, drying of the mouth; and 82%, degradation of their performance. When adjusted for personal characteristics, respiratory symptoms were 1.1–2.2 times more prevalent at –22–10°C than at 10–23°C. At –22–10°C, cardiac symptoms increased by 45%, chest pain by 91%, peripheral circulation disturbances by 25%, and drying of the mouth by 57%. Wearing protective clothing with at least 1.1 clo units was associated with marked reductions in symptom prevalence. Therefore, temperatures lower than 10°C increased prevalence of cold-related symptoms, which are largely preventable by appropriate clothing use.

**Key words:** Occupational epidemiology, Cold, Work environments, Thermal stress, Cardiovascular symptoms, Respiratory symptoms, Performance, Clothing

The effects of environmental cold on the occurrence of diseases<sup>1)</sup> and their symptoms<sup>2)</sup> are well established in the general population but are lesser-known in populations working in artificially cooled environments. However, low

temperatures encountered in the food industry, for example, elicit thermoregulatory responses in the human body that may lead to adverse health consequences, depending on how well the workers are protected. Breathing in cold air leads to drying and cooling of the airways, which in turn causes airway narrowing, as well as symptoms of dyspnea, cough, increased mucus production, and wheezing<sup>3)</sup>. Cold air also exerts proinflammatory effects, thereby

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worsening the course of chronic respiratory diseases, especially in conjunction with physical work. Exposure to cold air, typically in peripheral body parts, causes cutaneous vasoconstriction, which leads to a rise in blood pressure and a consequent increase in cardiac load that manifests itself as anginal symptoms. These cooling-related responses also cause hemoconcentration and hyperviscosity of the blood, which predispose the individual to blood clotting and possibly myocardial infarction. Cardiac arrhythmias may ensue by a reflexory mechanism involving coactivation of the autonomic nervous system<sup>4</sup>. The effects of cold not only manifest themselves as symptoms in various organs but may also increase the risk of hospital admission and death during long-term follow-up<sup>5</sup>.

Some previous studies have addressed various symptoms and complaints among food industry workers<sup>6</sup>. However, none of these studies has formally analyzed the prevalence of cardiorespiratory symptoms in relation to workplace temperature and considered workers' personal characteristics and workplace factors, which may confound the association. We, therefore, conducted an exploratory study among chicken meat industry workers in Thailand to determine whether respiratory, cardiovascular, and other relevant symptoms and complaints are associated with workplace temperature, as can be inferred from general population studies<sup>1, 2</sup>. We aimed to acquire quantitative estimates for the effect of the cold exposure, controlling for personal and workplace factors. Furthermore, we aimed to estimate how protective clothing modifies the association between temperature and the prevalence of symptoms. Such information would be useful in assessing the symptom burden imposed by the cold environment on workers and in deciding pre-emptive measures.

The population base consisted of 288, 5,034, 500, and 7,250 workers in four chicken meat processing factories in Thailand. The power calculations<sup>7</sup> based on the assumption of 50% of workers perceiving symptoms indicated that a sample size of 420 was sufficient to detect prevalence differences of 0.3 standardized units with a probability of 0.90. All workers across the four factories were offered the opportunity to participate by a local supervisor. Approximate quotas for the numbers of participants in each factory were set in advance, and the final numbers to be interviewed (59, 145, 70, and 148, respectively, for a total of 422) were determined by the availability of workers during their regular working hours and time schedules of the study team. The entire sample was used for a separate prevalence study. The present analysis is a sub-study of approximately 300 subjects who were measured

for worksite air temperature, relative humidity and air velocity (workers in cold storages and manufacturing halls and in office sections that volunteered to participate). The sampling is described in Table 1.

The study aim and protocol were reviewed and accepted by the Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University, Bangkok, Thailand. The interviewees were informed that their participation was strictly voluntary and that all information provided would remain confidential. All participants signed a written consent form.

