ORIGINAL ARTICLE

HEALTH PROBLEMS RELATED TO WORKING IN EXTREME COLD CONDITIONS INDOORS

Hugo Piedrahita [1], Juha Oksa [2], Christer Malm [3, 4], Hannu Rintamäki [2, 5]

[1] Human Work Sciences Department, Luleå University of Technology, Luleå, Sweden
[2] Finnish Institute of Occupational Health, Physical work capacity team, Oulu, Finland
[3] Winternet, Boden, Sweden
[4] The Muscle Research Group, Dept. Integrated Medical Biology, Section for Anatomy, Umeå, Sweden
[5] Department of Physiology, University of Oulu, Oulu, Finland

Received 27 July 2007; Accepted 4 March 2008

ABSTRACT

Objectives. To identify health problems among workers performing cleaning, maintenance and machine operation tasks inside cold storage rooms with temperatures between -43 ºC and -62 ºC in a freeze drying coffee company.
Study design. Descriptive study.
Methods. All 24 workers working inside the cold stores participated in the study. A questionnaire about cold-related health problems and the standardized Nordic questionnaire assessing muscle complaints were completed by all exposed workers. A physical examination was performed on each worker.
Results. The most relevant cold-related health problem was episodic finger symptoms (50%), followed by respiratory symptoms (21%), peripheral circulation symptoms (20%), and repeated pain in the musculoskeletal system (12%). Two subjects had a previous diagnosis of Raynaud's phenomenon (RP). The prevalence of musculoskeletal complains in the neck and low back was 21% in each.
Conclusions. The prevalence found for various complaints among the freeze drying coffee workers implies that the cold conditions inside cold stores may present a real risk of cold-related health problems and, due to lowered concentration level, for injuries, too. Greater efforts should be made to minimize the cold exposure by designing automation processes to prevent continuous exposure to cold during freeze drying process. In addition, improving the cold-protective clothing and guaranteeing its appropriate use will reduce health risks. *(Int J Circumpolar Health 2008;67(2-3):279-287)*

Keywords: cold-related illnesses, freeze drying, cold-protective clothing, cold injuries

INTRODUCTION

Work-related cold exposure may occur in an outdoor or indoor environment, with the majority of workers being exposed outdoors during winter season (1). Exposure to cold commonly occurs in fields such as construction, agriculture, traffic, fishing, forestry, gas and oil exploration, seafaring, mining, reindeer herding and rescue service. Indoor cold conditions are usually found in the food industry, where the most frequent air temperature when handling fresh food is from 0 to -10 ºC, while frozen food is usually stored and handled at temperatures around -25 ºC. In some cases, for example when handling tuna fish, the process involves colder storage with temperatures down to -60 ºC. Thus, cold indoor workplaces can expose the workers to very or extreme cold conditions. For example, in Japan there are about 4,000 cold storages, 85% of which are kept at a temperature below -20 ºC (2). In Denmark more than 20,000 people are employed by slaughterhouses, some of them working in cold storage rooms with temperatures down to -25 ºC (3). The cold conditions in an indoor environment are more predictable than outdoors, and usually the temperature is constant throughout the year with no daily variation.

A cold environment may be a significant health risk factor (1,2). Many types of chronic health problems, such as cardiovascular diseases, respiratory symptoms, musculoskeletal diseases, peripheral circulation problems, and skin diseases, are associated with cold exposure (4). In addition, varying amounts of exposure to cold environments may cause cooling injuries, such as local frostbites, and induce hypothermia.

Freeze drying (also known as lyophilization) is the process by which water and other solvents are removed from frozen foods by sublimation. It occurs when a frozen liquid changes directly into gaseous form without passing through the liquid phase. Freeze-drying results in a stable, readily re-hydrated product (5). This process has been used for a long time for food preservation. The freeze drying process has been used since 1938 (6) in soluble coffee production and it enables the preservation of the organoleptic qualities of the coffee, such as flavour and aroma. The freeze drying process employs cold stores with temperatures between -40 ºC to -60 ºC. The tasks performed by workers inside these stores include cleaning, maintenance and machine operation.

