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Health Problems in Cold Work

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Abstract: Cold in- and outdoor work can result in different adverse effects on human health. Health problems decrease performance and work productivity and increase the occurrence of accidents and injuries. Serious health problems can also result in absence from work due to sick leave or hospitalization. At its worst, work in cold conditions could be associated with deaths due to cold-related accidents or a sudden health event. Musculoskeletal complaints, like pain, aches etc. are common in indoor cold work. Breathing cold air while working may lead to respiratory symptoms, which can decrease performance in cold. The symptoms are usually worsened by exercise and ageing, being more common in persons having a respiratory disease. Cardiovascular complaints and related performance decrements could be especially pronounced during work in cold weather and involving physical exercise, especially among those with an underlying cardiovascular disease. The article also reviews the current information related to diabetes, skin disorders and diseases, as well as cold injuries and accidents occurring in cold work. Increasing awareness and identifying workplace- and individual-related cold risks is the first step in proper cold risk management. Following this, the susceptible population groups need customized advice on proper prevention and protection in cold work.

Key words: Cold, Occupational, Musculoskeletal, Respiratory, Cardiovascular, Diabetes, Skin, Injuries

Introduction

Cold exposure

The type of cold exposure encountered at work may come from exposure to cold air, immersion in water, or through touching cold surfaces. Accordingly, cooling may target different areas of the body¹⁾. Prolonged exposure to cold, often associated with insufficient clothing or physical activity, may result in whole-body cooling and a decrease in core temperature. This type of cooling is further aggravated by exposure to wind or cold water, which increases especially the convective heat loss to the environment. Cooling can also be restricted to the extremities (head, hands and feet) and is often enhanced by touching or handling cold objects. This type of cooling is especially common in occupational activities and involves a significant risk of cold injury. Cooling may also be targeted at specific body regions, like the respiratory tract. Respiratory tract cooling can be especially pronounced during heavy exercise in cold weather^{1, 2)}.

The available standards, norms and guidelines for cold

work define cold as conditions that cause uncomfortable sensations of cool or cold. In light physical work this may happen at +10°C or below³⁾. Other international standards have defined cold work as work in temperatures at or below +10 to +15°C^{4, 5)}. Several out- and indoor lines of industry, commerce and occupations involve marked exposure to cold. Cold indoor work mainly includes work in the food industry. Fresh foodstuffs are often processed at temperatures of 0 to +10°C, and frozen goods at temperatures below –20°C. In these conditions workers are subjected to cold exposure for several hours per day. Outdoor cold exposure can be substantial in industries such as agriculture, forestry, mining, factory work, construction work and related occupations⁶⁾. Another occupational group frequently exposed to cold is military personnel where adverse performance effects and cold injuries may be common^{7, 8)}. Although no scientific information is available, it can be assumed that persons employed in communal maintenance work are also exposed to cold to a significant degree.

The effects of cold

At its mildest, cooling causes unpleasant sensations and

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thermal discomfort. Discomfort may be a distraction factor reducing the performance of tasks requiring concentration and vigilance, and may increase the risk of occupational accidents and injuries. Furthermore, cooling of the tissues can result in decreased physical and mental performance, which may also contribute to the risk of accidents and injuries⁹). The energy cost of exercise is also increased in cold. This is partially due to lowered performance caused by cooling, but also to the increased energy costs of heavy cold protective clothing. It is estimated that each additional kg in clothing weight increases energy costs by approximately 3% and each additional layer by 4%¹⁰). Cold exposure may also be a triggering factor for certain diseases and aggravate the symptoms of prevailing chronic diseases. It is also well known that the coldest season is associated with increased morbidity and mortality^{11, 12}). Finally, if the cooling of the body is severe enough, cold injuries, such as frostbites and hypothermia, occur^{8, 9}). The effects of cold are related to several factors, like physical activity, clothing, climate, socioeconomic and individual factors (Fig. 1.) An example of individual factors is cold adaptation¹³) which affect the thermal responses and related cold responses.

In general, cooling may result in performance decrements, increased morbidity and cold-associated injuries and cause absence from work due to sick leave or hospitalization. In the worst case, death may occur, for example from cold-associated injuries (e.g. accidents

associated with cooling and performance degradation). Persons suffering from a chronic disease, however, have an increased sensitivity for cold. Therefore, occupational exposure to cold increases the manifestation of the symptoms of the underlying disease. Hence, these persons may experience performance decrements and health problems at an earlier stage than healthy employees. The above-mentioned adverse health outcomes involve an increased cost to the employer in terms of lowered productivity and increased health care costs.

This article reviews recent results concerning health problems in cold work. The major health effects related to cold are presented in Fig. 2. An illness is defined as a state where physical, mental and social well-being is not complete, and it is often a subjective estimate. A disease, on the other hand, as discussed in the present article, is limited to a doctor-diagnosed condition. Symptoms and complaints are manifestations of an illness or disease.