The work in the factories consisted of cutting and packing chicken meat in production halls, transporting the packages to cold storages and from there to shipping yards, and paperwork in offices by office workers. Protective clothing was provided by the employer and consisted of long-sleeved shirts and coats, long trousers, coveralls, gloves, and headgear. The clothing had no quality certification, but was specifically designed for cold protection and was changed daily and kept in good condition. Other protective measures included warming-up breaks, restrictions on the time spent in the cold, and rotating working shifts.

The structured interview conducted by trained interviewers asked about personal details and work-related factors and included questions such as "Have you experienced any of the following symptoms during work or after work because of the cold?" and "Does the cold decrease your performance at work?". The questions were derived from an international standard (ISO 15743) and were modified for the present purpose based on experiences from previous cold studies<sup>2</sup>. The detailed symptoms inquired of are presented in Table 2. The interviewees were also asked about 28 clothing items used at work, as described by the international standard (ISO 9920) and previously used in cold workers' studies<sup>8</sup>. Thermal insulation of the clothing ensemble ( $I_{cl}$ ) was calculated as basic thermal insulation  $I_{cl} = 0.161 + 0.835 \sum I_{clu}$ , where  $I_{clu}$  denotes the clo value of each clothing item<sup>8</sup>.

Air temperature and relative humidity were measured using Thermo-hygrometer 303 C (Shenzhen Graigar Technology, China) and air velocity using VelociCalc<sup>®</sup> 9545 (TSI Incorporated, MN, USA). The measurements were conducted at several points in the participants' regular working area. In areas where temperature and air velocity varied, the minimum and maximum values were recorded and expressed as averages. Relative humidity was stable in each area and was expressed as a single value. The values recorded from each working area were linked to the study

**Table 1. Numbers of workers and temperature in the base population and the sample studied, broken down by factory sections**

|                                  | Factory   |             |             |            | ALL         |
|----------------------------------|---|-------------|-------------|------------|-------------|
|                                  | A   | B           | C           | D          |             |
| <b>BASE POPULATION</b>           |   |             |             |            |             |
| No. of workers                   | 288   | 5,034       | 500         | 7,250      | 13,072      |
| Temperature °C (range)           |   |             |             |            |             |
| Cold storage                     | -25-4   | -20-4       | -24-4       | -35-4      | -35-4       |
| Production hall                  | 11-14   | 9-10        | -1-14       | 12         | -1-14       |
| Office                           | 23-27   | 25          | 23-27       | 25         | 23-27       |
| <b>SAMPLE</b>                    |   |             |             |            |             |
| <i>No. of workers</i>            | Interviewed sample/sample with temperature measurements |             |             |            |             |
| All sections                     | 59/42   | 145/78      | 70/68       | 148/116    | 422/304     |
| Cold storage                     | 5/5   | 44/35       | 32/31       | 85/71      | 166/142     |
| Production hall                  | 38/37   | 51/38       | 18/18       | 45/45      | 152/138     |
| Office                           | 14/0  | 47/4        | 16/15       | 18/0       | 95/19       |
| Other                            | 2/0   | 0/0         | 4/4         | 0/0        | 6/4         |
| <i>Temperature</i>               |   |             |             |            |             |
| All sections (mean, range) °C    | 5 (-20-13)  | 3 (-22-14)  | 12 (-19-23) | -1 (-20-2) | 4 (-22-23)  |
| No. of workers at <10°C (%)      | 43  | 67          | 46          | 100        | 65          |
| Cold storage (mean, range) °C    | -14 (-20-0)   | -7 (-22-14) | 7 (-19-23)  | -3 (-20-2) | -2 (-22-14) |
| No. of workers at <10°C (%)      | 100   | 74          | 68          | 100        | 87          |
| Production hall (mean, range) °C | 7 (0-13)  | 10 (10-14)  | 7 (-1-14)   | 2 (2-2)    | 6 (-1-14)   |
| No. of workers at <10°C (%)      | 51  | 0           | 56          | 100        | 54          |
| Office (mean, range) °C          | -   | 14 (14-14)  | 23 (23-23)  | -          | 21 (14-23)  |
| No. of workers at <10°C (%)      | -   | 0           | 0           | -          | 0           |
| Other (mean, range) °C           | -   | -           | 23 (23-23)  | -          | 23 (23-23)  |
| No. of workers at <10°C (%)      | -   | 0           | 0           | -          | 0           |