Based on two questionnaires and a medical examination, this paper presents the experience of 24 workers working inside cold stores in a freeze drying coffee company. The main objective of this research was to examine the effect of extreme cold indoor condition on the health condition of the workers.

MATERIAL AND METHODS

General design and study population

The research was carried out in a large and modern freeze drying coffee factory in Colombia, located at an elevation of 1,360 m and with an average temperature of 26 ºC. The descriptive study was based on all 24 workers performing tasks inside three cold stores housing an ongoing freeze drying process. All of the workers were male and the participation in the research was voluntary. The informed consent to participate in the study was obtained.

Musculoskeletal symptoms and discomfort

The participants completed a standardized questionnaire in Spanish on paid work time. One of the researchers explained the questionnaire individually to each worker. The questionnaire responses remained anonymous, and no company officer was present in the completion of the questionnaires. The questions about musculoskeletal symptoms were adopted from the Standardized Nordic Questionnaire (7). The specific symptoms inquired in the questionnaire were about pain, ache or discomfort in specified body parts during the preceding year and during the preceding 7 days. The questionnaire also inquired whether the symptoms suffered prevented the individual from doing his normal work. The questionnaire included demographic items such as age and gender, as well as questions on the number of years spent on the job, hand dominance, and type of contract with the company.

Health questionnaire about cold experience

For the detection of cold-related health problems, the Health-Check Questionnaire for Subjects Exposed to Cold (8) was translated into Spanish and applied individually to each exposed worker.

Physical examination

A medical history and physical examination were performed on each worker.

The skin and the musculoskeletal and cardiovascular systems were the focal points of the physical examination.

Job analysis and tasks

All workers worked eight hours per day and six days per week with a total of 48 hours per week as a is established by the Colombian regulations. They performed their tasks in three consecutive shifts of 06:00 to 14:00, 14:00 to 22:00, and 22:00 to 06:00 and rotated shifts regularly (every week) always in the clockwise order. The workers performed their tasks in three cold storage rooms. The environmental conditions according to the Engineering Department of the company were: air temperatures between -43 ºC to -62 ºC and air velocity varying between 0.5 m/s and 2 m/s. The workers were assigned to a cold storage room by the supervisor according the machine's function or the specific production necessities. The main tasks in the cold storage rooms were cleaning and maintenance and machine operation.

*Cleaning task*s consisted of removing ice and coffee residuals from the floor and walls using special tools, some of them with a metallic handle. Five workers performed this task.

Maintenance and machine operation consisted of some small reparations or replacement of machine parts and operating the machine's controls. These tasks were performed by 19 workers.

Both tasks (cleaning and maintenance-operation) were always performed in pairs and the exposure time was 60 minutes inside the cold stores, followed by 60 minutes of rest. During the rest period the workers did not perform any work-related tasks, and they could stay in a neutral room or move to the restaurant, toilet or elsewhere. They usually spent the time in the company of their co-workers.

The company provides the following cold-protective clothing to the workers: a work

overall (multi-component), regular trouser, gloves and mittens, a cap (covering the entire head), thick socks and over-boots. Except for the over-boots, the other garments are confectioned by local companies and the clo index values are not provided. In addition, the workers used briefs, a T-shirt, a long-sleeved shirt, a sweater, normal socks, and personal shoes. Thus, in addition to computing the insulation value (in clo units) required to maintain thermal equilibrium, approximate clo index for the clothing was estimated from tables according to clothing thickness and body surface area coverage (9).

RESULTS

Demographic characteristics of the population

All 24 workers were male and 79% of them had a permanent contract with the company. The other workers (21%) had a temporary contract. Of all workers, 92% were right-handed. The other demographic characteristics of the population studied are shown in Table I.