Effects of Cold on Respiratory Disorders and Diseases

Breathing cold and dry air causes physiological changes in the upper and lower respiratory tract. The acute and long-term effects of cold exposure on respiratory function have been reviewed by Koskela¹⁴). Furthermore, Latvala *et al.*¹⁵) describe the effects of cold in the upper respiratory tract. It is widely known that winter is associated

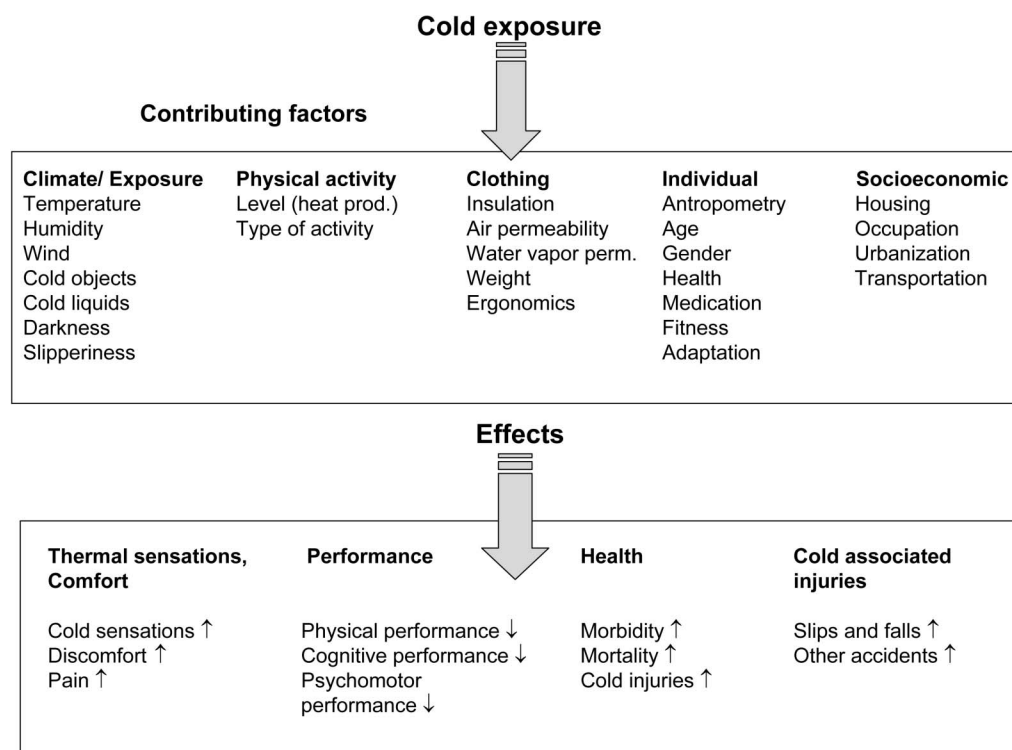


Fig. 1. The effects of cold (adopted from Mäkinen *et al.* Am J Hum Biol (2007) 19, 155–64).

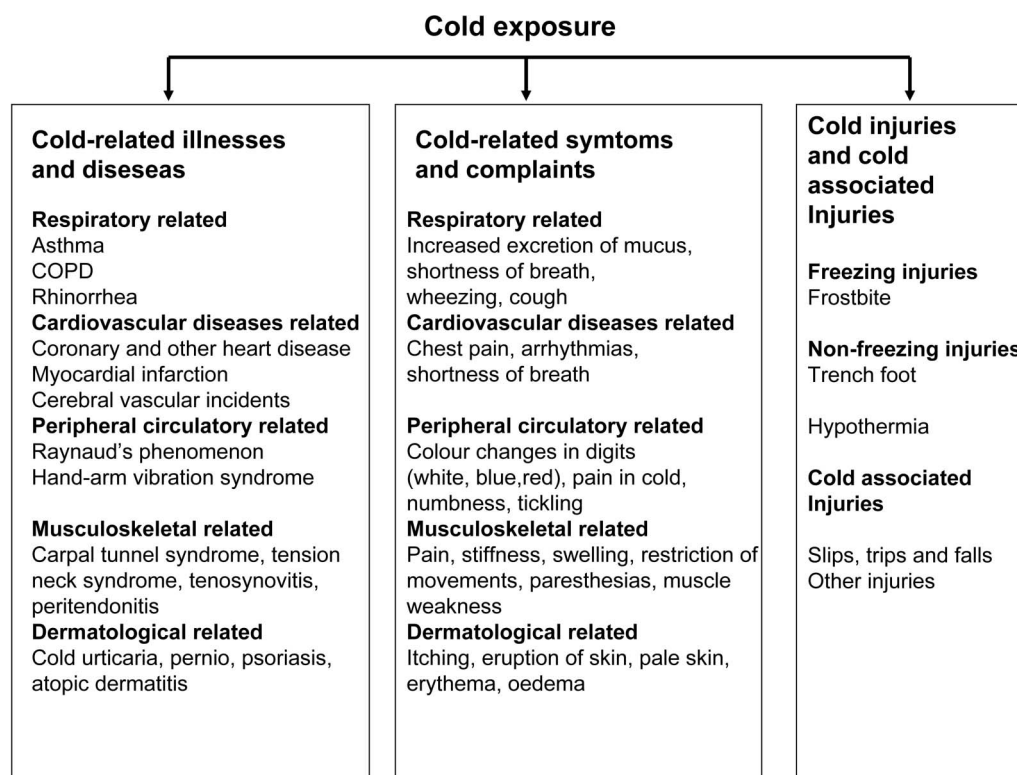


Fig. 2. The effects of occupational exposure to cold on human health.

with increased respiratory morbidity and mortality¹²). For example, a case-only epidemiologic study analysing 160,000 deaths occurring in Michigan showed that persons with chronic obstructive pulmonary disease (COPD) are at higher risk to die during cold days¹⁶). In addition, a large (n=81,243) hospital discharge register study evaluated seasonality of respiratory diseases and showed that both morbidity and mortality of asthma was highest in the winter months, with cold exposure being a potential contributing factor¹⁷). In the general population living in the north the prevalence of respiratory symptoms is high in winter, ranging between 25–29%¹⁸). These are shortness of breath, wheezing of breath, prolonged cough, or bouts of cough, or increased sputum production (Fig. 2). It seems that the prevalence of respiratory symptoms is even higher in asthmatics (prevalence 69% in males, 78% in females) and patients with chronic bronchitis (65%/76%) than in healthy persons (18%/21%)¹⁹). The occurrence of respiratory symptoms increases with age and they are more common in females. Furthermore, respiratory problems are generally more common during exercise involving increased ventilation of cold and dry air¹⁴).

