Public Health England

Protecting and improving the nation's health

Minimum home temperature thresholds for health in winter –
A systematic literature review

About Public Health England

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Executive summary

Background

In the UK, mortality is substantially higher during the winter months (December – March) when compared to other seasons. There are around 25,000 excess winter deaths in England each year. Excess winter deaths (EWDs) are the observed total number of deaths in winter compared to the average of the rest of the year.[1] The high prevalence of cold, damp, poorly energy efficient households in the UK is considered one of the main reasons why the UK continues to have higher excess deaths over the winter period when compared with other European countries.[2,3]

Cold weather is not only associated with an increase in deaths but also has a significant impact on morbidity.[4] Many population groups are particularly at risk from cold temperatures; vulnerable groups are widely distributed within the population and include older people, children and those with chronic illnesses, particularly cardiorespiratory disease. It is those most vulnerable to cold, who also spend the majority of their time indoors at home and may not always perceive cold temperatures because of physiological changes that occur particularly with ageing.[5] It is for these reasons that indoor temperature recommendations for homes are considered important to protect and improve health and wellbeing.

The Cold Weather Plan for England [4] previously recommended indoor temperatures of 18°C – 21°C. In 2014, PHE undertook to revisit the evidence on indoor temperature thresholds and review whether the recommendations should be updated. This was in recognition of:

- the importance of protecting health whilst reducing carbon emissions and avoiding unnecessary expenditure on fuel
- the guidance on which these original thresholds were based is now over 30 years old.

Aim

To review systematically the literature on the health impacts of cold indoor temperature thresholds to provide evidence-based recommendations for minimum home temperature thresholds to help reduce harm to health from cold home environments.

Objectives

1. Conduct a systematic literature review to look at the evidence on indoor temperature thresholds and their impact on human health.

2. Use the findings of the literature review and consultation with key experts in the field of cold weather and health to develop final recommendations that are applicable in practice.

Methods

A systematic literature review of peer reviewed papers, where the health impacts of specific indoor temperature(s) were assessed was conducted in February 2014. A summary of key findings was then presented to a number of experts at the national Cold Weather Plan seminar 2014. The feedback and opinions gained from this event were then combined with the findings of the literature review to develop the final recommendations.

Results

A total of 20 papers were included; they were very heterogeneous. Only two small randomised controlled trials, two cohort studies and one case control study were identified; the remainder were cross-sectional studies of varying sizes and quality, many of which were very small laboratory-based studies.

The evidence from the small number of epidemiological studies identified suggests an association between raised blood pressure with exposure to indoor temperatures of around 18°C or colder in the general adult population. Small laboratory studies support the findings that exposure to cold temperatures increases blood pressure and risk of blood clotting in healthy people who are sedentary and wearing minimal clothing, with one study suggesting these effects start at 18°C (+/-0.5°C). Findings on the association between body mass index and health effects of indoor temperature are conflicting.

These findings are also likely to be applicable to older people. When the effects of cold in older people were compared with those in younger people, the studies showed in general that the changes in outcomes such as blood pressure, clotting factors, cholesterol and in core and skin temperature were more profound, with slower recovery, in older people. Several studies also demonstrated reduced thermoregulatory control and thermal perception/discrimination with ageing.

For people with chronic illnesses, there was only very limited information on the effects of specific cold indoor temperature thresholds. Among older adults with chronic obstructive pulmonary disease, better respiratory symptom score was associated with more hours of indoor warmth (at least nine hours) at and above 21°C in the living room. Nights with bedroom temperatures of at least 9 h at 18°C showed a trend to association ($P = 0.04$). However the choice of these thresholds was based on existing temperature guidance, and it is not clear if other (lower) temperature thresholds might have also demonstrated health benefits.

For children, the literature suggests that there are small, and sometimes statistically significant effects on children’s respiratory health from increased indoor temperatures due to heating and energy efficiency interventions, but there is insufficient evidence available on the impact of specific indoor temperature thresholds.

Discussion

Whilst there is strong evidence that cold homes have a harmful effect on health, and there are good arguments for making recommendations for minimum home temperature thresholds in winter, the findings of this literature review demonstrate that there is very limited robust evidence on which to base these recommendations.

