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ORIGINAL

Thermal Stress and Impact on Health in Workers of Refrigeration

Estrés Térmico y su Impacto en la Salud en Trabajadores de una Empresa de Frigoríficos

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ABSTRACT

Objective: the objective of this research was to determine the thermal stress conditions generated by low temperatures in the refrigerated warehouses of a plant in Venezuela; it was carried out between 2022 and 2023.
Methods: it was carried out within the positivist paradigm, quantitative approach, under a field study, observational design, descriptive level and cross-sectional. The population was made up of 13 workers who worked the day shift, being the census sample. Environmental parameters such as temperature, humidity and air speed were measured in different areas, using calibrated instruments. With the data obtained, the localized cooling index was calculated and the metabolic load was evaluated by observing the tasks, as well as the thermal insulation of the workers' clothing.
Results: the sample studied had an average age of over 50 years and a work experience of over 8 years; 35 % of the sample reported a cardiovascular history. Most of the jobs had thermal comfort conditions according to the WCI; 15,38 % of the workers felt cold; where a potential risk was identified in one of the workplaces due to excessive air speed and in another due to insufficient thermal insulation of clothing.
Conclusion: therefore, it was concluded that it is necessary to complement the evaluation with medical checks for workers, due to the possible impact of prolonged exposure to cold on their health.

Keywords: Cold-shock Response; Freezing; Refrigeration; Occupational Health.

RESUMEN

Objetivo: la presente investigación tuvo como objetivo determinar las condiciones de estrés térmico generadas por bajas temperaturas en los almacenes frigoríficos de una planta en Venezuela; la misma se realizó entre los años 2022 y 2023.
Métodos: se realizó dentro del paradigma positivista, enfoque cuantitativo, bajo un estudio de campo, diseño observacional, nivel descriptivo y corte transversal. La población estuvo conformada por 13 trabajadores que laboraban en el turno diurno, siendo la muestra censal. Se midieron parámetros ambientales como temperatura, humedad y velocidad del aire en diferentes áreas, utilizando para ello instrumentos calibrados. Con los datos obtenidos se calculó el índice de enfriamiento localizado y se evaluó la carga metabólica mediante la observación de las tareas, así como el aislamiento térmico de la indumentaria de los trabajadores.
Resultados: la muestra estudiada tenía en promedio edades mayores a los 50 años y una antigüedad laboral superior a los 8 años; 35 % de la muestra reportó antecedentes cardiovasculares. La mayoría de los puestos de trabajo presentaban condiciones de confort térmico según el WCI; 15,38 % de los trabajadores presentó sensación de frío; donde se identificó un potencial de riesgo en uno de los puestos de trabajo por excesiva velocidad del aire y en otro por insuficiencia del aislamiento térmico de la ropa.
Conclusión: por tanto, se concluyó que se requiere complementar la evaluación con controles médicos, a los

trabajadores, debido al posible impacto de la exposición prolongada al frío sobre su salud.

Palabras Clave: Respuesta al Choque por Frío; Congelación; Refrigeración; Salud Laboral.

INTRODUCTION

In the world of work, the need to provide workers with thermal comfort has gained ground worldwide; macías-average[1] considers that "there is a need to create, design or improve comfortable spaces to obtain excellent productivity in the work environment of workers." Thus, many organizations where tasks are performed in cold environments have adapted their areas in order to provide their workers with thermal comfort during the performance of their tasks.[1]

According to Espinoza,[2] heat stress is a consequence of "the net heat load, which results from the combination of environmental conditions, the work environment, the characteristics of the activities performed, and the type of clothing used by workers." Therefore, cold stress, as stated by Flores [3], "is a product of the exposure of workers to environments with low temperatures, which are impossible to avoid."[2,3]

Therefore, the thermal environment plays a vital role in working conditions since it depends on the physical condition of the worker and his performance in production. In the case of cold, the National Institute for Safety and Hygiene at Work[4] (INSHT), in its Technical Note on Prevention (NTP-1,036), states that this sensation occurs when the worker is present in environments with temperatures below 15 °C, which can lead to a reduction in physical and mental performance.[4]