Respiratory symptoms and pulmonary obstruction triggered by cold exposure may lead to a decrease in working capacity in the cold. Especially in subjects with an obstructive respiratory disease (asthma, COPD), symptoms are worsened in the cold and may lead to a decline

in working capacity. For example, Koskela *et al.*²⁰) demonstrated that cold air (−20°C) decreases exercise performance in COPD, probably due to increased exercise dyspnoea. The reports on respiratory health in cold working conditions are few.

Living and working in a cold climate

Population-based studies have indicated that living and working in a northern environment results in an increased number of respiratory complaints. A large epidemiological study (over 12,000 participants) conducted in a northern climate revealed that respiratory symptoms (wheezing of breath, tightness of breath, cough, sputum) were more prevalent in the north, and the highest prevalence of COPD and its symptoms were detected among outdoor workers, and especially among smokers²¹). Another epidemiological questionnaire study (n=7,937) examined respiratory symptoms and obstructive pulmonary diseases experienced during exercise and found that the risk for shortness of breath and chronic bronchitis during exercise in cold weather was higher for out- than indoor workers²²).

The studies mentioned above suggest that living and working in a cold climate may be associated with adverse respiratory effects. There are only a limited amount of studies to confirm this finding. A study conducted among the Inuit of Arctic Canada assessing respiratory function

showed that respiratory function was good among young men, while it decreased among hunters and trappers of older age. The study suggested that inhalation of extremely cold air at maximum ventilation may be a prime factor in the chronic obstructive lung disease seen in Inuit hunters²³).

Respiratory function in specific occupational groups

There are relatively few reports addressing cold working conditions and respiratory health and they are limited to specific occupational groups. Regular exercise in cold weather is believed to be a predisposing factor for exercise-induced bronchospasms (EIB). Therefore, as a specific occupational group, elite winter athletes are at higher risk for these respiratory limitations²⁴. It is proposed that the pathogenesis of EIB in elite athletes relates to the epithelial injury arising from breathing poorly conditioned air at high flows²⁵. A study conducted in Scandinavia found differences in bronchial hyperresponsiveness (BHR) between elite skiers from Sweden and Norway, and speculated that the higher prevalence of BHR in Sweden could be due to the colder climate²⁶. Furthermore, Pohjantähti *et al.*²⁷ compared healthy elite skiers (n=20) and non-athletic students (n=18) and found that exercise-induced asthma was more prevalent in elite skiers. It seems that repeated chronic hyperventilation of cold dry air in cross-country skiers for several years can induce permanent bronchial disorders and induce ventilatory limitations during intense exercise²⁸.

Reindeer herders are an occupational group that is significantly exposed to cold at work. A small-scale clinical study (n=211) evaluating the respiratory function of reindeer herders did not detect any significant differences in respiratory symptoms, smoking habits or ventilatory function between full-time reindeer herders and their controls²⁹. In the study 14% experienced dyspnoea when inhaling cold air, and this was more common among ex-smokers than others²⁹.

The available information concerning respiratory function in cold indoor work is very limited. Jammes *et al.*³⁰ evaluated the effects of work in cold stores (n=11) on respiratory function after one year of continuous work in the cold (temp. +3 to +10°C), and concluded that a cold occupational environment elicits a modest but significant air-flow limitation, accompanied by bronchial hyperresponsiveness, with the effects beginning within six months of exposure³⁰. Hence, these results are in line with the population studies and results from some occupational groups indicating that repeated exposure to cold may result in alterations in respiratory function.

In order to take into account the adverse effects of cold exposure on respiratory health it is recommended that work activity is planned so as to avoid or minimize very

high physical activity levels. In some cases, especially for persons who have a respiratory disease, protection from facial cooling may diminish or prevent reflex bronchoconstriction and the related breathing difficulties¹⁴. Under conditions where cold-induced respiratory symptoms emerge, heat exchanger masks might also be useful. In the case of patients with a chronic obstructive condition (e.g. asthma, COPD) it is important to adjust their medication to optimal levels, taking into account the effects of cold exposure on respiratory function.

Musculoskeletal Disorders and Diseases in Cold

The effects of cold exposure on neuromuscular functions have been reviewed by Oksa³¹. At the population level, musculoskeletal symptoms, such as musculoskeletal pain, were the most common complaints (27–30%) reported to occur during winter (air temperature defined at 10°C or below)¹⁸.

Work-related musculoskeletal disorders are defined as involving the nerves, tendons, muscles and supporting structures and represent a wide range of disorders differing in severity. Examples of musculoskeletal disorders are carpal tunnel syndrome, tension neck syndrome, tenosynovitis and peritendinitis. The associated complaints include pain in the shoulders, neck, knees and lower back, swelling, movement restrictions, muscle weakness and paresthesia (Fig. 2). Most of the reports concerning musculoskeletal symptoms and complaints at work are derived from cold indoor work^{32, 33}.

Although scientific evidence suggests that there is an association between cold exposure and musculoskeletal complaints, there are methodological limitations in many of the epidemiological studies that do not allow forming a causal relationship. A review of these studies has been compiled by Piedrahita³² and Pienimäki³³.

