HEALTH IMPACT OF LOW INDOOR TEMPERATURES

Report on a WHO meeting

Copenhagen
11–14 November 1985

WORLD HEALTH ORGANIZATION
Regional Office for Europe
COPENHAGEN
1987

NOTE

FOREWORD

The undeniable success in controlling some preventable communicable respiratory diseases in Europe has created an impression that respiratory infections are no longer as dangerous as they once were, and efforts of public health services should be concentrated on other problems. However, epidemiological data do not exactly confirm this optimistic view, as acute respiratory diseases are among the leading causes of death in Europe. When morbidity statistics - which are usually less reliable - are considered, acute respiratory infections in Europe take the lead among all communicable diseases. For example, each year 15% of the population in Spain and 30% of the population in the United Kingdom have a recorded acute respiratory disease.

Several environmental risk factors of acute respiratory diseases have been recorded, the main ones being indoor and outdoor air pollution, overcrowding in dwellings and public transport, and poor indoor climate.

Improvement of the indoor climate of dwellings is recognized as an efficient means of secondary prevention of acute respiratory infection, especially in risk groups such as pre-school children and the elderly. Considering the large percentage of the aged in many European countries living in dwellings insufficiently heated or ventilated, or not heated at all, and considering the economic difficulties which complicate the quick improvement of this situation, it was considered useful to review the health impact of low indoor temperature and to recommend some lower limits to protect human health, especially of the very young and the elderly.

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1. INTRODUCTION

The Working Group was convened to review available evidence of the effect on health of low indoor temperatures, especially in dwellings occupied by the elderly, the sick, the disabled and preschool children. The scope of the meeting was to consider dwellings in Europe that are poorly heated during the cold months of the year.

The Working Group consisted of representatives from seven countries, including 10 specialists in the public and environmental health sciences: physicians, epidemiologists, environmental hygienists, thermal physiologists and biometeorologists (Annex I). Professor P.J. Lawther was elected Chairman and Dr K.J. Collins was appointed Rapporteur.

The WHO Working Group on the Effects of the Indoor Housing Climate on the Health of the Elderly, held in Graz in 1982 [1], concluded that insufficient knowledge was available on the effect of low indoor temperatures on the health of high-risk groups such as the elderly, the sick, the handicapped and young children. An agreed study protocol was designed to facilitate further studies in this area.

One of the purposes of the present Working Group was to review the results of studies in this area that have been carried out by collaborating institutes. Another main objective was to consider whether sufficient evidence from scientific studies and epidemiological investigations was available to demonstrate an adverse effect on health of low indoor temperatures, especially in high-risk groups. If this were so, it was proposed to proceed with a review of the evidence and to make recommendations on indoor temperatures below which the health of (a) the general population and (b) at-risk groups may be endangered. A final complementary task was to review the basic parameters and methodology for assessing the thermal environment, as proposed at the 1982 meeting, and to update procedures in the light of recent advances.

2. THE INDOOR ENVIRONMENT OF AT-RISK GROUPS

A basic requirement of thermally comfortable and healthy housing is to protect residents against condensation, extremes of heat and cold, and excessive draughts. Health specialists have expressed particular concern about the possible relationship between reduced indoor air temperature, reduced ventilation and increased humidity in housing, and the incidence of respiratory disease. Existing WHO publications [2,3] recommend a minimum indoor temperature of 18°C but a temperature 2-3°C warmer for rooms occupied by elderly persons. Low indoor temperatures also have adverse health effects in children, while the critical housing needs of the sick or handicapped also include an optimal thermal environment.

Following the so-called "energy crisis", several European governments introduced regulations to limit indoor temperatures to maximum levels in the 15-19°C range, and therefore below the WHO recommended minimum level of 20°C for at-risk groups. Furthermore, in some European countries many underprivileged groups, such as the elderly, large families and the poor, do not even achieve indoor temperatures of 15°C in winter. Morning indoor temperatures, including those in bedrooms, have been recorded at temperature levels as low as 0°C. In addition, the increased incidence, though admittedly a small absolute number, of cases of urban hypothermia during the winter months has raised public health and medical concern. Cold-induced cardiovascular and respiratory illnesses represent a further health hazard to a much larger proportion of the population at risk. WHO has therefore to reconsider its former recommendations regarding indoor climate in order to discourage excessively low indoor temperatures which may have detrimental effects on the health of at-risk groups.

3. ASSESSMENT OF THE INDOOR THERMAL ENVIRONMENT

Four main factors determine the thermal character of the indoor environment: ambient air temperature, radiant temperature, relative and absolute humidity, and air movement. Instruments and methods for measuring these parameters according to the International Organization for Standardization have been well described [4] and if required, an integrated assessment of the climate using several factors can be made. Most of the instruments employed by hygienists, health inspectors and engineers are calibrated to accepted standards, but commercially manufactured instruments available to householders may not be as reliable.

The hygrothermal determinants of the indoor environment are useful separately, but they may also be combined into a single, integrated index to provide a measure of the overall thermal stress. A number of thermal stress indices exist for different general conditions; they are designed to give appropriate weighting to the four major physical parameters, sometimes together with levels of physical activity and type of clothing [5]. At present, no measurement or index of the indoor environment is available that is particularly appropriate for cold conditions. The best single index appears to be the dry-bulb temperature. For conditions in normal indoor spaces, the "operative temperatures" of Winslow et al. [6] can be assumed to be the mean between air and wall temperatures.