Cold-protective clothing

According to ISO 9920 (9), the level of thermal insulation provided by the cold-protective clothing used by the workers was 2.36 clo. This

Table I. Descriptive data on the studied population, n=24.

Exposed workers (n=24)	Mean/range	SD
Age (yrs)	29.5 (18-54)	9.7
Years on the present job	7.1 (0.1-34)	9.0
Working hours per week[a]	48	
Weight (kg)	73.7 (57.5-98.2)	10.7
Height (m)	1.70 (1.58-1.80)	0.0

Mean and standard deviation (SD)

[a]The accepted number of hours per week according to Colombian legislation is 48

Table II. Estimated[a] clothing protection against cold in a freeze drying coffee company

Clothing protection provided by company	**Weight (kg)**	**Clo index**
Work coverall filling (multi-component)	2.9	1.03
Regular trouser	0.8	0.25
Over-boots (fur lined boots)	2.5	0.10
Cap	0.0	0.01
Thick socks, calf length	0.1	0.11
Thick gloves	0.0	0.08
Gloves (mittens)	0.1	0.05
Other clothing used by workers		
Briefs	0.0	0.04
T-shirt	0.2	0.12
Shirt, long sleeves	0.4	0.25
Sweater - Long sleeve, V neck	0.2	0.25
Normal shoes	0.2	0.05
Normal socks	0.1	0.02
TOTAL	**7.5**	**2.36**

[a]Values were estimated based on tables according to ISO 9920 (1995)

value is based on the clothing usually worn by the workers. The weight of this ensemble was of 7.5 kg (Table II). Based on calculations using IREQ index and estimated level of heat production (116 $W \cdot m^{-1}$) the thermal insulation provided by the clothing should be approximately 4.6 clo.

It is important to note that not all workers used all clothing provided by the company, with the consequence that there were important differences between workers with regard to their cold protection. In some cases they mentioned that for (minimal tasks or) short periods they may avoid using some pieces of the cold-protective clothing, and in some manual and fine tasks (for example screwing) they removed the mittens and gloves for short periods of time.

Prevalence of musculoskeletal complaints

Table III presents the prevalence of musculoskeletal symptoms among the participants. One out of five workers reported troubles (ache, pain, discomfort) in the low back and neck. However, there were no reports of muscle problems preventing the workers from completing their normal work tasks during the preceding year.

Table III. Prevalence of musculoskeletal symptoms during the preceding year (ache, pain, discomfort) in specified body regions, n=24.

Body parts	Exposed workers n=24	
	n	%
Neck	5	21
Shoulder	1	4
Elbow	0	0
Wrist/hands	1	4
Upper back	1	4
Lower back	5	21
Hips/thighs	0	0
Knees	0	0
Ankle/feet	0	0

Information from the Standardized Nordic Questionnaire

Prevalence of complaints, symptoms and injuries associated with cold

The highest prevalence of health problems related to cold exposure in the studied population was for the episodic white and red/purple finger symptoms reported by 21% and 17% of workers, respectively. Increased excretion of mucus from the lungs was reported by 17% of the workers. The prevalence of other cold-related problems is presented in Table IV.

Performance in cold

The responses from 24 respondents to the Health-Check Questionnaire for Subjects Exposed to Cold yielded the following findings:

Thermal sensation of cold in the whole body
- 4% unpleasant (1 respondent)
- 25% slightly unpleasant (6 respondents)

Thermal sensation of cold in fingers
- 4% unpleasant (1 respondent)
- 33% slightly unpleasant (8 respondents)

Thermal sensation of cold in toes
- 4% unpleasant (1 respondent)
- 29% slightly unpleasant (7 respondents)

Cold sensitivity
- 8% confirm exceptional sensitivity to cold (2 respondents)

Cold sensitivity for fingers
- 13% confirm exceptional sensitivity to cold for fingers (3 respondents)

The most commonly reported decrement in performance in cold was impaired concentration (17%) followed by decreased motivation (13%). Table V shows the prevalence of decreased performance in cold.