participants located in the same area. Air temperature was obtained for 304 participants and air velocity and relative humidity for 301 and 297 participants, respectively.

Each symptom (yes/no) was regressed on temperature using a generalized linear model with a logit link function and quasibinomial error distribution, first adjusting for personal factors (sex, age, education, body mass index) and then additionally adjusting for work-related factors (physical strain at work, daily hours spent in temperatures <0°C and 0–16°C, relative humidity, and air velocity). Using 10°C as the cut-off point between cold and warm, the temperature was treated as dichotomous (-22–10°C vs. 10–23°C). Thermal insulation of clothing was coded using the median  $I_{cl}$  as the cut-off point (0.25–1.1 clo vs. 1.1–2.21 clo). To determine how the effect of temperature was modified by the thermal insulation of clothing, the interaction between temperature and  $I_{cl}$  was added to the adjusted model. In addition to the crude prevalence of symptoms, the results were expressed in terms of adjusted prevalence ratios (PRs) together with their 95% confidence intervals, based on model-based marginal means<sup>9</sup>. The results were calculated in the R environment, release 3.50 ([https://cran.](https://cran.r-project.org/)

[r-project.org/](https://cran.r-project.org/)), and the `svydesign` function was used to allow for stratified sampling.

The age of the participants averaged 33 yr (standard deviation (SD) 10 yr; range 18–57 yr); half of them were men, and 27% had university or vocational school education. Thirty-nine percent were classified as obese (body mass index >25 kg/m<sup>2</sup>), 32% were regular smokers, and 16% consumed alcohol weekly. Four percent of the subjects reported elevated blood pressure, and 1–3% reported some respiratory condition. Most participants (48%) were manufacturing workers, followed by storage workers (32%), office staff (10%), and forklift drivers (8%). Forty-four percent of the subjects performed heavy or medium-heavy physical work. The subjects had been employed in the factory for an average of 6 yr, 4 yr of which were in the cold. The daily working time averaged 9 h, 2 h of which were at <0°C and 6 h at 0–16°C.

The thermal insulation of clothing averaged 1.1 clo (SD 0.3, range 0.4–2.2). Altogether, the workers wore 10.6 individual clothing items on average (range 4–16). The mean number of overlapping clothes on the upper body (camisole, shirt, vest, sweater, jacket) was 2.3 (range 0–5),

**Table 2. Percentage of workers perceiving various cold-related symptoms at different workplace temperatures and adjusted prevalence ratios (PR) for symptoms perceived at cold (−22–10 °C) vs. warm (10–23 °C) temperatures**