In still or slow-moving air, which is the condition found in most homes, relative humidity and air movement tend to play only a minor role in cool conditions. However, humidity and air movement become important when excess water vapour is released into the indoor environment, for example, in kitchens and bathrooms, or when gaps in the fabric of the building allow draughts into living spaces. Cold air may become saturated more easily, causing condensation indoors as well as providing a more favourable environment for some microorganisms and moulds to flourish. Local draughts decrease thermal comfort in cold indoor environments. Specification of conditions for thermal comfort requires a knowledge of the hygrothermal characteristics as well as the insulation values of clothing worn and the pattern of activity of the occupants [7,8].

3.1 Air temperature

In housing construction, the relevant range of outdoor temperatures need to be specified according to the local environmental conditions, and special recommendations required if external conditions fall outside this range. Detailed measurement inside dwellings should be based on the zone normally occupied by the residents. Average ambient air temperature is measured by the dry-bulb thermometer placed in the middle of the room at 0.6 m (sitting position) and 1.2 m (standing position) above the floor. However, not only the mean optimal temperature but the vertical and horizontal differences in air temperature are important. Horizontal differences should not exceed 1-2°C/m and the difference between temperature at floor level and temperature at a height of 1.5 m above the floor should not exceed 3°C.

Particular consideration should be given to the very young who are affected more by temperature and draughts at floor level.

3.2 Humidity

The indoor environment contains many sources of water vapour, and ventilation is necessary in static air spaces to prevent the build-up of humidity to unacceptable levels. In the household, several kilograms of water vapour may be emitted into the indoor environment during a day [9] (Table 1). Humidity levels may vary considerably in different rooms and spaces within a dwelling, though with adequate air movement and heating, water vapour will tend to equilibrate through communicating spaces. An optimum level of

Table 1. *Typical moisture production in a 5-person dwelling [9]*

Emission source	Moisture emission (kg/d)
5 persons asleep for 8 h	1.5
2 persons active for 16 h	1.7
Cooking	3
Bathing and dishwashing	1
Washing clothes	0.5
Drying clothes	5
Combustion products:	
Natural gas	(0.15 kg/h/kW)
Kerosene	(0.1 kg/h/kW)

relative humidity in the comfort zone of 18-24°C is 40-50% up to 20°C and 30-40% above 20°C environmental temperature. Atmospheric dryness tends to produce irritation of the skin and mucosal surfaces - a complaint of residents in northern Europe where conditions of low relative humidity and warm indoor temperature usually occur during the winter.

3.3 Radiant heat

A globe thermometer is conventionally used for measurement of mean incident radiant heat at a point in a room. Globe thermometers may, however, take a considerable time to reach equilibrium. When an indoor radiant heat component is significant, it is important to measure the "directional operative temperature" (the mean of hemispherical radiant temperature and the air temperature). Directional operative temperature should not differ by more than 5°C anywhere within the occupied zone of the dwelling.

The indoor climate has degrees of asymmetry which relate particularly to the radiant heat component. Sufficient attention should therefore be paid to the position of the radiating surfaces, including the furniture, in the dwelling. Similarly, sedentary individuals (e.g. the elderly) can lose a significant amount of radiant heat through a "cold-window effect". Therefore, beds should not be placed with the head of the bed towards cold windows during cold winter weather, as the source of greatest heat loss from a sleeping person is the head.

3.4 Air movement

Commercially manufactured anemometers are usually inadequate for measuring air movement at low air speeds in dwellings. Quite often, the flickering flame of a candle may be the most useful method for detecting minimum air movement. Environmental engineers use the more complex technique of tracer gas or smoke tracking. In cold environments a minimal level of mechanical ventilation (e.g. half an air change per hour) is necessary to help prevent condensation in dwellings. The practice of opening windows to increase natural ventilation will promote excessive local condensation in the indoor environment when the external temperature is very low.

4. INDOOR TEMPERATURE SURVEYS

Increasing awareness of the problem of the "old and cold" in the United Kingdom has encouraged many local surveys of indoor temperature conditions. The problem does not appear to be highlighted in other European countries, though in the more temperate areas in Europe unusually cold winters may cause it to arise in some owner-occupied dwellings. The basis for achieving acceptable thermal conditions in homes and workplaces has resulted in a number of reports and recommendations [10].

The elderly deserve special consideration, for many spend a great deal of time at home and their wellbeing may depend largely on the type of accommodation and environmental conditions in which they live. In the United Kingdom in the late 1970s, 90% of elderly people over the age of 65 years lived in their own or their family's accommodation [11] (one-third of which consisted of dwellings built before 1919) and 8% in accommodations for the elderly. A review of heating facilities in the houses of the former revealed that a relatively high proportion of the elderly (30%) had no heating in their bedrooms and a majority had unheated halls, corridors and lavatories. Thus, many of the elderly have to move repeatedly between warm and cold indoor environments. About 1 in 4 dwellings with an elderly head of household had central heating, which is a lower proportion than for the population of England and Wales as a whole where 30% of all households had full or partial central heating in 1970 and 55% in 1979.