Physical examination

Table VI shows the main results of the physical examination of the workers. The most relevant finding was that two of them had previous diagnosis of Raynaud's phenomenon (RP). The workers (29 and 54 years of age) were symptomatic during the examination and both were using medication for the problem. In one worker (54 yrs), the symptoms also affected the feet. Both subjects were working in the cold stores at the time of the study.

Table IV. Prevalence (%) of cold-related symptoms and complaints, n=24.

Complaint/Symptoms	n	% with symptoms or complaints
Skin symptoms		**8**
Itching and eruptions of skin	2	8
Respiratory symptoms		**21**
Shortness of breath	0	0
Persistent cough or bouts of cough	1	4
Respiratory wheezing	0	0
Increased excretion of mucus from the lungs	4	17
Cardiovascular symptoms		**4**
Chest pain	0	0
Cardiac arrhythmias	1	4
Peripheral circulation symptoms episodically		**20**
Circulation disturbances in hands and feet	2	8
Blurring of vision	1	4
Migraine type headache	2	8
Finger symptoms episodic		**50**
White fingers	5	21
Blue fingers	3	12
Red-purple fingers	4	17
Repeated pain in the musculoskeletal system		**12**
Neck/Shoulder or upper extremity pain	1	4
Back or Hip pain	1	4
Lower extremity pain	1	4
Injuries		**4**
Frostbite	1	4

Table V. Prevalence (%) of decreased performance due to cold, n=24.

Decreased performance due to cold	n	% of the decreased performance
Concentration	4	17
Motivation	3	13
Manual strength	2	8
Musculoskeletal function	2	8

Table VI. Prevalence (%) of findings from the medical examination during the study, n=24.

Medical examination	n	%
Raynaud's phenomenon	2	8
High blood pressure	1	4
Congestion of the nasal mucous	1	8
Red fingers	1	8
Skin blush and reddening	1	8

DISCUSSION

No previous studies have been published on health problems related to extreme cold indoor conditions comparable to those appearing in the freeze drying coffee industry. Considering that the workers in the company studied are exposed to extreme cold conditions during 50% of the working time and wear inadequate cold-protective clothing, our study unveiled some important cold-related complaints. The most relevant problem was episodic finger symptoms followed by respiratory symptoms, peripheral circulation symptoms, and repeated pain in the musculoskeletal system.

Workers' reactions to a cold environment include several symptoms and diseases. The risk of cardiovascular diseases has been found to be higher in populations exposed to cold particularly during wintertime (10). In our study, only one worker reported cardiovascular problems related to cold exposure (cardiovascular arrhythmia).

We found that peripheral circulatory symptoms were present in 20% of the workers, with circulation disturbance and migraine type headache as the most prevalent. In a working population (workers in the fish industry) exposed to a temperature of +10 ºC, a high prevalence of periodical circulatory disturbances in hands and/or feet (52%) was explained by inadequate protection of hands (11). Our results were also higher when compared with a general population exposed to cold during the long winter period. In this population study, the age-adjusted prevalence for peripheral circulatory symptoms was 12% (12).

Respiratory symptoms were frequent among the workers in the freeze drying coffee company. Increased excretion of mucus from the lungs and persistent cough or bouts of cough were present (17% and 4% respectively). Respiratory symptoms provoked by cold air are common in countries with a cold climate; however, a cold ambient temperature is more likely to function as a trigger for symptoms rather than an actual causal factor initiating lung diseases (13). Clothing is usually effective against many of the ill effects of cold, but it may not protect the respiratory system. The only unprotected part of the body of the workers was a small area of facial skin, which is thus considered a possible trigger site (including nasal mucosa) for cold air-provoked respiratory symptoms (13).