| Symptom/complaint       | Percentage of workers perceiving symptoms,<br>by temperature |             |              | PR adjusted for personal<br>characteristics <sup>1</sup> (95% CI) | PR adjusted for personal and<br>work-related factors <sup>2</sup> (95% CI) |
|-------------------------|--|-------------|--------------|---|--|
|                         | −22–23<br>°C   | 10–23<br>°C | −22–10<br>°C |   |  |
| Cardiorespiratory       | 81.2   | 65.2        | 85.7         | 1.77 (1.67–1.86)  | 1.36 (1.27–1.46)   |
| Respiratory             | 79.8   | 64.8        | 84.2         | 1.60 (1.49–1.72)  | 1.34 (1.23–1.46)   |
| Dyspnoea                | 52.2   | 52.8        | 51.9         | 1.18 (0.98–1.37)  | 1.67 (1.31–2.04)   |
| Wheezing                | 29.6   | 28.8        | 29.9         | 0.92 (0.67–1.17)  | 0.88 (0.52–1.24)   |
| Prolonged cough         | 43.1   | 37.2        | 45.5         | 2.13 (1.73–2.53)  | 1.56 (1.13–1.99)   |
| Mucus production        | 69.3   | 51.2        | 75.4         | 1.61 (1.46–1.76)  | 1.14 (0.96–1.31)   |
| Cardiac                 | 23.1   | 17.1        | 25.9         | 1.45 (1.02–1.88)  | 1.21 (0.65–1.77)   |
| Chest pain              | 16.3   | 9.8         | 19.8         | 1.91 (1.23–2.59)  | 0.66 (0.23–1.09)   |
| Arrhythmia              | 15.7   | 15.7        | 15.7         | 0.87 (0.53–1.21)  | 0.63 (0.22–1.05)   |
| Peripheral circulation  | 62.3   | 51.0        | 66.6         | 1.25 (1.09–1.40)  | 1.28 (1.04–1.51)   |
| Thirst                  | 41.7   | 45.9        | 40.0         | 1.09 (0.84–1.34)  | 2.10 (1.47–2.73)   |
| Drying of mouth         | 55.6   | 50.8        | 57.5         | 1.57 (1.33–1.80)  | 1.80 (1.46–2.13)   |
| Performance degradation | 81.8   | 82.5        | 81.5         | 1.03 (0.95–1.11)  | 0.98 (0.88–1.08)   |
| Concentration           | 37.0   | 53.5        | 31.0         | 0.61 (0.44–0.77)  | 0.62 (0.38–0.85)   |
| Motivation              | 34.8   | 49.9        | 29.4         | 0.61 (0.44–0.77)  | 0.82 (0.52–1.12)   |
| Endurance               | 50.3   | 54.1        | 48.8         | 0.95 (0.78–1.13)  | 0.68 (0.47–0.88)   |
| Ability to hold         | 28.1   | 31.3        | 26.9         | 0.89 (0.64–1.14)  | 0.29 (0.13–0.44)   |
| Handgrip force          | 67.8   | 69.4        | 67.2         | 1.08 (0.95–1.21)  | 0.87 (0.71–1.03)   |
| Finger dexterity        | 67.4   | 69.6        | 66.5         | 1.03 (0.90–1.16)  | 0.75 (0.59–0.90)   |

<sup>1</sup> Adjusted for sex, age, body mass index and education (vocational school or university vs other education).

<sup>2</sup> Additionally adjusted for air velocity, relative humidity, physical work strain (medium heavy or heavy physical work vs sitting or other light work), daily hours spent at <0 °C and daily hours spent at 0–16 °C.

on the lower body (dress, pants, trousers) was 1.0 (0–2), and on the head (hood, ski hat, hijab) was 1.4 (0–2). There was also an average of 2.0 (1–3) items of footwear (socks, shoes, boots) and 1.2 pairs (0–3) of gloves (cotton gloves, medical gloves).

The worksite air temperature averaged at 3.6°C (SD 13.1, range −21.6–23.0°C), relative humidity averaged at 47% (SD 13.0, range 27–72%), and air velocity averaged at 0.43 m/s (SD 0.38, range 0.01–3 m/s). In total, 65% of the subjects (87% in cold storages, 54% in production halls) worked regularly at temperatures lower than 10°C (Table 1). However, 80% and 86% of those regularly working at cold and warm sites, respectively, moved between cold and warm sites at least 4 times per day, and those regularly working at warm sites also spent 1/2 h per day at below-zero temperatures.

