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Exposure to cold environments at working places and cardiovasculare disease

Florin MITU[1], *Maria Magdalena LEON*[2],

Abstract

Cardiovascular diseases are among the most frequent causes of illness and death among the active population, especially in industrialized countries, but also in developing countries. In industrialized countries are registered between 15% and 20% of workers suffering from cardiovascular disease while risk increases with age: between 45 and 64 years more than one third of deaths are recorded in men and one fourth in women. Working in cold microclimate can lead to health problems, decrease performance and increase labor productivity determining the occurrence of accidents at work, absence from work because of sickness. The worst case working in cold conditions may be linked with deaths due to accidents related to cold or because of an acute event occur in a pre-existing condition. Cardiovascular symptoms and decreased performance occurs especially during working in cold weather, especially among patients with cardiovascular disease or cardiovascular important risk factors. Increased awareness and identification in the workplace of individual risks associated cold is the first step in assuring a proper risk management. After this assessment, sensitive population groups need individual advice regarding prevention and protection work in cold microclimate. An important asset of people is touched by an unidentified form of asymptomatic or cardiovascular disease. Working conditions and job requirements for employment can trigger brutal events, acute cardiovascular disease in asymptomatic active staff requiring the development of complex programs adaptation and/or retraining.

Keywords: cold; occupational; disease; cardiovascular; prevention.

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Introduction

Cold is a significant risk factor present in outdoor and indoor industrial activity. Working outdoors offers a seasonal exposure to cold, affecting many countries at northern latitudes. Microclimate indoor cold often includes the same climatic conditions throughout the year, all over the world. Cold compromises the quality of work. Cooling the tissues leads to discomfort, deterioration of performance and ultimately, to injuries. Much of the adverse effects of exposure to cold can be assessed through an analysis of relevant risk and prevented by adequate safeguards. Internationally there have been researches on various aspects of work in the cold: medical and physiological effects, methods of exposure assessment and preventive actions to reduce risks exposal to stress and cold (Baikoussis NG, Apostolakis EE, Koniari I, Dougenis D., 2010).

Exposure to cold contributes to increased morbidity and mortality (Bovenzi M., 2008). It is well known that deaths from acute myocardial infarction and coronary heart disease occur more frequently during winter. In addition, mortality from congestive heart failure also increases linearly with low temperatures (Brândușa Constantin, Veronca Oprea, Cornelia Mihalache, 2003).

There are no studies demonstrating the impact on cardiovascular cold microclimate. A review of epidemiological studies on cardiovascular risk factors and work environment revealed that cold and heat appear to have an acute effect on cardiovascular disease, but their possible chronic effects have rarely been investigated (De Lorenzo F, Sharma V, Scully M and Kakkar V.V., 1999). One study showed that cardiovascular symptoms such as chest pain and arrhythmias occur in humans exposed to cold, approximately 4% more than the general population. Exposure to cold causes vasoconstriction, increased peripheral resistance, central blood volume and thus the heart labor. Also, the pressure in the left ventricle at end of the diastole and increased filling volumes, increase the risk of stroke (Dessoille A., J.Scherrer, R.Truhaut, 1992).

Generally speaking, the cold can cause poor performance, increased morbidity and absence from work, with negative economic effect on the employer and the other employees. People suffering from a chronic illness have an increased sensitivity to cold. Therefore, exposure to cold leads to a manifestation of underlying disease symptoms, these persons presenting a decrease in performance and health problems in the early stage comparative with healthy employees (Donaldson GC, Robinson D, Allaway SL., 1997).

Microenvironment employment is determined by temperature and humidity, air currents and the environmental caloric radiation. All microclimate factors act combined and simultaneously upon the body. Air temperature is crucial, the other parameters enhancing or decreasing the temperature effects. Unfavorable microenvironment is defined as all microclimate factors whose combined action exceeds the body's adaptive capacity, soliciting the hyper activation of the thermoregulatory system in order to maintain the body thermal homeostasis. The body becomes cold-blooded animal in central body temperature over 40.6º and below 31ºC. Conscious state are compatible with temperatures between 32-43º, but the work can be effective only between 36-39ºC. Death occurs in the body core temperature of 24-25º and over 42-43ºC. The thermoregulation determines thermoregulatory heat stress (Emmett JD, 1995).