A population wide approach to minimum indoor temperature thresholds in winter is warranted for a variety of reasons. The currently available evidence base, alongside expert discussion, suggests indoor temperatures of at least 18°C poses minimal risk to the health of a sedentary person, wearing suitable clothing. Below 18°C, negative health effects may occur, such as increases in blood pressure and the risk of blood clots which can lead to strokes and heart attacks.

However, given the weak evidence to support this threshold, it would not be appropriate to frame this as a 'strong' recommendation. Furthermore the fact that certain groups are particularly vulnerable to cold, and that younger healthy adults may find it easier to increase activity levels and adjust their clothing, we consider that some nuancing of the message is needed to allow flexibility above and below the threshold to allow individuals to tailor their own actions. Stating clearly what the potential risks to health are in a simple, relevant and accessible way is important, to enable informed choice in heating behaviours and accommodate personal preferences.

On the basis of the evidence and discussions with experts and implementers presented in this review; the following recommendations on indoor temperature thresholds are proposed:

Heating homes to at least 18°C (65F) in winter poses minimal risk to the health of a sedentary person, wearing suitable clothing.

Daytime recommendations

- The 18°C (65F) threshold is particularly important for people **over 65yrs or with pre-existing medical conditions**. Having temperatures slightly above this threshold may be beneficial for health.
- The 18°C (65F) threshold also applies to **healthy people (1 – 64)*.** If they are wearing appropriate clothing and are active, they may wish to heat their homes to slightly less than 18°C (65F)

Overnight recommendations

- Maintaining the 18°C (65F) threshold overnight may be beneficial to protect the health of those **over 65yrs or with pre-existing medical conditions**. They should continue to use sufficient bedding, clothing and thermal blankets or heating aids as appropriate.

- Overnight, the 18°C (65F) threshold may be less important for **healthy people (1 – 64)*** if they have sufficient bedding, clothing and use thermal blankets or heating aids as appropriate.

*There is an existing recommendation to reduce Sudden Infant Death Syndrome (SIDS). Advice is that rooms in which infants sleep should be heated to between 16 – 20 °C (61 – 68F). http://www.lullabytrust.org.uk/roomtemperature

These updated recommendations should be widely disseminated to partners and other agencies working with people in high risk groups, and incorporated into future editions of the Cold Weather Plan for England and Keep Warm Keep Well documents.

Introduction

Many population groups are particularly at risk from cold temperatures; the risk is widely distributed within the population and includes older people, children and those with chronic illnesses, particularly cardiorespiratory disease. It is those most vulnerable to cold, who also spend the majority of their time indoors at home. Older people may not always perceive cold temperatures because of physiological changes that occur with ageing[5] and are therefore less likely to respond appropriately in dangerously cold environments. It is for these reasons that indoor temperature recommendations for homes are considered important to protect and improve health and wellbeing.

Excess Winter Mortality and Morbidity

Mortality has been shown to be substantially higher during the winter months (December – March) compared to other seasons.[1] There are around 25,000 excess winter deaths in England each year. Excess winter deaths (EWDs) are the observed total number of deaths in winter compared to the average of the rest of the year. There has been a decreasing trend in EWDs from around 60,000 in 1950s until 2005-6, after which there has been a slight rise. Although the evidence is insufficient to be certain of the underlying cause of this reduction, it is likely to relate to a broad range of socio-economic and other improvements, including improvements in health care, immunisation, diet and housing.

Around 80% of EWDs are in those aged 75 or more.[1] Most deaths are due to respiratory disease, circulatory disease, and dementia. Underlying causes of excess winter deaths are complex and inter-related, but the main causes are cold temperatures and circulating respiratory viruses, predominantly influenza. Following a cold snap, cold related deaths will continue to occur for up to four weeks; evidence suggests that many of these deaths are not those that would have occurred in the near future anyway.[6] EWDs continue to be higher in the UK compared to other European countries.[2,3] For these reasons, many of the EWDs observed in the UK are understood to be preventable and therefore amenable to intervention.