A national survey of temperature profiles in the elderly population in the United Kingdom in the winter of 1972, based on a random sample of 1020 people over the age of 65 years, showed that when the mean external morning temperature was 5°C, temperatures in the living room ranged from 6 to 22°C (mean 15°C), rising to a mean indoor temperature of 18°C in the afternoon [12]. The survey highlighted the fact that in the morning 75% of temperatures in the living room were below 18.3°C, 54% were below 16°C and 10% below 12°C. Many of the dwellings were poorly insulated and badly constructed. The implication was clear: in the 1970s, many elderly people endured particularly low indoor temperatures at some time of the day in winter.

A second major survey of house temperatures in the United Kingdom, this time for the general population living in all types of domestic dwelling, was undertaken in February and March 1978 when the outside temperatures were close to the seasonal average of about 5°C [13]. Mean temperature of living rooms was 18.3 +/- 3°C; those in households containing elderly people were 0.6°C cooler on average. Centrally heated homes were found to run 3°C warmer and between-room temperature gradients were smaller than in non-centrally heated houses. The change in dwelling temperature in relation to daily outdoor temperature indicated a weak correlation, with less than 10% of the variance in mean indoor temperatures being accounted for by external conditions. The minimum indoor temperature was 6°C when outdoor temperature was 0-1°C, and 8°C at outdoor temperatures of 3-4°C.

In a study of indoor climate in Danish schools some 20 years ago, Andersen and Lundqvist [14] stated that the room temperature is, in general, the most important parameter for health and the (globe) temperature should be maintained throughout the day between 19 and 21°C. Few surveys have been conducted specifically on the housing temperatures of children. One small survey in the United Kingdom during the winter of 1980 found that the weekly average levels of temperature in children's bedrooms ranged from 7.7 to 22.0°C (mean 13.2 +/- 2.7°C) when the mean outdoor temperature was 3.5°C [15,16]. The average minimum temperature measured in children's rooms in various buildings in Budapest in the winter of 1984-1985 was 16.3°C in log houses and 19.7°C in cast concrete dwellings, with an average outdoor temperature of 2.4°C (P. Rudnai, personal communication).

Strict comparisons of survey results are difficult to make because of differences in the timing of temperature recordings and in structure and occupancy of buildings surveyed. Clearly, the spot-reading approach has many limitations, though a wide range of domestic conditions can be sampled easily and cheaply with this method.

5. REQUIREMENTS FOR THERMAL COMFORT

Many environmental, physiological and psychological factors have a bearing on human thermal comfort, and it would not be acceptable to recommend limits for room temperature without specifying at least the appropriate levels of physical activity and clothing insulation. Generalizing from surveys carried out in individuals' homes is difficult, for preferences will vary widely and replies are often biased by personal circumstances which may have little to do with thermal comfort. In 1968, Goromosov [17] noted that official temperature standards for dwellings in winter were roughly the same in various countries: Federal Republic of Germany, 18-20°C; Switzerland, 18-20°C; USSR, 18-21°C; United Kingdom, 16-20°C; and USA, 19.6-21.8°C.

In controlled laboratory studies on the elderly and young adults in Denmark and the USA, thermal comfort was found to be the same in a range of ambient temperatures above 20°C [7]. In many respects, this is surprising because body temperature control mechanisms deteriorate, peripheral temperature perception is impaired and behavioural temperature regulation becomes less efficient in a proportion of elderly people [18]. The elderly appear to be quite capable of experiencing cold or cold discomfort, but some experience cold at a lower temperature than might be predicted [19].

In some European countries the range of room temperature during winter tends to fall below 20°C, and it is important therefore to determine thermal comfort for the elderly group in a lower range of ambient temperatures. Healthy elderly and young adult volunteers again did not differ substantially in their temperature preference [20]. However, a small number of old people with poor peripheral temperature perception showed a lower temperature preference for comfort than average. Overall, the optimum temperature in both old and young groups when sitting and wearing 1 clo[a] of insulation was 21.1 +/- 2.9°C. This standard would apply only to those at rest and to healthy people who show no marked differences in physiological response to temperature. An elderly person suffering from hypothyroidism may feel cold even in a temperature of 24°C. Similarly, a proportion of older people fail to detect temperature differences very precisely and they often do not complain if the room temperature is unusually low.

At the other extreme, the need to provide a thermally acceptable environment for newborn babies is particularly critical for the first few weeks of life. A room that is intolerably warm for an adult may be too cold for a young baby. A temperature

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[a] The clo is a unit of clothing insulation defined as 1 clo = R_{cl} x 0.18, where R_{cl} is the total heat transfer resistance from the skin to the outer surface of the clothed body (1 clo = 0.155 m^2°C/w).

between 21-24°C provides satisfactory conditions for a full-term, cot-nursed baby in the first weeks of life, but for a 1-kg baby, initially a temperature above 30°C would be required if the baby were in a cot instead of an incubator [21]. The thermal comfort of children has been studied extensively in secondary school children [22], and temperature preferences of adults and children appear to differ little. Young children have a higher basal metabolism than adults, have different restrictions on clothing and usually engage in more energetic activities. All of these factors will affect a spot check of thermal comfort, and in children this is usually related to their higher levels of activity.