Jobs in cool microclimate. In the working rooms microclimate is influenced by regional climate and its variations, but depends primarily on heat, heating and inside ventilation. Outdoor microclimate is primarily dependent on the season. In medicine it is important to distinguish between the three types of unfavorable microclimate: hot dry, hot or cold wet.

The main jobs are found in cold outdoors microclimate during cold season: the logging, construction, the army, marine, in fishery, agriculture, micro indoor meets cold meat cold stores , vegetables and fruits, ice factories and breweries (Greenstein D, Gupta NK, Martin P, Walker DR, Kester RC, 1995).

Thermoregulation of the body. Homeostasis of body temperature is the result of maintaining the balance between thermodispersion and thermoproduction through a series of physiological mechanisms defined as thermoregulation. Thermoproduction occurs through metabolism and exercise, based on chemical processes (thermochemical regulation). Some of the heat produced in the body is consumed for physiological needs, and part is removed by thermodispersion (thermolysis or physical thermoregulation). Thermolysis occurs 95% in skin, while 5% of heat is eliminated in the exhaled air, urine and faeces. In the skin thermolysis is achieved by cutaneous vasodilatation and sweat evaporation. Thermolysis routes are dry (radiant, convection and conduction) and wet (sweating). In thermal comfort conditions, thermolysis is carried in about the following proportions for different paths: 45% by radiation, convection and conduction 30% and 25% by evaporating perspiration. Nervous thermoregulatory centers are located in the hypothalamus (Hampel R, Breitner S, Rückerl R, Frampton MW, Koenig W, Phipps RP et al., 2010)

Adaptation to low temperature is achieved in about 3-4 weeks in healthy man, with the following modifications: prompt initiation reaction of thermoproduction which is sometimes expressed by chills, increased lability of peripheral vascular tone, vasoconstriction rapid reaction by switching to low temperature; increasing the threshold of excitability of skin and airways cold thermoreceptors, with increases body general resistance to cold (Juneau M, Larivée L, White M., 2002).

The slight decrease in temperature appears as unpleasant sensations and thermal discomfort. The discomfort can lead to distraction, reduction of tasks that require concentration and alertness and increase the risk of accidents at work. In addition, cooling tissues may lead to decreased physical and mental performance, which may also contribute to accidents and injuries (Kim JY, Jung KY, Hong YS, Kim JI, Jang TW, Kim JM., 2003). Energy consumed by the body to the same occupational tasks is increased in cold weather partly due to increased performance and wear heavy protective clothing. It is estimated that each additional kilogram of clothing increase energy costs by about 3%. Exposure to cold can be an aggravating factor or trigger symptoms in some chronic diseases. It is also known that winter is associated with increased morbidity and mortality (Kivimaki M, Leino-Arjas P., 2002). Finally, if cooling of the body is quite severe, occurs tissue damage, frostbite, hypothermia. The effects are related to the combination of several factors: cold, intense physical activity, clothing, and climate, socio-economic and individual factors. An example is the adaptation to cold individual factors that affect the body's response to cold (Kolb S, Radon K, Valois MF, Héguy L, Goldberg MS., 2007).

Occupational diseases by exposure to low temperatures

This also applies to two categories of diseases, as low temperature action may be direct or indirect. Illness through direct action, rare and accidental, is due either to request local thermoregulatory mechanisms (frostbite) or to exceed the capacity of general thermoregulation (hypothermia). They will be reported as occupational diseases. The indirect action may encourage so-called low temperature conditions "a frigore".

