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ORIGINAL ARTICLE

Assessment of Cold Stress and Its Effects on Workers in a Cold-Storage Warehouse

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ABSTRACT

Exposure to cold work environment is an occupational health hazard and poses adverse effect on workers health, performance and productivity. This study was performed in a cold food-storage warehouse complex in Tehran-Iran in order to evaluate the workers' exposure to cold stress. Twenty nine exposed workers and 33 non-exposed workers as control subject were included in this study. Climatic factors were measured based on ISO 7996 at the three levels of workers height. Physiological factors including skin temperature (ISO 9886), oral temperature (ISO 9886) blood pressure, pulse rate, workload (ISO 8996) were determined. Cloth insulation was estimated according to ISO 9920. The IREQ ($IREQ_{neut}$ and $IREQ_{min}$) were calculated following ISO/TR 11079 guidelines, and then, IREQ indices were compared with estimated cloth insulation through t-test. $IREQ_{min}$ in locations with above and below 0^oC was 1.7 and 3.63 clo, respectively. Exposed and control subjects had similar blood chemistry and physiological factors. The skin temperature in the extremities was considerably lower in the exposed subjects. The rate of pain (mostly in the knees, musculoskeletal, and pleurodynia) and skin cooling were higher in the exposed subjects. Lower skin temperature in the extremities and pain in the knees, musculoskeletal, and pleurodynia were the major health issues in this cold food-storage facility.

Keywords: *Cold stress, Insulation required indices, Food-storage warehouse, Iran.*

INTRODUCTION

When the net heat loss in the human body is more than the heat gain, thermoregulatory system may not be able to compensate for the heat loss leading to cold stress condition. Exposure to cold work environment is a significant hazard and poses adverse effects on the human comfort, performance and heath [1, 2]. Cold air combined with deep breathing (due to strenuous physical activity) can trigger an asthma attack (bronchospasm). Breathing cold air can cause coughing, chest tightness and discomfort such as burning-like sensation in the throat and the nasal passages. As the muscle temperature or body core temperature is cooled down, the physiological factors such as strength, endurance, and aerobic capacity are reduced slightly. In cold environment, musculoskeletal injuries may increase when exposed workers are engaged in vigorous physical activity especially in the absence of adequate pre-conditioning warm–up. Exposure to extreme cold stress can lead to wind-chill, frostbite, and hypothermia [2] and many other harmful effects [3-5]. Cold stress has been correlated to cold disorders as shown by several studies [6].

Workers may be exposed to cold while working outdoors in winter or indoor spaces are kept cold artificially. Individuals work outdoors in winter are generally become acclimatized to the cold condition naturally and gradually. Whereas, those who work in artificially kept cold food-storage facilities during all seasons, may not have the same opportunity for acclimatization when they return to work after being away for a few days. Lack of proper acclimatization

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may result in even higher levels of harm for workers in cold environments.

Since there is no report of work conditions in cold food-storage warehouses in Iran, this study was initiated to evaluate workers' exposure to cold stress in biggest cold food-storage warehouse complex in Tehran, Iran.

MATERIALS AND METHODS

Location

This study was conducted in a cold food-storage complex, the largest of its kind in Tehran, Iran in 2004. The complex consisted of 7 warehouses with a total storage capacity of 40000 tones of food.

Subjects

Of 260 permanent workers employed in this complex, all 29 exposed-to-cold employees (10 fork lift drivers and 19 laborers) were recruited for the study. A group of 33 employees with the same metabolic rate as the cold exposed workers, who worked routinely within the complex in non-cold material-storage areas were chosen as control subjects. Ethics Committee at Tehran University of Medical Sciences confirmed this study. Nevertheless, the company's permission has been secured. The participations in the study have been volunteers with no financial or other incentive. Subjects could end their participation in the study with no penalty and the identities of the subjects were kept confidential.

Climatic factors

(1) Air temperature was determined using a mercury thermometer (range: 0 – 100°C, precision: 0.1°C); (2) Globe temperature was determined using a globe thermometer (range: 20 – 100°C, precision: 0.1°C); (3) Relative humidity was measured using a digital relative humidity meter (Model: HT-601; Circuit Specialists, Inc; Arizona, USA ;and, (4) Air velocity was measured, using appropriate glass Kata thermometer (F =400, Model JISB735, Cassella, London). All the measurements were conducted following ISO 7996 recommendations [7], at the three levels of workers body fight (head, abdomen, feat).