The following symptoms were experienced by workers because of workplace cold: respiratory symptoms, 80%; cardiac symptoms, 23%; peripheral circulation disturbances, 62%; thirst, 42%; drying of the mouth, 56%; and degradation of performance, 82% (Table 2). Various respira-

tory symptoms, adjusted for personal characteristics, were up to two times more prevalent at temperatures below 10°C than at temperatures higher than that. The prevalence of prolonged cough was especially high (prevalence ratio 2.13); only wheezing remained unaffected by temperature. Cardiac symptoms, adjusted for personal factors, increased in the cold by 45%, with chest pain, in particular, increasing by 91%. Peripheral circulation disturbances increased by 25% in the cold, while drying of the mouth increased by 57%. Most items related to performance degradation were more common at warmer temperatures. Additional adjustments for work-related factors either enlarged the PRs (dyspnea and thirst), reduced them (cough, chest pain), or had no effect.

Table 3 compares the effects of cold among workers who had low thermal insulation of clothing with workers who had higher insulation. Respiratory symptoms increased marginally less (by 4%) in the cold if the worker had thermal insulation of more than 1.1 clos compared with those having less than 1.1 clos. In particular, mucus production increased by 35% less in the cold at higher

**Table 3. Adjusted<sup>1</sup> prevalence ratio (PR) for cold-related symptoms perceived at cold (−22–10°C) vs warm (10–23°C) workplace temperatures, separately for workers having low and high thermal insulation of clothing (I<sub>cl</sub>)**

| Symptom/complaint               | I <sub>cl</sub> <sup>2</sup> | PR for cold vs. warm temperature | Ratio of PRs for high vs. low thermal insulation |
|---------------------------------|------------------------------|----------------------------------|--|
| Cardiorespiratory               | Low                          | 1.42 (1.33–1.53)                 | 1  |
|                                 | High                         | 1.33 (1.21–1.44)                 | 0.93 (0.85–1.01)                                 |
| Respiratory                     | Low                          | 1.39 (1.26–1.51)                 | 1  |
|                                 | High                         | 1.33 (1.20–1.45)                 | 0.96 (0.87–1.05)                                 |
| Dyspnoea                        | Low                          | 1.98 (1.39–2.58)                 | 1  |
|                                 | High                         | 1.60 (1.22–1.97)                 | 0.80 (0.62–0.99)                                 |
| Wheezing                        | Low                          | 1.14 (0.36–1.93)                 | 1  |
|                                 | High                         | 0.78 (0.44–1.11)                 | 0.68 (0.39–0.97)                                 |
| Prolonged cough                 | Low                          | 1.08 (0.59–1.57)                 | 1  |
|                                 | High                         | 1.77 (1.26–2.27)                 | 1.64 (1.17–2.11)                                 |
| Mucus production                | Low                          | 1.55 (1.17–1.92)                 | 1  |
|                                 | High                         | 1.01 (0.84–1.18)                 | 0.65 (0.55–0.76)                                 |
| Cardiac                         | Low                          | 2.53 (0.82–4.23)                 | 1  |
|                                 | High                         | 0.94 (0.48–1.41)                 | 0.37 (0.19–0.56)                                 |
| Chest pain                      | Low                          | 0.65 (0.03–1.28)                 | 1  |
|                                 | High                         | 0.69 (0.24–1.14)                 | 1.06 (0.36–1.75)                                 |
| Arrhythmia                      | Low                          | 1.75 (0.15–3.35)                 | 1  |
|                                 | High                         | 0.43 (0.13–0.73)                 | 0.25 (0.08–0.42)                                 |
| Peripheral vascular disturbance | Low                          | 2.49 (1.85–3.13)                 | 1  |
|                                 | High                         | 1.08 (0.86–1.30)                 | 0.43 (0.35–0.52)                                 |
| Thirst                          | Low                          | 1.19 (0.53–1.85)                 | 1  |
|                                 | High                         | 2.56 (1.81–3.31)                 | 2.15 (1.52–2.78)                                 |
| Drying of mouth                 | Low                          | 1.98 (1.41–2.54)                 | 1  |
|                                 | High                         | 1.74 (1.39–2.09)                 | 0.88 (0.70–1.06)                                 |
| Performance degradation         | Low                          | 1.17 (0.97–1.36)                 | 1  |
|                                 | High                         | 0.94 (0.84–1.04)                 | 0.80 (0.72–0.89)                                 |
| Concentration                   | Low                          | 0.85 (0.36–1.35)                 | 1  |
|                                 | High                         | 0.55 (0.32–0.78)                 | 0.64 (0.38–0.92)                                 |
| Motivation                      | Low                          | 1.35 (0.74–1.96)                 | 1  |
|                                 | High                         | 0.71 (0.41–1.00)                 | 0.52 (0.31–0.71)                                 |
| Endurance                       | Low                          | 0.84 (0.43–1.26)                 | 1  |
|                                 | High                         | 0.64 (0.43–0.85)                 | 0.75 (0.51–1.00)                                 |
| Ability to hold                 | Low                          | 0.45 (0.08–0.82)                 | 1  |
|                                 | High                         | 0.24 (0.10–0.37)                 | 0.53 (0.23–0.83)                                 |
| Handgrip force                  | Low                          | 0.98 (0.76–1.20)                 | 1  |
|                                 | High                         | 0.84 (0.67–1.01)                 | 0.85 (0.68–1.03)                                 |
| Finger dexterity                | Low                          | 0.87 (0.64–1.11)                 | 1  |
|                                 | High                         | 0.71 (0.55–0.88)                 | 0.82 (0.63–1.01)                                 |