6. LOW TEMPERATURE, HUMIDITY AND RESPIRATORY DISORDERS

When air temperatures are low in winter, the moisture content (absolute humidity) of the outside air is also low even though the relative humidity (RH) may approach 100%. Infiltration of this air into the indoor environment, accompanied by warming, will usually create low RH conditions, though probably not much lower than 35% RH in homes in the United Kingdom [5]. Indoor RH below this level may occur in North America and northern Europe, where outside temperatures are lower and indoor heating generally efficient. The indoor environment has many additional sources of water vapour (Table 1), and adequate ventilation is therefore necessary to prevent humidity from rising to unacceptable levels. In the 18-24°C range of indoor climate, an RH between 20 and 70% is regarded as being compatible with health.

In a field survey of house temperatures in the United Kingdom in 1978 [13], the average dwelling temperature was 15.8 +/- 2.9°C dry bulb and 12.2 +/- 2.2°C wet bulb (RH = 67 +/- 11%). Forty-six per cent of respondents had a condensation problem somewhere in the home, with a higher proportion in non-centrally heated (50%) compared with centrally heated (43%) housing. Homes with condensation problems were 0.5°C cooler on average. Mould growth was reported in the homes of 20% of respondents. The observations of this survey are in broad agreement with the usually accepted view that 70% RH is sufficient to sustain mould growth once it has started.

6.1 Physiological effects of air humidity

At low and moderate temperatures, variations in atmospheric humidity have little influence on purely thermal exchanges. Therefore, the humidity factor is unlikely to contribute substantially to the thermal stress at normal indoor temperatures in Europe. RH does have a profound effect on thermoregulation and comfort in high temperatures, meaning that a dry atmosphere is more desirable than a moist one. However, at low temperatures, "damp cold" is often believed to be more unpleasant than "dry cold", but there is no physical basis for supposing that the RH of cold air will have any significant effect on its convective cooling power [23]. Actual wetness of clothing or footwear has, on the other hand, a considerable cooling effect in the outdoor environment. Since the RH in winter is high outdoors, the moisture content of clothes will also be high. On coming indoors, evaporation from clothes will have an immediate cooling effect and delay the feeling of warmth.

High indoor humidity increases the moisture content of clothing and bed-clothing. This moisture content is reduced when the body warms the material, thereby causing an initial increased heat loss from the body, usually for about 1 h.

The influence of dry air on the mucous membranes of the nose and throat has long been regarded as an important factor increasing respiratory infections. Earlier studies [24] have shown that whatever the temperature and humidity of the inspired air in a normal range of climates, the expired air will be in the temperature range of 32-35°C and its RH 90-98%. The degree of moisture present on the surface of the oral mucosa is not related to atmospheric temperature or RH but to the absolute humidity of the environment. Thus, the drying of the mucosa in an indoor temperature of 21°C and 10% RH is no more harmful than it is in outdoor air saturated at a temperature of 0°C. The critical point for drying of the oral mucosa is a vapour pressure of about 10 mm Hg [24]. Drying of the mucosa must therefore occur at air temperatures below 11.5°C with any moisture content, at 15.5°C with less than 77% RH, at 21°C with less than 54% RH and at 26.5°C with less than 39% RH. However, whether the drying of the mucosa is actually harmful and increases the chance of respiratory infections requires further investigation.

6.2 Respiratory illness in cold environments

In very cold outdoor air (temperatures below zero), the temperature of the respiratory airways can fall, impairing the function of the bronchial epithelium and encouraging respiratory infection. Water mist, as occurs in fog, greatly increases the thermal capacity of respired air. Thus, in a very cold, misty environment, the temperature of the airways may fall sufficiently to impair the function of the ciliated, goblet and mast cells in the bronchial epithelium. Cold air of this nature is also thought to exacerbate respiratory illness, such as bronchitis, by increasing respiratory air flow resistance [25]. During the London (freezing) smog of December 1952, deaths from bronchitis, especially in the elderly, increased greatly (ninefold) and deaths from heart attacks increased 2-3 times. Cold air is also seen as a principal cause of exercise-induced asthma in younger people [26]. Lesser degrees of cold in indoor temperatures may reduce the resistance of the body to infections secondary to colds and influenza. This effect is believed to be prevented by heating the indoor environment to a minimum of 16°C and by ensuring adequate but not excessive ventilation [27].

Although the incidence of the common cold increases in winter, cold winter temperature does not in itself appear to be the cause. Isolated communities in cold climates may be completely free from colds and upper respiratory tract infections for the whole of the winter, but epidemics occur when first contact is made with visitors [28]. Again, the view that resistance to infection is lowered by "chilling" is not supported by experimental work [29,30]. Objective data are lacking of a causal relationship between body chilling and a subsequent respiratory illness. Another reason sometimes given for the high incidence of winter colds is that low indoor humidity predisposes to infection by drying the oral and nasal mucosa [31]. The flow rate of the mucus bed of the nose has been found to be slowed by low humidity [32], but this observation was not confirmed when longer exposures to dry air were used [33].