Physiological factors

The workers' skin temperature was measured on 5 body parts (finger top, forehead, back of hands, cheeks, and nose top) using a dual thermometer (Model TM-905Lutron, Japan) and following ISO 9886 recommendations [8]. Subject's oral temperature was determined five times per shift work; (1) just before shift at 7am., (2) at 10 am., (3) just before 12 Noon, (4) at 2 pm., and (5) finally after shift at 3.30 pm. Oral temperature was measured using a medical thermometer (range: 35– 42°C, precision: 0.1°C) according to the ISO 9886 recommendations. The subjects were asked to (1) not eat, drink, or smoke for at least 15 min before oral temperature measurement, (2) close the mouth during the measurement to eliminate outside environmental effects, and (3) keep the thermometer in the mouth at least for 8 min.

Prior to each of the five oral temperature measurement, subjects' blood pressure (systolic and diastolic) and one-minute pulse rate were determined using an electronic measuring device (Model Aneroid N500V, Alpk2 Company, Japan). Including the subjects in the study was done according to the findings of blood pressure, pulse rate and general health condition. They were matched with the subjects' history of diseases, their medical files, and physician supervision. Workloads (physical activities) of subjects were estimated according to ISO 8996 recommendations [9] based on each subject's rest-activity regimen.

Cloth insulation

Cloth insulation was estimated individually according to ISO 9920 (E) recommendations [10]. Cloth insulation estimation based on this standard was within desired accuracy because it included: (1) the thermal characteristics in steady-state conditions for a clothing ensemble from known garments, ensembles and textiles, (2) the influence of body movement and air penetration on the thermal insulation and evaporative resistance, (3) the changing of the thermal insulation value due to washing is within measuring accuracy. Then, the Insulation required (IREQ) indices (IREQ and $IREQ_{min}$) were calculated following ISO/TR 11079 guidelines [11].

IREQ is defined as the resultant clothing insulation required during the actual environmental conditions to maintain the body in a state of thermal equilibrium at acceptable levels of body and skin temperature. IREQ integrates the effects of ambient climatic factors such as temperature, mean radiant temperature, humidity, air velocity and subject's metabolic heat production. The levels of IREQ calculated using a computer software program written based on ISO/TR 11079. The calculated IREQ (clo) was compared to the subjects clothing insulation to evaluate the levels of cold stress. In addition, DLE was calculated, using above mentioned software. Duration Limited Exposure (DLE) to cold is defined as the recommended maximum time of exposure with available or selected clothing.

Blood biochemistry

Biological factors included in the blood biochemistry analysis of each subject were glucose, blood urea, uric acid, cholesterol, and triglyceride. These factors were used as indices of subjects' general health and indicators of certain cold stress related cardiovascular disorders. Biological specimens were collected in the morning, while the subjects had been fasting overnight. Each subject was explained the procedure and requirement of a valid test.

Pain complains

The subjects were surveyed for the existence and frequency of persistent and considerable pain in different parts of their body such as the legs and knees. The survey was performed by administrating a questionnaire and examining subjects' medical files. Cold sensation of subjects in different parts of their body was asked through interviewing with them.

Table 1. Mean value of climatic factors for different warehouse halls

Food Stuff halls	td (^{O}C)	V (m/s)	tr (^{O}C)	RH (%)	H ($^{mcal}/_{cm^2.s}$)	$IREQ_{neut}$ (clo)	$IREQ_{min}$ (clo)	DLE_{max} (h)
Oil	4.8	0.6	6.07	63.6	16.5	2.07	1.68	4.4
Egg	5.3	0.6	4.9	59.3	16.3	2.06	1.71	4.6
Blood plasma	-16.6	0.5	-17.3	33.1	27.4	4.03	3.63	0.6
Frozen fowl	-16.8	0.5	-17.6	13.4	27.4	4.02	3.62	0.6
Non packed meat pieces	-14.4	0.8	-14.9	51.7	30.3	3.83	3.49	0.75
Packed meat	-17.8	0.6	-20.2	77.3	30.1	4.14	3.80	0.5

td = ambient temperature, v = air velocity, tr = mean radiant temperature, RH = relative humidity; IREQ (required insulation)$_{min}$ and IREQ $_{neut}$ are calculated based on M [Farida: Epalin M] = 90 $^{W}/_{m^2}$ ، DLE_{max} (maximum recommended time or maximum duration of limited exposure) is estimated based on I = 2 clo.