Frostbite defines freezing due to local action of low temperature. Etiological it might be discussed about humid low-temperature acting on unprotected extremities of the body, The ethiopathogenic mechanisms involved are: vasoconstriction, decreased blood supply and local temperature, circulatory disorders, metabolic disturbance of membrane balance and permeability gradually installed before freezing, extracellular freezing, followed by cellular and tissular dehydration and destruction. Diagnosis is easy, knowing the exposure and by clinical examination (Korhonen I., 2006).

Hypothermia (general freezing). Etiology involves low temperature with moisture, wind that favorite's evaporation. Predisposing factors are: age, trauma, fatigue, chronic diseases malnutrition states such as diabetes, mixedema, anemia, kidney or liver failure, central nervous system injuries with significant vasomotor disorders, alcoholism, lack of exercise (Van Hoof et al., 2010). The pathogenesis is complex. Exposure to cold for several hours with a heat loss in the 3-4 kcal/min, can be compensated if the thermal equilibrium is maintained. Loss of 4-5 kcal/min decreases the body temperature in successive steps, because deep regions supplies the heat towards the superficial regions to protect them from cold, thus explaining the emergence of skin hyperemia. When the body temperature diminishes to 30ºC appears a slowdown in the temperature drop, consecutively the temperature drops quickly and may occur even death. Effects of lower body temperature are functional depression of all tissues, organs and systems, metabolism decrease, confusional state, although the central nervous system is the most resistant to this decline. The heart is very sensitive at 29ºC appearing atrial fibrillation, ventricular fibrillation often followed by reflex mechanisms in the central nervous starting point, hemodynamic disorders by increasing blood viscosity and metabolic disturbances. Clinically are two distinct evolutionary phases, the first of defense and the second of purging. During the defense phase, after shivering appears muscle pains, exaggerated reflexes, polyuria, polipnee, tachycardia and increased blood pressure. At the stage of exhaustion installs bradycardia, slow breathing, shallow breathing, hypotension, adinamy, mental disorders with decreased ability to concentrate, indifference and confusion, unconsciousness and death followed by cardiac arrest (Kristensen TS., 1989).

The current literature has described three clinical forms. The mild form when the body temperature drops to 35-32ºC, appears a slowness of ideation and a compensated dysarthria. In the moderate form temperature is between 32-24ºC, the patient presenting metabolic depression, bradycardia and slow breathing, hypotension and dizziness. In the severe form the temperature falls below 24ºC, and coma is installed followed by death by ventricular fibrillation.

Treatment is based on two main principles: maintaining the body heat and warming. The patient should be placed in a sleeping bag or blanket, and covered with blankets impervious to moisture and wind. There will be applied hot water bottles and given hot drinks. It will be applied a vigorous treatment by immersion in hot water 34-35ºC, then increasing the water temperature 40-43ºC in the next 5 to 10 minutes. When body temperature returned almost to normal, the patient will remain at rest in bed, being well covered. In need it may also be administered saline infusion, glucose and vitamin C and, where appropriate, oxygen therapy, artificial respiration or cardiac massage (Kuper H and Marmot M., 2003).

Diseases "a frigore" are favored by low temperature conditions, sudden changes of temperature change from hot to cold, high humidity and air currents. Ethiopathogenetic, switching from hot to cold, when cutaneous vasodilation and sweating are massive, produce increased loss of intense heat, while the thermoregulatory centers were previously high temperature broken. By lowering the phagocytic activity and the aglutinine titer body is prone to infections. The clinical forms are varied: the respiratory system involvement may occur in rhinitis, pharyngitis, laryngitis, bronchitis, bronhopeumopaties, pneumonias; in the cardiovascular system are favored the obliterate endarteritis, coronary heart disease, hypertension; in the musculoskeletal system may occur rheumatic fever, arthritis, etc. lombosciatics, while as renal disease may occur acute diffuse glomerulonephritis, and neurological, neuritis, neuralgia (Lally EV, 1992).