Cold indoor work

Cold indoor work is characterized by adjusted and constant low temperatures and sometimes damp/wet/moist conditions and local draughts. Furthermore, work in the food industry often mainly involves light physical activity and repetitive movements. In these conditions, some of the musculoskeletal complaints may be due to the combined effects of cold exposure and the repetitive work on muscle performance, which results in increased muscle strain and fatigue³⁴.

There are several reports describing the association between musculoskeletal symptoms and cold in the food industry. For example, moderate cold exposure, experienced by workers (n=1,213) in the food industry in Germany showed increased frequencies of musculoskeletal complaints, and prevalence ratios of 1.3, 1.47 and 1.8

for pain in the neck or shoulder, and pain in the back and lumbago, respectively³⁵). A study on female workers (n=225) in a meat processing factory showed an increased prevalence of tenosynovitis and peritendinitis in sausage packers (working at +8 to +10°C) compared with sausage-makers (working at +20°C)³⁶.

It seems that individual risk factors are related to the prevalence of musculoskeletal complaints. For example, a questionnaire study (n=1,117) assessing the prevalence of musculoskeletal symptoms in food-processing facilities (most of the respondents exposed to +1 to +10°C) indicated that ageing and female gender was associated with increased amounts of musculoskeletal symptoms. In addition, factors related to the workplace (draught, cooling and prolonged exposure to cold) were thought to increase musculoskeletal symptoms³⁷). In addition, Aasmoe *et al.*³⁸) found that the odds ratio for symptoms from the upper limbs was significantly higher for females compared to men in the fish industry.

The intensity of cold exposure seems to be at least partially related to musculoskeletal symptoms and complaints. A cross-sectional epidemiologic study of meat processing workers (n=162) showed that the reporting of neck, shoulder and low back pain symptoms increased in workers who were more severely exposed to cold (+2°C) compared to less exposed (+8 to +12°C) workers³⁹). Also, a sensation of cold, which is often related to adverse local or whole-body cooling, is associated with musculoskeletal complaints. For example, industrial workers (n=1,767) in the seafood industry (measured air temp +2 to +18°C), who reported that they often felt cold, had a significantly increased prevalence of symptoms from muscles, skin, and airways, compared to those who never felt cold at work⁴⁰). Musculoskeletal symptoms were found among the majority of production workers in the whitefish, shrimp and salmon industry, and cold work was an important risk factor for these symptoms³⁸).

A part of the musculoskeletal complaints in cold indoor work may be due to the combined effects of cold exposure and repetitive work. A recent case-control study examining occupational risk factors (n=127 cases, n=102 controls) for carpal tunnel syndrome found that both work with repeated movements of the wrist (OR=2.15, 95% CI=1.14–4.07) and work in a cold environment (OR=3.52, 95% CI=1.08–11.47) increased the risk for carpal tunnel syndrome. However, “cold” was not more precisely defined in the article⁴¹). Furthermore, Chiang *et al.*⁴²) found in a study examining workers (n=207) in frozen food plants that the combination of repetitive work and cold resulted in an increased occurrence of carpal tunnel syndrome (9.4 fold risk) compared to repetitive work without cold exposure (2.2 fold risk).

Musculoskeletal problems also occur frequently in

work performed in cold storerooms. Employees (n=64) working in cold storerooms at –20°C had increased odds of reporting back symptoms during work (OR = 4.8, 95% CI = 1.8–13.0) compared with their colleagues (n=58) working at regular temperatures⁴³). A cross-sectional questionnaire study conducted among female workers (n=160) in a consumer cooperative (temp +5 to –21°C) showed that ca. 70–80% of workers (n=46) who classified cold storage food complained of cold sensation in different body regions, as well as shoulder stiffness and back-related problems. Supermarket checkers and office workers who were working in a warmer environment had a high prevalence of cold sensation in their feet during their work⁴⁴). A cross-sectional study in supermarket cashiers (n=210) also revealed that exposure to cold was a risk factor for shoulder disorders⁴⁵). A small-scale questionnaire study (n=24) conducted among workers employed in extremely cold conditions (–43 to –62°C, exposure ca 60 min/occasion) in a freeze-dried coffee company demonstrated a high prevalence of reported cold-related symptoms (circulatory disturbances, respiratory and musculoskeletal symptoms). In this study repeated musculoskeletal pain was experienced by 12%⁴⁶).

Cold outdoor work

Reports on musculoskeletal symptoms from cold outdoor work are fewer than from indoor work.

An epidemiological questionnaire study of workers (n=2,030) from 24 different occupations queried concluded that climatic factors were related to low-back and neck-shoulder symptoms and sick leave due to neck-shoulder symptoms⁴⁷). Draughts were in particular related to neck-shoulder symptoms, which were also inversely related to frequent outdoor work. Approximately 25% considered that their musculoskeletal symptoms were related to climatic factors⁴⁷). A case-controlled questionnaire study in the UK (n=217) indicated that men working frequently in very cold or damp conditions had a four- and six-fold risk of shoulder pain and disability compared with those not working under such environmental conditions⁴⁸). A critical review was conducted of studies of work-related low back pain in the People's Republic of China. This study revealed higher prevalence for low-back pain for low-temperature exposure⁴⁹).

Musculoskeletal complaints are also common in occupations involving frequent snowmobile driving. A postal questionnaire on reindeer herders (n=1,793) revealed that 38% reported symptoms in upper limbs, 34% in knees and 42% in the back, all of which were considered by the respondents to be related to snowmobile use⁵⁰).