The weight of evidence from several studies in humidified and non-humidified buildings tends to support the view that the occurrence of upper respiratory tract infections increases when indoor RH is low [34]. The most commonly suggested cause for this is the increased transmission of infection because of the greater survival of airborne microorganisms at lower humidities [35]; higher RH produces larger particles which, it is claimed, have reduced infectivity [36]. Unfortunately, meeting the statistical requirements of investigations in which environmental and behavioural factors are all strongly correlated is difficult. Therefore, the relationship between the incidence of respiratory infection and low indoor RH must be regarded as suggestive rather than conclusive.

High levels of RH are also regarded as having specific effects on health by enhancing the spread of droplet infection; a RH of about 50% appears to be most harmful to microorganisms [37] and a RH of 86-95% the optimum range for the spread of droplet infections [38]. In a study on primary school children [15,16], the RH in the home environment ranged from 37 to 98% and this was negatively correlated with indoor temperature. After allowing for effects such as smoking in the home, a significant positive association was found between the prevalence of respiratory illness and high levels of RH. On the other hand, studies in schools with air temperatures of 21-23°C and low RH (18-49%) suggest that absentee rates increase with lower RH [39]. The effects of high rather than low RH in the indoor environment is important for asthma patients because high humidity encourages the growth of house dust and storage mites that cause allergic responses. The occurrence of these mites is partly related to the water vapour content of indoor air, the highest concentration of mites being at air humidities above 40% at 22°C [40]. A study of Danish apartments [41] found that the concentration of house dust mite was positively correlated with the absolute humidity of the indoor environment. A seasonal variation in dampness and concentration of house dust mite often occurs, and allergic reactions may occur as the result of moulds and fungi growing on damp areas of building interiors when indoor humidity is excessive. Health hazards, for example, humidifier fever [42], can be created by humidification devices which are not cleaned regularly. Steam injection systems or a spinning-disc vapourizer using piped water will effectively overcome this problem.

7. TEMPERATURE REQUIREMENTS FOR HEALTH

The influence of low indoor temperatures on health is likely to affect all age groups, though infants, the disabled, the sick and the elderly must be at greater risk. Because the elderly have a more sedentary life style, it has been recommended that dwellings inhabited by them should be heated, or be capable of being heated, to 2-3°C higher than for young people. However, surveys in the United Kingdom have shown that houses occupied by elderly people are colder than average.

If health is taken to mean normal physiological functioning in the absence of stress, such as that produced by thermal discomfort, then we should start by considering temperatures outside the comfort range. Thermal conditions of discomfort and disturbances of thermal equilibrium are often associated with minor illnesses such as colds, pharyngitis and neuralgia. However, a WHO Working Group [1] has proposed that an indoor temperature between 18 and 24°C offers little thermal threat to appropriately clothed sedentary people when there is also an air movement of less than 0.2 m/s, a relative humidity of 50% and a mean radiant temperature within 2°C of air temperature. The risk to health will obviously be greater the lower the indoor temperature and the longer the exposure period. The question of adaptation is also important here, for physiological responses may change with continuous or repeated experience with cold indoor environments.

Below the zone of thermal comfort, cold-induced responses and cold-related diseases may take many forms. With air temperature as low as 6°C, cardiovascular reflexes can be initiated by cold air on the face or hands that result in changes in heart rate and blood pressure and consequently in increased cardiovascular strain. Similarly, cold air in the respiratory tract damps down the action of cilia that help prevent airway contaminants from being absorbed by the respiratory mucosa. Although, the underlying cause is unknown, respiratory infections are often preceded by a "chill" after getting cold, and resistance to infections appears to be diminished, especially if indoor ventilation is poor. Disorders of thermoregulation in the elderly have long been associated with inefficient temperature control and sometimes the development of hypothermia.

Many of the adverse effects on health induced by low indoor temperatures in the elderly may be manifest also in children. These include respiratory infections and obstructive airways disease, with asthma being more prevalent in the young and sometimes hypothermia in the very young.

Since the WHO Working Group in 1982 [1], two large-scale epidemiological studies in Europe have been conducted on the correlation between morbidity, especially respiratory disease, and the temperature of the indoor microclimate: one on residents in homes for the elderly and one on urban preschool children.

7.1 An epidemiological study on indoor temperatures and health in homes for the elderly in Czechoslovakia[a]

The subjects were 2356 elderly residents (60 years or more) housed in homes for the elderly, which included 5 new buildings constructed in the last 10 years, 7 modernized older buildings and 5 mansions adapted for geriatric use. The homes were situated either in industrialized areas or, in contrast, in areas with relatively clean air. All homes were centrally heated. Air temperature, humidity and globe temperature were monitored in the occupied zones of the homes every 6 h during the period of study (January to June 1985). The incidence of acute respiratory illnesses and rheumatic disease was monitored, and morbidity from these illnesses ranged from 6 to 40% in individual homes. In four homes with an average indoor temperature of 19°C (range 14-25°C), the incidence of acute respiratory illness was higher (34.6%) than in nine other homes with a mean temperature of 23°C (range 20-26°C) and where the incidence was significantly lower (10.8%).