Cardiac function and work in cold microclimate

According to an Emmett analysis, several studies suggest that cardiovascular responses at rest and during exercise in cold profession differ between patients with coronary artery disease and healthy subjects. For example, according to an experimental study in patients with angina pectoris and coronary insufficiency (n = 26), about half of patients presents more pronounced ECG changes in a chili room at -15ºC than in a normal temperature room (9). Another study in patients with angina pectoris (n = 9), cold (-8ºC) showed no marked decrease in work capacity. However, the ECG showed ST depression in cold temparature, which could be related to increased activity of the heart. Tests at different temperatures (20 to -30ºC) showed a significant reduction in maximum work capacity in cold (-10ºC) temperature (Lodi G, Resca D, Reverberi R. , 2010). Patients with congestive heart failure also had a decrease in sub-maximal and maximal performance in the cold. Patients with ischemic heart disease (IHD) showed a decrease in coronary blood flow. In some cases, these patients may experience a coronary spasm with chest pain and even myocardial infarction (Maroules CD, Chang AY, Kontak A, Dimitrov I, Kotys M, Peshock RM., 2010).

As a specific occupation, snow removal is known as an intense physical activity and could be a contributing factor in cardiovascular events during winter.

An experimental study (n = 9) assessed the energy cost of the snow removal process and stated that manual snow removal, under conditions of heavy snow proved to be a strenuous physical work and is not suitable for people with heart disease and risk factors. In addition, a study in patients (n = 10) with ischemic heart disease (IHD), which raised gravel in different environmental conditions (-8 to 29ºC) demonstrated that low-risk patients with stable CAD were hemodynamic changes induced by temperature and VO2 modest responses to a static-dynamic labor intensity moderate for 30 min without EKG or suggestive symptoms responses (Meade TW, Ruddock V, Stirling Y, Chakrabarti R, Miller GJ., 1997).

Hypertension and occupational exposure to cold

According to experimental studies regarding exposure to cold, increased systolic and diastolic blood pressure in healthy subjects is 7-26 mmHg. The increase in cold blood depends on several factors, such as intensity and type of cooling (whole body, local, water, air) and individual factors. Type of cooling is important for cardiovascular responses. A sudden local exposure, at severe cold (local immersion in cold water) is more stressful than an average form of whole-body exposure at long-term cold (Mercer JB. 2003). Increased blood pressure is one of the most important risk factors for cardiovascular events. The risk for hypertension may be increased by long term exposure to cold, such as unsuitable living conditions as cold housing. On the other hand, low temperatures can exacerbate high blood pressure in hypertensive patients. For example, hypertensive patients showed a slightly increased blood pressure during the cold season, an effect that increases with age. Repeated exposure to cold at work may increase the risk of hypertension. A study by Kim et al. (Kim JY et al., 2003) showed that men who work around one third (about 3 h/day) of the total work time in the inner cold (-20 -50ºC), develop asymptomatic hypertensive episodes at work compared with employees working in a hot environment. A study in Poland (n = 102) among workers exposed to cold temperatures from -26 to 20ºC in deposits measured the physiological responses (cold pressure test, blood pressure monitoring). It was found that systolic and diastolic blood pressure during the day and at night were significantly higher in those working in cold (0-10ºC) compared with those who work in an environment less cold (10-14ºC) with an increased response in women.

Experimental studies assessing the effects of antihypertensive drugs on blood pressure responses to cold have shown that. although these drugs did not affect the magnitude of BP increase, induced by cold, low BP kept cold peaks closer to the recommended threshold limit values (Näyhä S., 2005).

Peripheral circulation and occupational exposure to cold

Raynaud's phenomenon (FR) is a common clinical disorder manifested by recurrent vasospasm in fingers and toes, often associated with exposure to cold temperature or emotional stress. Aggravated vasoconstriction in response to cooling, may lead to decreased job performance in people with Raynaud's phenomenon. Patients with primary Raynaud's phenomenon presents a modified cold vasodilatation and a delayed recovery of blood flow after cooling (Lally EV., 1992). An experimental study with healthy individuals and patients with Raynaud phenomenon showed that cold exposure decreased sensory perception and manual performance in subjects with Raynaud's phenomenon. In addition, an experimental study in which women worked in a cold environment showed that subjects with FR had lower blood flow in all the stages of the test, the response was prolonged and digital reheating basal temperature lower than in the control group. This indicates a failure of thermoregulation in patients with RF (Nia AM, Fuhr U, Gassanov N, Erdmann E, Er F., 2010).