In summary, musculoskeletal problems seem to be associated with cold work. Longitudinal studies and studies involving cold outdoor work are needed to confirm

causality. For reducing or preventing cold-related musculoskeletal problems, a special emphasis on cold risk management, and especially organizational measures would be useful. This includes e.g. planning of appropriate work-rest regimes. For example, a recent experimental study simulating the work conducted in the food industry showed that muscular performance can be partially restored by intermittently breaking the monotonous work cycle⁵¹. Other options might include applying local and auxiliary heaters, reducing drafts and paying attention to proper cold protection. Individuals with a musculoskeletal disease need special advice on proper cold protection.

Cardiovascular Disorders and Diseases in Cold

Cold exposure contributes to increased cardiovascular morbidity and mortality^{11, 12}. It is well known that deaths from myocardial infarction and coronary heart disease occur more frequently during winter¹². In addition, mortality from congestive heart failure also increases linearly with cold temperatures, with a lag of 2 d after a cold spell⁵². The potential explanatory factors have been reviewed by Vuori⁵³. A population study has shown that cardiovascular symptoms, such as arrhythmias and chest pain are experienced in the cold by ca. 4% of the general population¹⁸.

Cardiac function during exercise in cold

The cardiac load is higher in the cold due to cooling-induced vasoconstriction, which increases the peripheral resistance and central blood volume. Furthermore, cardiac filling pressure, left ventricular end-diastolic pressure and volume, and stroke volume are increased⁵³. Cold exposure is strenuous for the heart and the increased workload may be further aggravated by exercise in cold.

Work in the cold can be even more strenuous for patients suffering from a cardiovascular disease than for healthy persons. According to a review by Emmett⁵⁴ several studies suggest that cardiovascular responses at rest and during exercise in the cold differ between patients with coronary arterial disease and healthy subjects. For example, according to an experimental study in patients with angina pectoris and coronary insufficiency (n=26), approximately half of the patients had more pronounced ECG changes in a cold room at -15°C than at room temperature⁵⁵. They worked less, their subjective rating of exertion during exercise was higher and the heart performed less work, expressed as the heart rate blood pressure product⁵⁵. Another study conducted with exercising angina pectoris patients (n=9) in cold (-8°C) did not show marked decreases in work capacity. However, the ECG showed a ST depression in the cold, which could

be related to augmented heart work in these patients⁵⁶. In addition, patients (n=11) with effort angina and a history of cold intolerance performing short-term bicycle exercise tests at various room temperatures (+20 to -30°C) showed a significantly reduced maximal working capability in the cold (-10°C)⁵⁷. Patients with congestive heart failure also showed decreased submaximal⁵⁸ and maximal⁵⁹ performance in the cold. Patients with ischemic heart disease (IHD) show a decrease in coronary blood flow. In some cases, these patients may exhibit a coronary spasm with chest pain and even myocardial infarction⁶⁰.

Cardiac function in cold work

To our knowledge, there are no studies which examine cardiovascular problems with a special emphasis on cold work. A review of the epidemiological studies concerning cardiovascular risk factors and the work environment indicated that "Heat and cold appear to have an acute effect on the incidence of cardiovascular diseases, but the possible chronic effect has seldom been investigated"⁶¹. As a specific occupational activity, clearing of snow is known to be physically strenuous, and could be a contributing factor for cardiovascular events in winter. Heavy snow shovelling elicits myocardial and aerobic demands corresponding to maximal treadmill and arm-ergometer testing in sedentary men⁶². An experimental study (n=9) assessed the energy expenses of snow clearing and showed that manual clearing of snow in conditions representing heavy snowfalls was found to be strenuous physical work, not suitable for persons with cardiac risk factors⁶³. Furthermore, a study conducted in patients (n=10) with ischaemic heart disease (IHD), who shovelled gravel in different environmental conditions (-8 to 29°C) demonstrated that low-risk patients with stable IHD showed modest temperature-induced alterations in haemodynamic and VO₂ responses during 30 min of moderate intensity static-dynamic work without adverse electrocardiographic responses or symptomatology⁶⁴.

Hypertension and cold work

According to experimental studies cold exposure increases systolic and diastolic blood pressure in healthy subjects by 7–26 mmHg^{54, 65–67}. The increase in blood pressure in the cold is dependent on several factors, such as the intensity and type of cooling (whole body, local, water, air), as well as individual factors. The type of cooling on cardiovascular responses is important, and a sudden local exposure to severe cold (e.g. local cold water immersion) is more stressful than a long-lasting, milder whole-body exposure to cold⁶⁵. Elevated 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, and for example poor housing condition⁶⁸). On the other hand, cold temperatures exacerbate hypertension in hypertensive patients^{69, 70}). For example, mildly hypertensive patients demonstrated an increased blood pressure during the cold season, an effect that was increased by age⁷¹).

Repeated exposure to cold at work can also increase the risk for hypertension. A study by Kim *et al.*⁷²) demonstrated that men who work for about one third (ca. 3 h/d) of their total working time in severe cold indoor (−20 to −50°C) work have more unrecognized hypertension and higher blood pressures compared to employees working in a warm environment. A study conducted in Poland (n=102) among cold storage workers exposed to temperatures from −26 to +20°C measured physiological responses (e.g. cold pressor test, blood pressure monitoring). Not surprisingly, systolic and diastolic blood pressure (BP) in the daytime and at night was significantly higher in those working at colder (0–10°C) compared to work in a less cold environment (10–14°C), and with a higher blood pressure response in women⁷³).

Experimental studies assessing the effects of antihypertensive drugs on blood pressure responses in the cold showed that, although these drugs did not affect the magnitude of the cold-induced rise in BP, the drug-induced decrease in the level of BP kept the peak values in the cold closer to the recommended threshold limit values^{66, 67}). This could be an important finding, especially among hypertensive patients working in the cold.