In this sense, at work, many jobs involve the performance of tasks in cold environments, such as cold rooms or cold stores, which can generate health risks; according to Macias-Aveiga,[1] low temperatures can cause discomfort, musculoskeletal problems, deterioration of physical and manual execution of tasks; freezing of fingers, toes, cheeks, nose, and ears; hypothermia, this is due to the fact that the body loses more heat than it can generate and its temperature begins to drop 35 °C below; if the worker is not treated in a timely manner, he/she may even suffer cardiac arrest, coma or death.[1]

In fact, occupational exposure to cold without sufficient prevention and control measures can induce diseases and injuries in exposed workers and even promote the onset or aggravation of symptoms associated with certain cardiovascular diseases such as Raynaud's syndrome and facilitate the generation of occupational accidents.

It should be added that, as mentioned by Molina,[5] the starting date for the evaluation of cold stress are environmental measurements of temperature, air speed, humidity, radiation, and the estimation of the metabolic load of general cooling of the body and local cooling of certain parts of the body, such as the extremities and face.

Based on the above, it is possible to elucidate that due to these circumstances and the importance of this risk factor with respect to the significance of protecting the health of workers, this study was carried out in a cold storage company where sausage and cured foods are produced from meat raw materials; in addition to the packaging, storage, and distribution of these products in Venezuela; these tasks are carried out in a thermal environment of low temperatures.

Thus, in this work center, there is an urgent need to study the conditions of the thermal environment in order to determine the existence of thermal stress due to low temperatures in response to the thermal discomfort reported by the workers in order to reduce the risk of presenting occupational diseases and accidents due to exposure to cold and to provide the employer with the best practices that allow, in addition, to take care of the health of their workers and efficient performance of their industrial activities.

METHODS

This field research was conducted within the positivist paradigm, quantitative approach, observational design, descriptive level, and cross-sectional. It was carried out in the cold storage warehouses of a plant in Venezuela.

The population consisted of 13 workers in the production areas exposed to low temperatures in a single shift from 7:00 a.m. to 4:00 p.m., with the positions of meat operator, mill operator, mixer operator, filler operator, and supervisor. The sample was a census sample.

For the evaluation of risk due to heat stress, the localized cooling index (WCI) and the estimation of thermal resistance of clothing (IREQ) methods were used; thermo-hygrometric variables were measured with instruments such as the heat stress monitor (WBGT, Extech Model HT 30®) and the Anemometer (Extech 4 in 1 45170®), duly calibrated and certified, used for each of the work stations.

With the measurement of these thermo-hygrometric parameters, the air temperature (Ta), relative humidity (RH), air velocity (Va), wet bulb temperature (WBGT), and globe temperature (TG) were determined after locating the sampling points by means of a sketch of the areas and considering the condition of a closed

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environment with variable air flows that affect specific areas. Each parameter was measured for 01 hour, with 10 repetitions at the height of the thorax for each workstation and at the time of the working day of most significant exposure to cold, in December at a time between 8 a.m. and 12 m., taking into account the provisions of the Venezuelan Commission of Industrial Standards[5] (COVENIN: 2254-95); due to the extent of the data obtained, an average of the results was taken.

Based on the results obtained, the localized cooling index was calculated for each of the tasks analyzed from the variables wind speed (V) expressed in m/sec and air temperature (Ta) in ºC by means of the following formula:

$$WCI = 1{,}16\ (10{,}45 + 10\sqrt{V} - V) * (33 - Ta)$$

Once the results were obtained, they were placed according to the cold effect table for different values of WCI and freezing temperature indicated by the technical prevention standard [6] (NTP-462) to determine the sensation effect. Subsequently, the physical, metabolic rate was calculated by estimating the occupational energy expenditure based on the observation method in the workstations; to calculate the metabolic activity of the personnel, we took into account the sum of parameters such as basal metabolism, metabolic rate, and workload.