From an epidemiological viewpoint, an association has been established between cold exposure and musculoskeletal symptoms and complaints, especially for the neck and upper arms (14-17). A high prevalence of muscle problems in the neck and low back was detected in the study: 21% in each area. The use of cold-protective clothing has been considered to be involved with some adverse effects on workers' work performance and health. For example, each additional kg in clothing weight increase energy costs approximately by 3% (18). Also cold-protective clothing can increase the physical work due to bulkiness (19). The weight of the cold-protective clothing ensemble of the studied workers was high (7.5kg), probably increasing the workers' muscle strain.

An interesting finding was the identification of two workers who had been diagnosed previously with primary Raynaud's phenomenon (RP). This condition is the best recognized of the cold-related disorders. The prevalence of the RP varies considerable between populations, countries and regions,

and depends for example on the method used for the diagnosis (20). In spite of the fact that both cases were diagnosed a long time ago (6 and 10 years ago), both workers still continued working inside the cold stores. It is known that several mechanisms are involved in the etiology of primary Raynaud's phenomenon, including neurogenic mechanism, blood and blood vessel wall interactions, and abnormal immunological responses. Cold exposure is recognized as one factor that may provoke an attack (21). Patients with RP should avoid any form of cold exposure.

The use of cold-protective clothing is the responsibility of the workers, while the company should provide a clean, well-fitting and complete ensemble of clothing. It was observed that not all workers used the provided clothing in its complete form and on some occasions removed, for example, the gloves. Removal of the cold-protective clothing and/or direct contact of any metallic object to bare skin areas present a significant risk of frostbites and other injuries while working in very cold or extreme cold conditions. In addition, considering that the actual clothing protection is 2.36 clo, and the estimated IREQ index was 4.6 clo, the company should increase the clothing protection and reduce the exposure time.

Among the skin reactions related to cold, "cold urticaria" is cited as the most common skin problem (1). We did not find any urticaria problem between the exposed workers, although itching and eruptions of skin were observed in 8% of the workers. This is lower than the figures gained in a study among seafood industry workers, who often felt cold at work (22), and of whom 15% reported skin itching. However, in the seafood processing industry, low temperature, wetness, protein juices, and the gloves used may constitute independent risk factors of skin symptoms. A study conducted among the general population exposed to cold during a large part of the year in Finland, itching and eruptions of the skin were present in 9% of men and 14% of women (12).

One worker reported a previous cold injury (frostbite) related to the cold work environment. Reported cold injuries (frostbites) usually occur among workers in outdoor occupations (agriculture, oil and gas extraction, trucking and warehousing, protective services, and interurban transportation), although cold injuries have also been detected in people involved in the processing, distribution, and preparation of food (23). The low temperature and high air velocity inside the cold stores requires substantial cold protection by clothing especially of the workers' hands; this level appeared adequate in the studied company.

Difficulties in concentration was the most commonly reported (17%) decrement in performance among the workers. This is in line with a report stating that for 22% of the general Finnish population concentration is affected by cold weather (12). A reduced concentration capacity can increase the risk of injuries when operating equipment inside the cold stores.

Considering the extreme cold conditions to which these workers are exposed, most of the cold-induced symptoms were fairly light. However, the prevalence of various complaints implies that the cold conditions inside cold stores may increase the risk of cold-related health problems, and through decreased concentration, may also heighten the likelihood of injuries. Efforts should be made to minimize the cold exposure of the workers

by designing automation processes to avoid the permanent presence of the workers inside the freeze drying cold stores. In addition, the risk would be reduced by the appropriate use of the cold-protective clothing provided.