The right-hand column compares the PRs between the high and low I<sub>cl</sub> groups. 96% confidence intervals are shown in parentheses

<sup>1</sup>Adjusted for sex, age, body mass index, education, air velocity, relative humidity, physical work strain (medium heavy or heavy physical work vs sitting or other light work), daily hours spent at <0°C, daily hours spent at 0–16°C and interaction between temperature and I<sub>cl</sub>.

<sup>2</sup>Low I<sub>cl</sub>: 0.25–1.1 clo; High I<sub>cl</sub>: 1.1–2.21 clo.

clos, wheezing by 32% less, and dyspnea by 20% less. Cardiac symptoms increased in the cold by a factor of 2.5 at low clo values but decreased by 6% at higher clos—a reduction of 63% in the prevalence ratio due to higher thermal insulation. A respective trend was observed

separately for cardiac arrhythmias, with a 75% smaller prevalence ratio due to more clothing. Peripheral vascular disturbances increased 2.5-fold in the cold at low thermal insulation, but not at all with any certainty at higher insulation. Most PRs for cold-related performance degradation



were lower in the cold, usually more so in workers with higher clo values compared with those with lower clo (Table 3). Exceptional patterns were seen in cold-related cough and thirst, which increased only at high clo.

We observed that despite protective measures, most workers experienced cold-related symptoms, and more workers perceived symptoms at  $-22$ – $10^{\circ}\text{C}$  than at  $10$ – $23^{\circ}\text{C}$ . The overall prevalence of cardiorespiratory symptoms was high and comparable to that reported previously among cold workers in Thailand<sup>6)</sup>. Also participants working at temperatures of  $10$ – $23^{\circ}\text{C}$  commonly perceived symptoms from the cold. This is not unexpected considering the recommended neutral indoor temperature of  $26^{\circ}\text{C}$  in this country<sup>10)</sup>, potential overcooling of indoor premises by air conditioning<sup>11)</sup>, and the fact that workers who regularly worked at warmer sites were occasionally exposed to the cold by frequently moving between sites during the day. Vulnerability to low temperatures due to adaptation to the tropical climate is also a possibility and requires further study.