In one home that was well-heated throughout the study period, morbidity was high (25.8%). The occupants of this home were, on the

[a] A. Krtilova, personal communication.

whole, much more mobile than those in other homes, often taking walks and visiting. Because of this activity, there may have been a much greater opportunity of cross-infection. The investigation, however, failed to demonstrate any differences between the health of elderly living in homes situated in industrialized areas compared to those in non-industrialized areas. The homes studied in this investigation were on the whole well-heated and would to some extent represent the housing in sheltered accommodation for the elderly. A majority of the elderly in some countries are known to live in their own or their families' accommodation where heating is often a matter of individual choice. It is in individual houses that a wider range of low indoor temperatures may be found.

7.2 Study of the effects of building construction type and hygrothermal conditions on morbidity in children in Hungary[a]

The relationship between the hygrothermal indoor environment and the incidence of respiratory infections in 1289 preschool children living in different types of housing (flat) unit was studied in a district of urban Budapest. Measurements were carried out in January and February when mean outdoor temperatures were lowest, that is, -3.9°C and -2.1°C, respectively. The studies were made in the children's room in four types of building construction: panel, conventional, cast concrete and log house; and with five different types of heating system: district heating, gas, central heating, electric and stove (coal, wood, oil). Both district and central heating systems provided a relatively stable and uniform temperature in the whole flat, while electric and stove heating often caused marked temperature gradients between the rooms.

In comparison with the conventional type of construction, children in both the panel and log buildings had a higher total morbidity from respiratory infections. Asthma was ten times more frequent in panel buildings than in conventional buildings, and the incidence was even higher in log houses. Panel buildings appear to have the most unfavourable influence on respiratory morbidity, which may be due to low RH. The average RH was 38% in panel buildings, 46% in conventional buildings and 42% in log houses. Apart from the factor of low humidity, indoor air pollution may also have contributed to the higher respiratory morbidity in panel buildings. The concentration of formaldehyde and NO_2 was highest in log houses.

[a] P. Rudnai, personal communication.

8. BLOOD PRESSURE IN COLD INDOOR ENVIRONMENTS

A seasonal influence on blood pressure was first described in 1961 [43] and the Medical Research Council's Treatment Trial of Mild Hypertensives found that systolic blood pressure for each age, sex and treatment group was higher in winter than in summer [44]. Increases in blood pressure due to cold may be initiated by a sympathetic nervous reflex from skin cooling in accord with the known response of the "cold pressor test" [45].

Investigations undertaken recently on elderly people exposed to cold [46] suggest that cold extremities and a slightly lowered core temperature may lead to short-term increases in blood pressure. Thermal and cardiovascular responses were examined in indoor climates ranging from 23 to 6°C and during repeated daily exposure to 6°C. After 2 h at 6°C, the mean increase in blood pressure was significantly greater in the older subjects than in young adults. A small rise occurred in older men after 1 h in 12°C but not in the young. At 15°C, blood pressure did not increase in either group. The rise in systolic pressure and the (slight) fall in deep body temperature showed a high degree of association and the fall in skin temperature and the rise in blood pressure a lower association. In addition to raised arterial pressure, platelet and red blood cell concentrations and blood viscosity increased when young adults experienced mild surface cooling for periods of longer than 1 h [47]. These factors may help explain the marked increases in coronary and cerebral thrombosis which occur within the first few days of a period of cold conditions.

Blood pressure responses to cold indoor temperatures appear to occur significantly more slowly in the elderly at first, but such reactions are generally more marked than in younger adults after 2 h of cold exposure. Significant rises in blood pressure in elderly people at rest were observed in indoor temperatures of 6, 9 and 12 °C but not at 15°C.

9. HYPOTHERMIA

One approach to defining the lower limits of health temperature conditions might be based on ambient conditions in which the body can no longer maintain thermal equilibrium. An assessment of such conditions may be made by using a computed model of human thermoregulation [48]. From such a model, a sedentary adult wearing 1 clo can be predicted to maintain thermal balance and normal body temperature for at least 7 h in an environmental temperature of 5°C. In the absence of shivering thermogenesis, which might apply to a few elderly people at risk, body temperature would drop to hypothermic level (35°C) within 7 h in an ambient temperature of 10°C and within 4 h at 5°C. Thermoregulatory responses will normally protect core temperature for many hours at low temperatures even though, as in some elderly people, the responses are less efficient. Thermoregulation does not usually fail in old age, but the physiological potential to respond to cold may diminish.

The question arises as to whether elderly people who are submitted for several consecutive days to cold temperatures at home in the winter can become adapted to cold. This seems to be unlikely from studies of cold exposure of the elderly at 6°C for 4 h per day during 7 to 10 days while sedentary and wearing 1.5 clo [46]. Deep body temperature and blood pressure responses of the elderly showed little adaptive change from day to day. Younger control subjects did, however, show a more powerful vasoconstrictor response after repeated cold exposure to 6°C. A much greater cold stimulus is apparently required, such as that induced by significant repeated falls in core temperature, to bring about adaptive changes.