REFERENCES

1. Hassi J, Mäkinen TM, Holmér I et al. Handbok för kallt arbete [Handbook for cold work]. Stockholm: Arbetslivsinstitutet; 2002. ISBN 91-7045-626-7 (In Swedish).
2. Tochihara Y. Work in artificial environments. J Physiol Anthropol Appl Human Sci 2005;24(1):73-76.
3. Nielsen R. Characteristics of cold workplace in Denmark. In: Holmér I and Kuklane K, editors. Problems with cold work. Sweden: National Institute for Working Life; 1998: 16-18.
4. Hassi J, Rytkönen M, Kotaniemi J, Rintamäki H. Impacts of cold climate on human heat balance, performance and health in circumpolar areas. Int J Circumpolar Health 2005;64(5):459-467.
5. Simione FP, Brown EM. ATCC Preservation Methods. Freezing and freeze-drying. 2nd ed. USA, Md. American Type Culture Collection: Rockville; 1991.
6. Viani R. Coffee. In: Ullmann's Encyclopedia of Industrial Chemistry. 5th ed. revised. Germany, Weinheim: Wiley-VCH; 1996. Vol. A7:315-339
7. Kuorinka I, Jonsson B, Kilbom A, et al. Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon 1987;18:233–237.
8. Hassi J, Raatikka V-P, Huurre M. Health-check questionnaire for subjects exposed to cold. Int J Circumpolar Health 2003;62(4):436-443.
9. ISO 9920. Ergonomics of thermal environment – the estimation of the thermal insulation and evaporative resistance of clothing ensemble. ISO 9920:1995 (E). 1st ed. ISO Geneva. Switzerland.
10. Näyhä S. Cold and the risk of cardiovascular diseases: A review. Int J Circumpolar Health 2002;61(4):373–380.
11. Påsche A. Occupational health in the fish processing industry – An activity to improve the work environment by preventing cold exposures. Barents Newsletter on Occup Health and Safety 2001;4(1):12-14.
12. Raatikka V-P, Rytkönen M, Näyhä S, Hassi J. Prevalence of cold-related complaints, symptoms and injuries in the general population: the FINRISK 2002 cold substudy. Int J Biometeorol 2007;51(5):441-8.
13. Koskela HO. Cold air-provoked respiratory symptoms: the mechanisms and management. Int J Circumpolar Health 2007;66(2):91-100.
14. Chen F, Li T, Huang H, Holmér I. A field study of cold effects among cold store workers in China. Arct Med Res 1991;50 Suppl 6:99-103.
15. Hilderbrandt VH, Bongerst PM, van Dijk FJH, Kemper HCG, Dul J. The influence of climatic factors on nonspecific back and neck-shoulder disease. Ergonomics 2002;45(1):32-48.
16. McGorry RW, Hsiang SM, Snook SH, Clancy EA, Young SL. Meteorological conditions and self-report of low back pain. Spine 1998;23(19):2096-2102.
17. Pope DP, Croft PR, Pritchard CM, Silman AJ, Macfarlane GJ. Occupational factors related to shoulder pain and disability. Occup Environ Med 1997;54(5):316-321.
18. Rintamäki H. Protective clothing and performance in cold environments. Proceeding of the Third International Conference on Human-Environment System; 2005 Sep 12-15; Tokyo, Japan.
19. Rissanen S, Rintamäki H. Thermal responses and physiological straing in men wearing impermeable and semipermeable protective clothing in the cold. Ergonomics 1997;40(2):141-150
20. De Angelis R, Salaffi F, Grassi W. Raynaud's phenomenon: prevalence in an Italian population sample. Clin Rheumatol 2006;25:506–510
21. Belch JJF. The phenomenon, syndrome and disease of Maurice Raynaud. Br J Rheumatol 1990;29(3):162-165.
22. Bang BE, Aasmoe L, Aardal L, et al. Feeling cold at work increases the risk of symptoms from muscles, skin, and airways in seafood industries workers. Am J Ind Med 2005; 47: 65-71.
23. Sinks T, Mathias CGT, Halperin W, Timbrook C, Newman S. Surveillance of work-related cold injuries using workers' compensation claims. J Occup Med 1987;29(6):504-509

Hugo Piedrahita
Human Work Sciences Department
Luleå University of Technology
SE-97187, Luleå
SWEDEN
Email: hugo.piedrahita@ltu.se