Table 2. Subjects' personal characteristics, physiological and biochemical factors

Factors	Exposed subjects (n = 29)		Control subjects (n = 33)	
	mean	SD	mean	SD
Age (years)	47.0	8.6	43.0	7.9
Weight (kg)	69.9	7.4	72.4	10.0
Height (cm)	172	28	172	29
Service duration (years)	15.7	6.4	12.7	6.7
Systolic blood pressure (mmHg)	111.7	13.4	117.1	10.7
Diastolic blood pressure (mmHg)	72.6	7.3	75.3	7.6
Oral temperature (°C)	36.9	1.3	37.0	1.4
Pulse rate (number/min)	75	6.2	73	6.9
Hemoglobolin (g/dL)	15.7	1.12	16.0	1.08
Urea (mg/dL)	30.2	5.92	27.5	7.00
White blood count (number)	6700	952	7436	1376*
Triglycride (mg/dL)	148.9	60.0	196.8	136.8
Creatine (mg/dL)	1.01	0.21	1.00	0.26
Hemotocrite (%)	47.0	3.6	48.3	3.2

n = number of subjects, SD = standard deviation, * Significantly higher in controls

Physical activities

Of the two groups of exposed subjects, the forklift drivers transported food packages inside the warehouses continuously. The laborers manually handled the food packages within the warehouse complex, which included receiving and shipping of the food packages weighing 10-35 kg. The control subjects performed light work such as maintaining devices within those warehouses that kept at normal temperatures.

RESULTS

Climatic factors as well as $IREQ_{neut}$ and $IREQ_{min}$ are presented in Table 1. Accordingly, $IREQ_{neut}$ and IREQ $_{min}$ increased with decreasing the air temperature and there was a considerable difference between IREQ for the air temperatures below and above 0°C. The maximum allowable time of exposure to cold environment has an inverse relation with IREQ. It is demonstrated that in indoor environment, dry bulb and radiant temperature play more effective role in cold stress judgment and selection of required clothing in order to control the cold stress rather than other climatic factors (V, RH).

Personal characteristics of the study male subjects are given in Table 2. The exposed subjects and controls showed no statistical difference in their age, body weight, body height and duration of service. As shown in Table 2, the levels of the blood pressure, oral temperature, and pulse rate were not statistical different between the exposed and the control subjects (p<0.05). No significant differences were found between the levels of blood biochemistry elements in the exposed subjects and the control subjects (Table 2) (p<0.05). The skin temperature (Table 3) was significantly lower in the exposed subjects (16.8°C and 27.0°C for air temperatures below and above zero, respectively) than those in the control subjects (32.5°C).

Types and frequencies of complaints expressed by the subjects are shown in Table 4. The calculated odd ratios showed that the pain in knees, musculoskeletal, and pleurodynia in the exposed-to-cold subjects were approximately 10, 6, and 6 times greater than those in the control subjects. Fisher exact test showed that there was a significant correlation between pain in the legs and the levels of cold stress exposure (p<0.05).

Table 3. Skin temperatures (°C) of cold-exposed and control groups

Exposed subjects				
Air temp.	Forhead temp.	Cheeck temp.	Back of hands temp.	Finger tip temp.
Below zero	25.2	18.3	14.8	9.0
Above zero	30.5	27.0	25.6	25.0
Control subjects				
Maximum skin temp.			33.1	
Minimum skin temp.			32.0	

Table 4. Type and frequency of complaints in subjects

Complaints	Exposed subjects n = 26	Control subjects n = 33
Knee pain	21	7
Musculoskeletal pain	19	8
Lumbago	8	2
Pain in the leg muscles	13	0

n = number of subjects

DISCUSSION

The optimum temperature for performing safely in a cold workplace depends on the thermal insulation of the subjects' clothing and their physical activities. For this purpose, IREQ has been introduced as the cold stress index by ISO. IREQ is a criterion for determination of required clothing insulation in cold environments [11].