Cold weather is not only associated with an increase in deaths but also impacts significantly on morbidity by increasing the risk of heart attacks, strokes, respiratory illnesses, flu and other diseases.[3] The majority of breaches of the Emergency Department less than 4 hour waiting standard occur between November and March, and emergency admissions for respiratory disease show a particularly marked seasonal variation.[7] Acute bronchitis in older people (>65yrs) at the end of December and in early January provide the peak surge of hospital respiratory admissions and are responsible for the annual respiratory illness burden on health care services.[8] In the UK, GP consultations for respiratory illness in older people increase by as much as 19% for every degree the outdoor temperature drops below 5°C.[9] Factors which increase the risk of admission to hospital in older people include limited contact with family or friends and social isolation. Those with Chronic Obstructive Pulmonary Disease (COPD) are four times more likely to be admitted for a respiratory complication in winter and having an additional chronic disease significantly increases this risk.[10,11]

Cold homes and fuel poverty

Cold homes are an important cause of excess winter mortality and morbidity.[12] One study showed that residents of the 25% coldest homes have around a 20% greater risk of dying during the winter months than those in the warmest homes.[13]

Fuel poverty in England is measured by the Low Income High Costs definition,[14] which considers a household to be in fuel poverty if:

- they have required fuel costs that are above average (the national median level)
- were they to spend that amount they would be left with a residual income below the official poverty line

The proportion of EWDs attributable to cold homes and fuel poverty is debated, with some conflation of the separate, but overlapping issues of excess winter deaths, cold homes and fuel poverty. Estimates suggest that about 30% of EWDs are due to cold homes [15] and around 10% due to fuel poverty,[14] although this latter estimate has been contested. Currently about 2.5 million people live in fuel poverty [16] with 4.9 million homes non-decent because of excessive cold, damp, poor air quality or inadequate facilities.[17] Local public health teams report that paradoxically EWDs tend to be higher in more affluent areas, thought likely to represent owner occupiers living in older, colder homes.[18]

There is reasonably strong evidence for positive health effects of interventions related to heating and energy efficiency upgrades in housing; there are potential benefits for reducing symptoms of respiratory and other chronic diseases, improvements in mental health, reduced contact with health services, and absence from school or work.[19,20] The balance of costs and benefits varies widely between studies, and the best justification for supporting housing energy efficiency upgrades is if the health, social, environmental and economic objectives are considered together.[21] The National Institute for Health and Care Excellence (NICE) will shortly be publishing guidance to address excess winter deaths and illnesses from cold homes.

The Cold Weather Plan

The Cold Weather Plan for England (‘the plan’) was launched in 2011 as a framework intended to protect the population from harm to health from cold weather. It aims to alert people to the negative health effects of cold weather and enable them to prepare and respond appropriately. A series of steps is recommended for the NHS, local authorities, social care, and other public agencies, professionals working with people at risk, individuals and the voluntary and community sector.[4]

The plans of 2011-13 recommend minimum indoor temperature thresholds of 21°C for living rooms and 18°C for bedrooms.[4] These recommendations were derived from a number of policy and research papers including the World Health Organization's (WHO) report 'Health Impacts of Low Indoor Temperatures'.[22] The same temperature range is used to inform housing standards,[23] is used in fuel poverty statistics [24] and is used in the Hills Fuel Poverty Review 'Getting the Measure of Fuel Poverty'.[14]