Exposure to vibration of the hand can cause a variety of disorders collectively named as hand-arm vibration syndrome (VHA). The neurovascular component is represented by white finger (VWF), which appears to users of vibrating tools or machinery such as chain saws, pneumatic hammers or snow. It is characterized by episodes of finger blanching attacks, often triggered by exposure to cold. Thermal sensitivity to cold may also be affected, shown at young workers exposed to hand-arm vibration early in their careers (Nilsson T, Burström L, Hagberg M, Lundström R., 2008). Workers who suffer from these symptoms may experience many difficulties while working in cold environments. For example, in a Swedish study, the examination staff stated workers (nâ140) with HAV symptoms and than workers without these symptoms. An occupational group that is frequently exposed to cold and are forestry workers using vibrating tools. A study (n=128) investigated the occurrence of VWF phenomenon and digital arteries cold response in a group of forest workers using anti-vibratory tools. It has been shown that VWF phenomenon is still common among workers despite the anti-vibration tools, but the end of exposure to vibration was associated in retired workers with a benefic effect on digital arteries cold response (Pasterkamp G, de Kleijn D., 2010).

To manage the adverse cardiovascular effects of cold at work are suggested some ways to reduce or prevent them. For healthy persons and early exposure to cold is recommended gradually initial physical exercise. This is because both cold exposure and increased blood pressure by exercise may have an additive effect. For patients it is important to identify the cardiovascular response to cold. For patients with primary FR is recommended that they avoid the cold in the workplace and to protect the hands well.

Coronary heart disease and occupational exposure to cold

Numerous studies have reported an increase in acute coronary heart disease mortality in winter. The increase in CVD mortality was related to thrombosis secondary to hemoconcentration. It also significantly the increase of the blood pressure, hemoglobin (Hb), red blood cell counts, serum albumin, changes that may persist for 1-2 days (Revich BA, Shaposhnikov DA., 2010). A longitudinal cohort study showed significant differences in winter-summer in plasmatic fibrinogen and coagulation factor VII activity (FVIIc), independent risk factors for coronary heart disease and non-fatal fatal. Several mechanisms have been suggested that the increase of plasmatic fibrinogen produces vascular disease, including early involvement in the formation of atherosclerotic plaque, endothelial response, platelet aggregation and increased plasma viscosity. Increased FVIIc may indicate the presence of a hypercoagulable status, with increased thrombin and a greater chance of occlusive thrombus formation in response to the splitting of athermatous plaques. Other authors have demonstrated seasonal changes in LDL cholesterol, with peak levels during winter with an increase in total cholesterol by 5%. Increased fibrinogen, neutrophilia and C reactive protein may be secondary to infection. Hemoconcentration is induced by peripheral vasoconstriction, increased peripheral vascular resistance, changes in Starling forces and the passage of intravascular fluid in the interstitial space.

Increased myocardial load (vasoconstriction, increased blood pressure), and the need to continue the supply of oxygen by increasing the volume ejected, tachycardia and coronary vasoconstriction to cold stress can increase further infarction in patients with ischemic heart disease (Sestito A, Lanza GA, Di Monaco A, Lamendola P, Careri G, Tarzia P et al., 2010).

Plasmatic noradrenaline and adrenaline increases after exposure to cold air, cold stimulation of skin receptors, leading to vasoconstriction in the skin, increased heart rate, systolic blood pressure and central blood volume increase. This leads to an increased cardiac filling pressure, left ventricular end diastolic pressure. This chain of events may precipitate a variety of functional abnormalities clinically relevant in patients with ischemic heart disease. It has been observed an increase in the circulating atrial natriuretic peptide (ANP) (Stellman J.M., 2002).