The results of this study showed that IREQ index increased with decreasing air temperature. For example, for the same level of physical activity, IREQ $_{neut}$ at the temperature of + 5°C was 1.97 clo (in the warehouse storing eggs or oils) almost half the IREQ of 4.08 clo at the temperature of -18°C (in the warehouse storing frozen meat). Therefore, it is anticipated that the cold stress in the warehouse storing frozen meat (-18°C) is two times higher than the cold stress in the warehouse storing eggs or oils (+5°C).

The metabolic rate has an inverse effect on IREQ value; the higher the metabolic rate the lower is the IREQ value. Lower physical activities (approximately 90 w/m^2) exposed the lift-truck drivers to greater levels of cold stress when compared to those laborers with higher physical activities (approximately 120w/m^2).

Average calculated IREQ$_{min}$ for cold food-storage warehouses with the temperatures slightly above 0°C was 1.7 clo. While, the assessment of subjects' clothing insulation based on ISO 9920 (I $_{clr}$ (resultant clo = resultant thermal insulation of the clothing)) was 1.2 clo. Thus, the exposure duration should be decreased. The maximum recommended time (maximum duration of limited exposure), DLE $_{max}$, was calculated as one hour per shift. IREQ $_{min}$ for warehouses with air temperature below 0°C was predicted at 3.63 clo. [12], complying with the IREQ requirements does not by itself provide complete thermal comfort. In addition to meeting IREQ requirements, it is necessary to provide the exposed workers with a local heating for their hands and arms.

The findings of blood biochemistry indicated no statistically significant differences between the exposed subjects and the control subjects. These results are in agreement with the previous researchers findings [13]. The only exception was the white blood count (WBC); in our study. WBC of the exposed subjects was less than that of the control subjects; though in both groups WBC remained in the normal range. The higher WBC may be attributable to work conditions that can interfere with WBC, such as catching cold while working in cold environment.

Forklift drivers complained mostly from pain in their knees, legs and muscles. Lower physical activities of the forklift drivers exposed them to a greater cold stress than the other exposed subjects with higher physical activities. Furthermore, relatively high speed forklifts in the storage-halls, approximately 10 km/hr or 2.8 m/s, resulted in higher chilling effects of the cold environment on the forklift drivers. Additionally, lack of wind-shield in front of the forklifts exposed the forklift drivers, particularly their knees and legs, to higher air velocity. Pain in workers' knees and legs of those exposed subjects handling the packages manually might have been related to the combined effects of handling heavy packages (approximately 35 kg) and exposure to cold environment.

The temperature gradient between the indoor (within cold food-storage warehouses) and the outdoors in winter and summer was 30 ± 2°C and 50 ± 4°C, respectively. It seems reasonable to believe that the temperature gradient may be an important effective factor in the prevailing muscles pain [14], physical activity of a worker decreases considerably due to temperature gradient. Thus, the temperature gradient is a factor that can affect both the health of workers as well as their productivity.

The job satisfaction of cold exposed workers in winter was higher than that in summer (67% against 33%). Lumbago of forklift drivers is mostly related to an inappropriate ergonomic conditions of the forklifts used. None the less, cold environment can act as a synergetic factor with inappropriate ergonomic condition. Lower prevalence of lumbago in other less exposed workers may support this claim.

According to the statements of cold-exposed subjects, the body extremities such as the tip of nose, fingers and toes were exposed to higher levels of cold stress than the other parts of the body, and these body extremities gradually lost sensation and became numb.

The results of the skin temperature determination confirm this issue.

The results of this study did not show any relation between the lumbago and kidney problems. However, based on subjects' interview and the results of completed questionnaires (general questionnaire and health condition questionnaire) analysis, a relatively large percentage of subjects, observing those with longer exposure to cold anticipated that the kidney problem and pleurodynia would eventually be imposed upon the cold exposed subjects.

CONCLUSION

The results showed that IREQ index increased with decreasing air temperature. Lift-truck drivers (with lower metabolic rate) were exposed to greater levels of cold stress than the other laborers (with higher physical activities).

Lower skin temperature in the extremities and pain in the knees, musculoskeletal and pleurodynia were the major health issues in this cold food-storage facility especially in forklift drivers.

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