Peripheral circulation and cold work

Raynaud's phenomenon (RP) is a common clinical disorder manifested by recurrent vasospasm of the fingers and toes, often associated with exposure to cold temperature or emotional stress⁷⁴). The aggravated vasoconstriction in response to cooling can result in decreased performance in persons with RP. Patients with primary RP show an altered cold-induced vasodilatation⁷⁵) and a delayed recovery of blood flow after cooling⁷⁶). An experimental study with healthy persons and patients with RP showed that cold exposure decreased sensory perception and manual performance in the subjects with RP to a lower level than in the healthy subjects⁷⁷). Furthermore, an experimental study where women were cooled showed that subjects with RP had lower blood flow at all stages of the test, their digital rewarming response was prolonged, and core temperatures lower compared with controls. This indicates an impaired thermoregulation in RP patients⁷⁸).

Exposure to hand-transmitted vibration may cause a variety of disorders collectively known as the Hand-arm vibration syndrome (HAV). Its neurovascular component is vibration-induced white finger (VWF), which is a sec-

ondary form of Raynaud's phenomenon occurring in professional users of vibratory tools or machines, such as chains saws, pneumatic hammers or snowmobiles. It is characterized by episodes of finger blanching attacks often triggered by exposure to cold. Thermal sensitivity to cold may also be impaired, which was shown already in young employees exposed to hand-arm vibration early in their careers⁷⁹). Workers suffering from HAV symptoms may experience more difficulties while working in cold environments. For example, a Swedish study examining employees with and without HAV symptoms (n=108) from a heavy manufacturing plant, showed that workers with HAV symptoms experienced more difficulties with their daily activities, especially while working outdoors in cold weather, than workers without these symptoms⁸⁰). An occupational group that is frequently exposed to cold and uses vibratory tools is forest workers. A follow-up study (n=128) investigated the occurrence of VWF and the cold response of digital arteries in a group of forestry workers using antivibratory tools. The study showed that VWF is still prevalent among forest workers despite anti-vibration tools, but the cessation of vibration exposure in the retired workers was associated with a beneficial effect on the cold response of digital arteries⁸¹). Another study examining the effects of cessation of the use of pneumatic tools in shipyard metal workers (n=204) showed that the recovery of skin temperature after a cold challenge in subjects with VWF remained reduced in the symptomatic subjects several years after exposure removal⁸²).

One occupational group suffering from VWF is reindeer herders, who are frequently exposed to cold and vibration while using their snowmobiles for herding. A questionnaire to 334 snowmobile users demonstrated that 18% had experienced white finger attacks and 43% numbness of the hands⁸³).

For managing the adverse cardiovascular effects of cold work, some possibilities to reduce or prevent these are suggested. For healthy persons and at the beginning of the cold exposure, it is recommended that physical exercise is initiated gradually. This is due to the fact that both cold exposure and physical exercise increase blood pressure, and the effect can be at least to some extent additive. Hence, it is advisable to avoid sudden, intensive physical exercise. For cardiovascular patients, it is important to identify who is a "high responder" with regard to cold, and target the cold risk management methods accordingly. As coronary deaths peak during the winter, especially employees having a coronary heart disease should receive advice on how to prevent cold-related adverse effects.

For patients with primary RP it is recommended that they should avoid cooling at work, if possible.

Concerning the treatment of RP several pharmacological treatments have been reported, but there is still no cure or golden standard for the optimal outcome⁸⁴). It is especially important for RP and HAV patients to protect their extremities well. One of the key factors is appropriate organizational planning taking into account these special needs. Customized information and guidance should also be given.

Cold and Diabetes

Diabetes is associated with metabolic disturbances, which may affect thermoregulation and increase the risk of cooling. The disease is also commonly associated with peripheral neuro- and vasculopathies, which alter the ability to regulate heat loss in the extremities. For instance, the vasoconstriction response towards local cooling is impaired in diabetics compared with healthy subjects⁸⁵). Furthermore, an experimental study indicated that blood flow in the extremities is lowered during and after cold exposure in Type 1 diabetics with neuropathies compared with diabetics with normal vascular tone⁸⁶). Also, Mitchell *et al.*⁸⁷) detected lower capillary blood flow in insulin-dependent diabetics before and during a cold challenge. It should be noted that comorbidity is often associated with diabetes, and many diabetics have a cardiovascular disease at the same time.

Research information concerning the association between diabetes and cold exposure is scarce, and especially reports on diabetics in an occupational context are lacking. To the best of our knowledge, there is only one population study (n=6,462) describing cold-related symptoms in diabetics at the population level (Hassi *et al.*, unpubl. observation). In this study diabetic patients report cardiac symptoms in the cold more frequently (53%) than non-diabetic persons (39%). Due to the fact that the prevalence of Type 2 diabetes is increasing at an alarming rate worldwide, knowledge related to its relationship with regard to its symptoms and effects on performance in cold work, is warranted. For diabetics working in the cold advice is needed on the effects of cold, especially with reference to cardiovascular disease. Self-care and taking into account possible comorbidity during exposure to cold is important.

Skin Disorders and Diseases in Cold

Temperature-dependent skin disorders include erythema, physical urticarias, chilblains, cold panniculitis and cryoglobulinemias⁸⁸). A review of the effects of cold on skin is provided by Lehmuskallio *et al.*⁸⁹). Abnormal skin responses to cold usually occur when subjects are exposed to moderate cold (0 to +15°C) for prolonged periods⁸⁸).