The condition of hypothermia can arise in elderly people because of less-efficient temperature control mechanisms [18]. However, this is rarely the direct and only cause of hypothermia in moderately cold conditions, though it will increase vulnerability to the effects of cold. Secondary hypothermia arising from some underlying medical condition appears to be the most common reason for elderly people to be admitted to hospital with hypothermia. This form of hypothermia may sometimes be quite unconnected with low temperatures in dwellings. Therefore, the importance of hypothermia in the elderly, and whether it is a cause or effect of cold-related illness are difficult to assess. A salient feature of the national study of body temperatures in the elderly in the United Kingdom [12] was the finding that only a small number of elderly people at home were actually hypothermic. Further, the morning hypothermia detected by urine temperature was mild, with most temperatures at or just below 35°C, the lowest being 34.2°C. By the afternoon, body temperatures were all above the hypothermic level.

In the 1950s, low indoor temperatures were shown to be the cause of hypothermia in infants when home deliveries occurred during cold winter conditions and when rooms lacked heating, particularly at night, and infants were bathed in cold rooms [49]. A full-term baby lying fully clothed under blankets in a cot might suffer a drop in body temperature if the room temperature falls below 10°C [21]. With improved heating conditions in homes and the increased use of hospitals for deliveries, the number of infant deaths from accidental hypothermia is now extremely small (less than 2 per year in England and Wales during the period 1979-1983, with similar mortality figures found in other European countries such as France and Sweden).

10. ENVIRONMENTAL TEMPERATURE AND SEASONAL MORTALITY

An analysis of daily death rates and environmental temperatures in the United Kingdom and United States [50] has shown that deaths from heart attacks, strokes and respiratory infections increase linearly as the outdoor temperature falls from 20 to -10°C. This relationship was much more marked in people over 60 years of age. A similar relationship between mean monthly temperature and mortality can also be found in the case of infants, since there appears to be a two-fold seasonal variation in sudden infant deaths (cot deaths) in the United Kingdom. Short-term temperature changes have only a small effect on death rates, but more significant effects occur when temperature changes last from 1 to 3 weeks. After a change in temperature, deaths from heart attacks tend to occur 1-2 days after, from strokes 3-4 days after and from pneumonia about 1 week [51].

Seasonal fluctuations in mortality thus appear to be determined by seasonal temperature cycles as well as by the types of disease prevalent in a particular region. Socioeconomic pressures such as impoverishment and unemployment and factors such as diet and housing conditions are also likely to contribute to seasonal mortality. If increases in winter morbidity and mortality are largely due to environmental temperature changes, then adequate control of the indoor environment should reduce the impact of winter cold. Coldness in winter is not an insurmountable natural obstacle: in North America and northern Europe, where winter temperatures drop well below freezing point, efficient housing insulation and large-scale district heating of homes are normal. The evidence suggests that an artificially maintained warm climate indoors may help reduce winter deaths [52].

Table 2 illustrates the seasonal mortality ratio (number of deaths occurring in a particular month expressed as a percentage of the number expected if mortality were spread evenly over the whole year (where 100 = average mortality for the whole year)) for a number of temperate countries during 1968-1972. A high coefficient of variation suggests a large seasonal effect as is shown for the United Kingdom. In such countries the winter climate is more variable, with unexpected swings in environmental temperature, rather than being consistently cold each year as in North America and northern Europe. To some extent the comparatively large seasonal effect in the United Kingdom is accentuated by a lower summer mortality (Table 2) and there is now evidence of a decline in seasonal mortality in recent years (Table 3) [53-56]. Winter appears to make less of a contribution to the annual death rate in the United Kingdom than it did 25 years ago, though peaks in January and February remain. The differences in seasonal mortality ratio cannot be due to the effects of colder regional outdoor temperatures, for the countries with the colder winter climate

Table 2 *Seasonal mortality ratios*[a] *showing monthly variations in mortality from all causes for selected temperate countries during 1968-1972*[b]

Country	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	C.V.[c]
Canada	114	104	99	97	98	97	99	94	95	98	99	105	.056
Denmark	114	106	103	99	98	97	93	92	95	97	101	106	.064
England and Wales	130	114	111	100	93	89	86	84	86	91	99	119	.151
Finland	110	107	100	96	99	101	97	92	94	97	99	110	.058
France	114	112	110	101	94	91	92	86	89	94	99	117	.105
German Democratic Republic	117	112	106	99	92	96	92	90	91	95	99	113	.093
Netherlands	118	106	102	97	94	95	95	91	93	97	101	109	.079
New Zealand	90	88	88	94	101	111	120	114	106	99	90	71	.141
Norway	113	103	103	97	98	99	97	94	94	97	100	107	.057
Scotland	131	113	110	100	94	91	88	85	89	90	97	111	.135
Sweden	111	104	99	99	95	99	98	93	95	98	99	110	.055
USA	114	106	100	97	97	96	95	94	93	97	101	108	.062

[a] See page 16 for definition of seasonal mortality ratio.
[b] Based on data from [56].
[c] C.V. = Coefficient of variation. Standard deviation divided by the mean derived from the 12 monthly ratios for each country and indicating the degree to which there is a seasonal swing.