Prevention. Among the technical and organizational measures we may include: sealing of the openings to the outside (doors, windows), installation of curtains or hot air sealants in front doors, the introduction of adequate heating systems, avoid prolonged standing, exercise recommendation, establishing measures of labor protection, accident prevention, breaks in fixed and mobile spaces, air-conditioned or heated, facilities for drying clothes, protection through clothing insulation and waterproof materials with several layers, and enough sub clothing space; balanced diet in order to cover energy needs. At workplaces with low temperatures (below 5ºC) will be provided hot tea (0.5-1 l/person/shift).

Employment medical examination and periodical medical examination will be made taking into account NGPM/2002 (artificially low temperatures below 10ºC). Professional activities are classified according to energetic metabolism. Minimum thermal limits allowed in the workplace are provided in *Table 1*.

Table 1 Minimum thermal limits allowed in the workplace

The metabolism class (M) (W)	**Temperature in globe thermometer**	**Air velocity (m/s)**
M<117	18	<0,2
117<M<234	16	<0,3
234<M<360	15	<0,4
M>360	12	<0,5

In some workplaces (offices, control rooms, rooms with display screen, socio-cultural spaces, etc.) where professional activity requires thermal comfort must be provided conditions outlined below. In the winter: operative temperature between 20-24ºC difference of vertical air temperature values at 1.1 m and 0.1 m above the ground, relative humidity and velocity of air currents as in summer;

differences of less than 10ºC between the temperature of the radiation window or other vertical surface radiation temperature of objects in the room. Operational temperature is calculated using the formula: to = Ataplus (1-AX, your air is dry temperature (ºC), = is the average radiation temperature (ºC), and A is a coefficient whose values are in relation to the speed air currents, ie 0.5 when the speed is less than 0.2 m/s, 0.6 if the speed is between 0.2 to 0.6 m/s, if speed is between 0.7 and 0.7 -1 m/s. When the speed is less than 0.2 m /s or if the average temperature difference between radiation and air temperature is below 4ºC operational temperature can be calculated as the average air temperature values and average temperature of radiation (Stellman J.M., 2002).

Strategy cold work is presented in ISO15743. This International Standard outlines a strategy and practical tools for assessing and managing risks at work cool microclimate and includes models and methods for risk exposure to cold, assessment and management, a checklist for identifying cold-related problems at work, a model, method and questionnaire for the use of occupational medicine specialist in order to identify persons with symptoms suggestive of sensitivity to cold. With such methods of identification it might be provided guidance and optimum instructions for personal protection in cold, guidance on the application of thermal standards and other validated scientific methods assessing cold related risks (ISO15743, 2008).

Conclusions

Cold is a significant risk factor in industrial activity, present in outdoor and indoor. Working outdoors offers a seasonal exposure to cold, affecting many countries at northern latitudes. Microclimate indoor cold often includes the same climatic conditions throughout the year, all over the world. Cold compromises the quality of work. Cooling the tissues leads to discomfort, deterioration of performance and finally to work accidents (Tiina M. Makinen, Juhani Hassi, 2009).

Exposure to cold contributes to increased morbidity and mortality. It is well known that deaths from acute myocardial infarction and coronary heart disease occur more frequently during winter. In addition, mortality from congestive heart failure also increases linearly with low temperatures (Töro K, Bartholy J, Pongrácz R, Kis Z, Keller E, Dunay G., 2010).

In general, the cold can cause poor performance, increased morbidity and absence from work. It might be increased the awareness of the effects of cold on human performance and health assessment of potential occupational hazards related to cold at work and to identify individual risks for health.

Cardiovascular disease can be reduced by good management program of risk factors at work, the role of physician decision-making algorithm work as prevention of cardiovascular diseases. This requires multidisciplinary teamwork: occupational physician - ergonomics - cardiologist - neurologist and psychologist.

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