Finally, with the Ta, M, and V data, the required insulation index of the clothing or IREQ min, according to the tables expressed in the NTP-462, which corresponds to the thermal resistance value of the clothing that allows for zero heat loss, was located and compared with the thermal insulation level calculated for the workers' clothing according to NTP-462 tables, according to the values for the Clo Index (Icl) according to the metabolism, according to ISO-9920:2009.[6,7]

RESULTADOS

The sample was represented by 54 % women and the rest of the men; in terms of age, 54 % were between 51 and 60 years of age, 30 % between 41 and 50 years of age, 8 % between 30 and 40, and between 61 or more years of age; 84 % had 8 or more years working in the company, and 16 % had between 1 and 7 years of work experience (see Table 1).

Table 1. Socio-demographic and labor characteristics of the workers.

Variables	Workers Exposed to Cold	
Sex	**No.**	**%**
Female	7	54
Male	6	46
Age Groups		
30 - 40	1	8
41 - 50	4	30
51 - 60	7	54
61 or more	1	8
Seniority		
1 - 3	1	8
4 - 7	1	8
8 or more	11	84

The work process involved in the production of sausage products consists of two fundamental stages: the first consists of receiving and storing the raw material and the second of processing the raw material into finished products, from which are derived various processes that take place in low-temperature environments such as: grinding the raw meat material, mixing the different bases for the products, stuffing the mixtures and packaging the product.

The health status of the workers was identified in terms of primary pathologies by apparatus and systems, determining that 39 % of the workers had no pathological antecedents; however, the circulatory system was found to occupy an essential place with 35 %, demonstrating that established in the literature, it is a health indicator, although pre-existing, closely related to occupational exposure to cold.

The results of the application of the simple EVALTER OBS method for the evaluation of thermal discomfort and risks due to thermal stress are presented in table 2.

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Table 2. Thermo-hygrometric variables, localized cooling index and sensation effect

Work areas	Job Title	Ambient temperature (°C)	Wind speed (m/s)	Localized Cooling Index (WCI, w/m2)	Sensation effect
Mixing and Grinding	PT 1	15,71	0	209,58	comfort
	PT 2	15,57	0	211,28	comfort
	PT 3	15,66	0	210,19	comfort
	PT 4	15,69	0	209,83	comfort
Sausage	PT 5	15,84	0,48	406,36	cold
	PT 6	15,69	0,53	401,37	cold
	PT 7	15,56	0,04	251,04	comfort
	PT 8	19,89	0,03	184,80	comfort
	PT 9	20,12	0,7	270,67	comfort
	PT 10	20,12	1,24	303,97	comfort
Packaging	PT 11	19,95	0,01	173,17	comfort
	PT 12	19,58	0	162,67	comfort
	PT 13	19,39	0	165,10	comfort

As for the localized cooling index, which turned out to be more noticeable in the stuffing area, for workstations 5 and 6, this was conditioned by environmental factors such as temperature and air speed, which, in this area, are around 15 °C, with a speed of 0,53 m/sec respectively, with the highest cooling index in workstation 5 with 406,36 w/m2, manifesting the effect of a cold sensation.

Likewise, it was observed that in 84,6 % of the workstations studied, the localized cooling index remained within the limits for a comfortable sensation effect, which indicates acceptable working conditions. In addition, an air speed of 1,24 m/sec was observed at workstation 10 in the packing area, which is above the permissible 1 m/sec, according to NTP 462.

The insulation conditions of the work clothes provided to the company's workers in the stuffing, grinding, and mixing areas are adequate while maintaining a level of 1,35 clo for the performance of the workers, as well as in the packing area with a level of 1,00 clo.

Table 3. Metabolic load, required and specific isolation of workers' attire

Work areas	Job Title	Metabolic load (w/ m2)	Metabolic load class	IREQmin (clo)	Thermal resistance of clothing (clo)
Mixing and Grinding	PT 1	269	very high	0,33	1,35
	PT 2	269	very high	0,33	1,35
	PT 3	269	very high	0,33	1,35
	PT 4	171	moderate	0,4	1,35
Sausage	PT 5	266	very high	0,37	1,35
	PT 6	269	very high	0,37	1,35
	PT 7	115	low	1,16	1,3
	PT 8	171	moderate	0,4	1
	PT 9	269	very high	0,42	1
	PT 10	206	high	0,61	1
Packaging	PT 11	186	moderate	0,4	1
	PT 12	162,67	moderate	0,4	1
	PT 13	269	very high	0,33	1