Table 3 *Seasonal mortality ratios*[a] *showing monthly variations in mortality from all causes for selected temperate contries during 1974–1978*[b]

Country	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	C.V.[c]
Canada	111	97	104	97	99	96	99	97	95	100	98	105	.056
Denmark	106	100	116	100	100	96	93	96	91	98	99	106	.085
England and Wales	115	112	117	103	97	90	89	87	87	95	97	112	.119
Finland	110	102	104	99	100	99	97	94	93	96	96	108	.067
France	110	98	110	102	99	94	96	93	90	99	98	110	.079
German Democratic Republic	114	100	112	105	99	94	94	92	90	97	98	108	.093
Netherlands	108	103	109	101	98	96	95	96	92	98	98	105	.067
New Zealand	94	84	95	95	112	113	125	119	107	101	94	61	.170
Norway	110	99	104	98	100	95	98	97	96	99	97	108	.059
Scotland	116	106	116	104	99	90	88	88	89	94	96	113	.123
Sweden	108	101	111	101	98	97	97	96	92	97	97	108	.068
USA	115	100	104	98	99	95	98	96	94	100	97	106	.061

[a] See page 16 for definition of seasonal mortality ratio.
[b] Based on data from [56].
[c] C.V. = Coefficient of variation (see Table 2).

appear to maintain warmer indoor ambient temperatures and smaller seasonal fluctuations in mortality.

The decline in the seasonal mortality ratio observed in recent years [53] cannot be explained by fewer severe winters or less serious influenza epidemics. Two environmental changes have, however, occurred since the 1960s. The first is the increased use of central heating. In countries such as Japan and the United States, central heating is claimed to have had a major impact in reducing seasonal mortality [52]. This effect may also apply to the United Kingdom where central heating and home insulation have greatly improved. The second environmental factor is the reduction of air pollution. The period since the early 1960s has witnessed a considerable fall in air pollution, which may have contributed to the decline in seasonality of deaths in the United Kingdom. While increases in indoor temperature brought about by more efficient heating and a reduction in outdoor air pollution may contribute substantially to the decline in winter deaths, causality cannot yet be established from such trends.

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

1. In agreement with the findings of previous working groups on indoor housing climate (the WHO Working Group in Graz in 1982; ISO/7730), there is no demonstrable risk to the health of healthy sedentary people living in air temperatures of between 18°C and 24°C. This temperature range applies under conditions of appropriate clothing, insulation, humidity, radiant temperature, air movement and stable physiology.

2. No conclusions could be reached on the average indoor ambient temperature below which the health of the general population may be considered endangered.

3. For certain groups, such as the sick, the handicapped, the very old and the very young, a minimum air temperature of 20°C is recommended.

4. There is evidence that ambient air temperatures below 12°C are a health risk for groups such as the elderly, the sick, the handicapped and preschool children.

5. At air temperatures below 16°C, relative humidities above 65% impose additional hazards, particularly from respiratory and arthritic diseases and allergic reactions to moulds, fungi, house dust mites and allergens from domestic animals.

6. It should be recognized that the elderly and the very young may be at special risk when bedroom temperatures are low at night.

11.2 Recommendations

While it should be understood that the above conclusions are based on the best available evidence, there is scope for more comprehensive and corroborative work on the topic. A number of proposals for further action and research related to the effect on health of low indoor temperatures have therefore been put forward.

1. Physical environment. The relationship between winter indoor and outdoor environments and their diurnal ranges should be investigated.

Improved techniques should be developed for measuring the microclimate of clothed individuals indoors.

Research and development should be carried out into inexpensive, simple and reliable methods for assessing the thermal conditions and ventilation rates of occupied spaces.

The thermal properties of clothing in damp indoor conditions and the thermal effects of furniture should be studied.

Methods of measuring thermal asymmetry in the physical environment should be developed with special reference to radiant temperatures.

2. Environmental physiology. Morphological and anthropometric studies should be made of the heat exchanges of obese and thin elderly people exposed to cold.

Studies should be made of the effects of age and cardiovascular and thermoregulatory responses to cold.

The role of the physiological parameters of the body shell, such as skin temperature, in the assessment of thermal balance should be investigated.

A study should be made of temperature ramps and the impact of the sudden transition between indoor and outdoor thermal environments on cardiovascular responses.

Research should be carried out into acclimatization and adaptation to cold in at-risk groups, such as the elderly and preschool children.

Investigations should be made into therapeutic agents that affect body temperature control, especially drugs whose side effects may increase the risk of hypothermia in the elderly.

A study should be made of night-time temperatures indoors in relation to the thermal balance of the elderly in bed and of bedridden patients.

3. Environmental health. Investigations should be made of the effects of cold indoor climates on the incidence and etiology of arthritis, muscular dysfunction and back pain.

An analysis should be made of the interrelationship of low indoor temperatures, the viability of microorganisms and the concentration of other particles affecting respiratory function and disease.

A study should be made of the relationship between cold, damp indoor housing conditions and respiratory infections in preschool children.

Epidemiological studies should be made of the correlation between the growth of moulds, other microorganisms and mites in relatively high indoor humidity and the incidence of respiratory disease.

The epidemiology should be investigated of the effects of low indoor temperatures on arthritis, cardiovascular disease and cold-related accidents.

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Annex 1

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19. Professional Profiles of Environmental Health Personnel