In chronic skin disease the features of the skin are altered, which can increase its susceptibility to cold and result in discomfort, pain, performance degradation, and even injuries. There is little information available on the incidence and prevalence of the common dermatoses, such as atopic dermatitis, psoriasis and acne in cold. It is supposed that the problems of dry skin (atopic dermatitis, psoriasis) could be worsened in cold partially due to low humidity. However, the effects of temperature itself on the symptoms and course of the skin diseases have not been distinguished⁸⁹).

Cold urticaria

Cold urticaria is one of the physical urticarias and represents hypersensitivity to cold with cutaneous swelling, wheals and hives after rewarming of skin after cold exposure^{89, 90}). The cases are often idiopathic, but sometimes cryoglobulins are detected, possibly in the context of a recent viral infection or lymphoproliferative disease^{91, 92}). The symptoms may have a profound effect on the patient's quality of life. The condition may be life threatening if large skin areas are exposed to cold (e.g. cold water immersion) and causing an anaphylactic reaction⁹¹). If untreated, cold urticaria persists for 4–5 yr and women are more often affected than men. The best treatment of cold urticaria is to avoid cooling, which is not always possible, however. It is also often treated with antihistamine⁹¹).

Chilblains (Pernio)

Pernio is a vasospastic disorder that affects unprotected skin regions of individuals exposed to non-freezing, damp cold. It is also often categorized as a cold injury⁹³). It may be idiopathic or associated with other systemic diseases, particularly cryopathies and lupus erythematosus. Acute pernio manifests several hours following exposure, whereas chronic pernio may persist even long after the cold season has ended. The pathophysiology is complex and related to patient and environmental factors⁹⁴). To the best of our knowledge, there is not much information on the occurrence of chilblains in an occupational context. Reports from military training have detected cases of chilblains^{93, 95}).

Local exposure to cold may also be beneficial for some of the adverse occupational skin symptoms. An experimental study in the fish industry (n=14) showed that cooling of the skin <20°C reduced symptoms of itching by 50%. In the same study it was discussed that possibly due to lowered skin temperatures in the hands and fingers, symptoms of itching and erythema are localized to forearms and hands in the fish industry⁹⁶).

Skin diseases may limit the possibility to be engaged in cold work. Though, studies assessing the occurrence

of skin symptoms and performance in cold work are lacking. It is also not known what the proportion of persons having a skin disease is that are involved in cold work. However, for all types of activities occurring in cold, it is important for patients with a skin disease to minimize cooling of the affected skin areas by appropriate cold protection.

Frostbites and Cold-Associated Injuries

Freezing injuries, Frostbite

The occurrence and risk factors for frostbite have previously been reviewed by Hassi & Mäkinen⁹⁷⁾. Furthermore, updated information related to the occurrence, risk factors and treatment is separately provided⁹³⁾. Although frostbite and other local cold injuries have frequently been reported during wartime manoeuvres, the available scientific evidence suggests that cold injuries also occur frequently in the civilian population, especially in high-risk groups, such as outdoor workers, the elderly, the homeless and people with drug, alcohol or psychiatric problems⁹³⁾.

A study analysing cold injuries by using workers' compensation claims (n=657) and examining meteorological parameters showed that the rate of injury began to increase when temperatures fell below -12°C (10°F) and wind speeds exceeded 4.5 m/s (10 mph)⁹⁸⁾. Industries with the highest rates of injury included agriculture, oil and gas extraction, trucking and warehousing, protective services and interurban transportation. Vehicle breakdown or contact with water, gasoline, alcohol or cold water were noted as contributing factors on many of the compensation claims.

A specific occupational group at high risk for frostbite are reindeer herders, the annual incidence of frostbites being 22% (n=453). The amount of snowmobile driving, area of operation and white finger symptoms were related to an increased risk of frostbite⁹⁹⁾. Furthermore, it was also observed that VWF associated with snowmobile use further increased the risk of frostbite in reindeer herders¹⁰⁰⁾.

Contact cooling is frequent in occupational situations and may lead to frostbites injuries. The degree of cooling while touching cold materials is dependent on the surface temperature, type of material, duration of contact and several individual factors. A European joint research project was carried out to establish safe limit values for touching or gripping cold surfaces^{101, 102)}. For example, from these experimental studies it was concluded that frostbite can develop within 2–3 s when touching metal surfaces that are at or below -15°C ¹⁰²⁾. Therefore, touching surfaces at ambient temperatures below 0°C with bare hands is not recommended. Liquids used in industry may

also cause unexpected freezing injuries. For example, some case reports describe incidents where pressurized liquid ammonia¹⁰³⁾ or petroleum¹⁰⁴⁾ has caused serious freezing injuries in industrial workers due to evaporative freezing.

It should be noted that over 60% of frostbitten persons suffer from sequelae. These were reported to worsen in the cold environment, and working ability was considered to decrease in 13% even after a moderate cold injury¹⁰⁵⁾. The adverse effects of the frostbite sequelae may persist for several years after the cold injury.

Multiple factors influence the risk of frostbites. These are environmental, individual (anthropometry, age, sex, race), behavioural (cold adaptation, alcohol use, fatigue, smoking, use of protective ointments, inappropriate or constrictive clothing, prolonged stationary position), and health-related factors (Raynaud's phenomenon, VWF, diabetes, peripheral neuropathies, psychiatric disorder, medication)⁹³⁾.

Prevention of frostbite includes appropriate advance planning, information and advice, as well as organizational measures (adjustment of clothing, workspaces, work-rest regimes, coating or warming tools etc.). Special population groups (e.g. diabetics, patients with RP, persons with skin disorders or having a previous frostbite) at work should especially be given advice on proper protection. Emollients are not recommended as they may increase the risk of frostbite^{106–108)}.