It was determined, according to the metabolic load and the thermal insulation provided by the workers' clothing, that there is a hygienic risk of heat stress due to cold in workstation 7 or sausage process control, conditioned by the low metabolic load involved in performing the tasks with a value of 115 w/m2 and by the thermal insulation obtained from the clothing of 1,3 clo. In this sense, the rest of the workplaces showed values

that determined metabolic loads between moderate and very high for the tasks performed by the workers evaluated and with adequate thermal insulation attire, not implying risks of thermal stress.

DISCUSSION

Exposure to cold working environments represents a substantial occupational hazard that can have significant adverse effects on workers' health, performance, and productivity. It is to be considered that when the heat loss of the human body exceeds the capacity of the thermoregulatory system to generate heat, a cold stress condition can occur. Therefore, prolonged and intense exposure to cold stress has been associated with health disorders, such as rheumatic diseases and musculoskeletal and vascular disorders. Refrigerated warehouse workers are particularly exposed to these harsh working conditions.[8]

Regarding the sociodemographic characteristics of the workers, the predominant population was aged between 51-60 years. It had been working for more than 8 years, which is evidence of prolonged exposure to cold conditions. These findings are consistent with previous research carried out in this type of industry, where the workforce corresponds to personnel with a long trajectory in the activity.[8,9]

When evaluating the thermal stress conditions, most of the workstations (84,6 %) registered a comfort sensation effect, according to the localized cooling index. However, workstations 5 and 6 in the stuffing area showed higher WCI values that determined a cold sensation, influenced by the temperature of 15 °C and air velocities between 0,4 and 0,5 m/sec. These results are in agreement with other studies that report higher risk in areas where raw materials are handled or processes with direct exposure to cold are carried out.[8,9]

It should be noted that in a workstation in the packaging area, air velocities higher than those established (1,24 m/sec) were measured, factors that, if not controlled with corrective measures, could generate more significant risks in the medium term. In this regard, Holmér[10] and Mäkinen et al.[11] emphasize the importance of considering wind speed as a relevant climatic factor in the evaluation of cold stress. This is because it acts as an enhancer of heat losses from the organism, increasing the adverse effects of low temperatures on health. In particular, increased wind favors forced convection and can exacerbate problems such as hypothermia or frostbite.[10,11]

Regarding the evaluation of the metabolic load, a potential risk was determined in workstation No. 7 due to the low physical activity required and the level of thermal insulation of the clothing. This finding coincides with what has been reported in other studies in cold storage warehouses on the importance of adjusting the caloric balance with respect to the demands of each activity. The rest of the positions had adequate loads and work clothes according to the established parameters.[8,9]

It is worth mentioning that although the conditions analyzed were mostly found to be within acceptable parameters, prolonged exposure to these temperatures can gradually trigger alterations in the health of workers. Several studies have reported cases of osteo-articular and cardiovascular pathologies in workers in cold environments, where they relate greater exposure to cold with an increase in the risk of suffering musculoskeletal disorders, joint pain, and decreases in skin temperature.[8,9,10,11,12]

Likewise, research by Thetkathuek et al.[12] and Holmér[10] warns of possible long-term effects of cold on cardiovascular health. This supports the findings in the present study, where 35 % of workers reported a cardiovascular history.

Another relevant aspect was the measurement of environmental parameters with calibrated instruments, following internationally validated methods and criteria, which guarantees the reliability of the results. However, it would be convenient to complement this evaluation with biomedical monitoring of the workers, in order to determine possible health effects.

CONCLUSIONS

The present investigation made it possible to determine the thermal conditions, which are acceptable for the most part, except in some specific workplaces where corrective measures should be taken. Periodic follow-ups are recommended, including medical examinations, given the possible association between prolonged exposure to cold and health alterations. The results constitute a baseline reference for the company in order to implement preventive actions to ensure the protection of the health of its workers exposed to low temperatures.

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CONFLICT OF INTEREST

We declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

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