The major findings of this study were the marked excess prevalence of respiratory symptoms in the cold, which was strengthened or weakened depending on work characteristics or physical workplace factors, and the excess prevalence of cardiac symptoms, notably chest pain, which disappeared after adjustment for work-related factors, possibly due to health-based selection. The increase in peripheral circulation disturbances in the cold also mirrors the spectrum of cold effects on the body and loading of the cardiovascular system. This is important since cold-related cardiac and respiratory symptoms predict increased morbidity and mortality in the general population<sup>5)</sup> and may also do so in working populations. The increased prevalence of thirst and drying of the mouth in the cold can be explained by cold-induced diuresis<sup>4)</sup> and voluntary reduction of fluid intake<sup>12)</sup>. This suggests that the workers may be dehydrated, which may predispose them to hemoconcentration and hyperviscosity of the blood<sup>4)</sup>. As coldness causes blunting of the feeling of thirst<sup>12)</sup>, older workers should especially be advised to consume fluids before they are thirsty.

We observed a lower prevalence of cold-related performance degradation at colder temperatures than at warmer temperatures. This is inconsistent with previous findings from experimental studies that report a decline in cognitive performance<sup>13)</sup> as well as hand and finger function<sup>14)</sup> in the cold. One may assume that in this observational epidemiologic study, some workers considered only temperatures lower than  $10^{\circ}\text{C}$  as cold enough to require good protective

clothing and therefore perceived less performance degradation at these temperatures. Nevertheless, higher thermal insulation was associated with less performance problems.

A decrease in cold symptoms with more protective clothing is unsurprising, but we quantified this effect in terms of the decreased prevalence of symptoms. With a few exceptions, the prevalence of cold-related symptoms was markedly lower in the subgroups of workers who had clothing with thermal insulation of 1.1 clo or more compared with those who had less insulation. Cardiac and peripheral circulation symptoms were especially much rarer when clothing insulation increased. This is understandable in terms of a lesser need to preserve bodily heat through cutaneous vasoconstriction and consequently smaller increase in blood pressure and cardiac load with better protection of the limbs and trunk. Cold-related respiratory symptoms, which are largely based on cooling of the respiratory tract, also showed some decrease at higher  $I_{cl}$  values, perhaps because cold can also provoke respiratory symptoms by cooling of the skin<sup>3)</sup>. Information bias remains a possibility, due to some interviewees having difficulties in making a distinction between various cardiorespiratory symptoms. Thus, an unknown component of cardiac symptoms such as chest pain may have been reported as a respiratory symptom such as dyspnea.

Because the symptoms are subjective perceptions, their validity cannot be assessed against any external gold standard, but our previous experience points to adequate face validity<sup>2)</sup>. The non-probabilistic sampling scheme may have introduced some bias to the crude prevalence figures, but it is unlikely to have markedly affected the associations between the symptoms and the cold as they were carefully controlled for confounding. One limitation was that air temperature measured in working areas may not accurately reflect the actual cold exposure of each individual. Uncontrollable cultural factors may also have introduced unknown bias to how the questions were understood. With these reservations, we believe that the results show important associations of workplace temperature with symptoms and clothing used and demonstrate the need for better protection against the cold.

The main conclusion of our study is that the workers in this industry are not adequately protected against the cold. Insufficient protection has harmful consequences for central bodily functions, also causes economic loss, and may increase severe health consequences over long-term follow-up periods<sup>5)</sup>. However, our results also suggest that the symptoms attributable to the cold are largely preventable. In an industrial setting, the effects of the cold can be

mitigated by technical measures and by limiting the time spent in the cold, but the central means is protective clothing<sup>15</sup>). The main reasons underlying insufficient clothing are 1) failure to follow the regulations because clothing hampers work performance<sup>8</sup>), 2) warming-up breaks that are too short compared with the time spent in the cold, or 3) the thermal insulation provided by the clothing is simply insufficient due to few clothing items or not enough clothing layers. Occupational health personnel should pay more attention to the respiratory, cardiac, and circulatory symptoms that workers attribute to the cold in their workplace. Greater awareness of cold symptoms may also aid the early detection of undiagnosed medical conditions.

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