Non-freezing cold injuries, hypothermia at work

Whole body-cooling may occur in occupational situations, especially in work activities that are sedentary or only involve light physical work. It should be noted that a decrease of 1°C in core temperature (subclinal hypothermia) may already markedly impair performance¹⁰⁹⁾ and could increase the risk of occupational injuries and accidents.

Clinical hypothermia (core temperature $<35^{\circ}\text{C}$) cases occur rarely in occupational situations and it is often associated with accidents, like sudden immersion in cold water. Hence, fishermen are at a higher risk for hypothermia-related fatalities. A retrospective study analysing the workers' compensation claims related to deaths occurring in the fishing industry in British Columbia (n=130) detected that the underlying cause of death in fishermen was often related to a cold chock due to sudden immersion in cold water (5.4%) or hypothermia (5.4%)¹¹⁰⁾. The study emphasized the importance of proper training to fishermen. Another retrospective study from Alaska in 1990–2002 detected 228 deaths from cold-water immersion, and indicated that many of the fatalities could have been prevented by using personal flotation devices¹¹¹⁾.

Another study examining hospitalizations in Alaska

($n=327$) revealed that the most common cause for hospitalization was hypothermia (46%), followed by frostbite of the foot (42%) or hand (19%) or face (4%). Among those injured while working 50% were active-duty military personnel, and 14% were professional fishermen, hunters or trappers. Furthermore, the most common cause of the injuries was outdoor cold exposure followed by cold water immersion¹¹²).

Cold associated injuries

A cold-associated injury can be a consequence of altered environment (e.g. ice, snow, limited visibility) increasing the risk of slip, trip and fall accidents. The risk of these injuries may also be increased by cooling of the body and possible changes in performance related to it. Recently, a questionnaire study among French workers ($n=2,888$) assessed the roles of job demands, living conditions and lifestyle in occupational injury and identified a wide range of factors that predicted injury. In the study cold exposure separately increased the risk of injury almost threefold¹¹³.

An occupational epidemiologic study examined the association between injuries and cold ambient temperature in the mining industry and reported that the injury rates for both freezing injuries and cold-associated injuries (slips and falls, fractures etc.) increased when the temperatures decreased¹¹⁴. The association of slip and fall injuries with temperature was inverse but not strictly linear, and the strongest association appeared with temperatures of ca. 2°C and below¹¹⁴. According to a questionnaire study performed for various outdoor occupations (mail delivery, mining, military and construction) falls and associated injuries on icy and snowy surfaces are prevalent in outdoor occupations¹¹⁵. Furthermore, a study analysing injury statistics from various occupations in Sweden showed that ice and snow was associated with slipping, tripping and falling injuries in 17% of men and 28% of women and the injury rate increased with ageing¹¹⁶. In addition, a follow-up study conducted among the postal delivery service detected that ice and snow was involved in 70% of the slip and fall injuries¹¹⁷. Fall events occur most frequently on ice covered with snow (2/3 of all falls), which might be due to the difficulty of perceiving the hidden risk and adjusting gait strategy¹¹⁵. The reasons for slip and fall injuries are multifactorial and they have been reviewed by Gao and Abeysekera¹¹⁸.

Management of Cold Health Risks at Work

Advice for proper risk assessment and management strategy for cold work is given in ISO15743³. This international standard presents a strategy and practical tools for assessing and managing cold risk in the work-

place, and includes models and methods for cold risk assessment and management; a checklist for identifying cold-related problems at work; a model, method and questionnaire intended for use by occupational health care professionals in identifying individuals with symptoms that increase their cold sensitivity and, with the aid of such identification, offering optimal guidance and instructions for individual cold protection; guidelines on how to apply thermal standards and other validated scientific methods when assessing cold-related risks; a practical example from cold work³).

Managing with cold at work includes awareness and assessment of its potential risks, as well as implementing different management strategies¹¹⁹. Increasing individuals' awareness of the effects of cold on human performance and health is essential, as the modern lifestyle may have somewhat eroded the traditional skills related to operating in cold climatic conditions. Assessing potential occupational cold-related risks in the workplace as well as identifying individual health-related risks is a prerequisite for advance planning. In health care, the special needs of the susceptible population groups should be taken into account when planning and practising health care and when providing individual recommendations. For this purpose a specific health questionnaire for cold work was developed, described by Hassi *et al.*¹²⁰.

The different cold management strategies include organizational and technical measures as well as the proper use of cold protective clothing¹¹⁹. An evaluation study of the implementation of the cold risk management model at the level of the organization emphasized the importance of setting organization-wide rules and practices for implementation, emphasizing concrete activities and information for improving visibility and awareness, and ensuring ownership and constant updating of the implementation process, as well as allocating the resources needed for the implementation¹²¹.

Conclusions

Cold work involves several adverse health effects that are observed both in in- and outdoor work. Many of these adverse outcomes may be further aggravated in persons having a chronic disease. For indoor work the climatic conditions are constant and predictable, which facilitates cold risk management. For outdoor work, on the other hand, climatic conditions vary including changes in temperature, wind and precipitation which complicate appropriate cold protection. The climate change projections indicate not only a permanent warming, but also suggest the likelihood of extreme weather events relative to the mean climate¹²². Therefore, health consequences related to working in cold climates will remain common, rep-

representing the majority of climate-related adverse health effects¹²³). Mitigation of the adverse effects and adaptation to the climate change in cold outdoor work will require interdisciplinary analyses and integrated preventive planning.

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