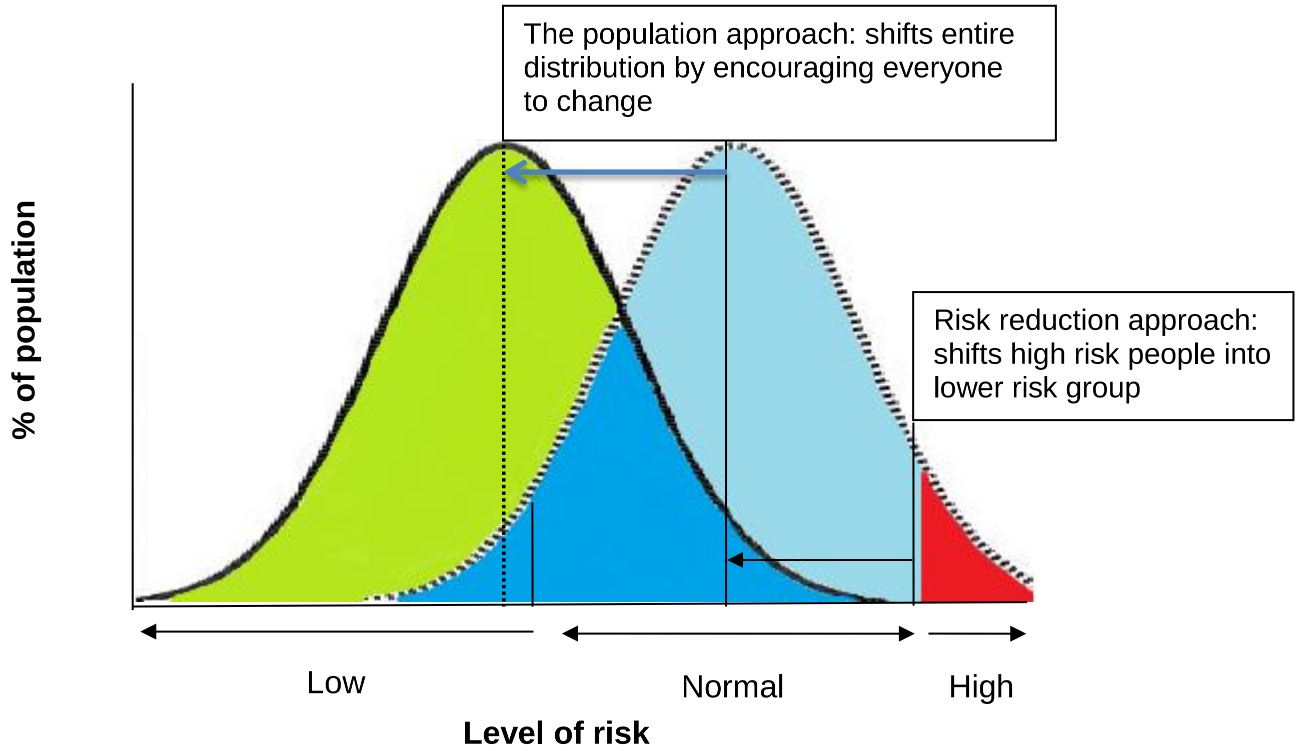
The WHO guidance aimed to protect health of those considered more at risk of the negative health impacts of cold, such as the very old and very young.[22,23] They concluded that for sedentary individuals, there is minimal risk to health if temperatures are maintained at a range of between 18°C - 24°C. The guidance recommended a minimum air temperature of 20°C for 'the sick, the handicapped, the very old and the very young'. This often cited report [22] is now over 30 years old with much of the evidence used even older.

In recognition of the importance of protecting health whilst reducing carbon emissions and avoiding unnecessary expenditure on fuel, PHE undertook to revisit the evidence on indoor temperature thresholds and review whether the recommendations should be updated. The need to review this evidence was further highlighted when the Cold Weather Plan for England 2013 [4] was published during a period of intense public concern regarding energy prices in October 2013. PHE received a number of enquiries seeking clarification on the evidence base for indoor temperature threshold recommendations contained in the plan, and to which population groups they applied.

Setting recommendations

One of the key issues this review seeks to address is whether the advice given in the plan should be targeted at the general population or whether messaging should be aimed at specific high risk groups. This population versus risk reduction approach can be illustrated by the 'Prevention Paradox', whereby greater benefits may be obtained through a whole population approach than a high-risk only approach (Figure 1).

Figure 1: High risk or population approaches to health interventions



(Adapted by R Wookey from: Rose, G., 1985: Sick individuals and sick populations. *In:* Int J Epidemiol. 12:32-28.)

An additional advantage to this wider approach is that it may assist in addressing the issue of people not identifying with themselves as vulnerable.

Understanding the distribution and determinants of vulnerability to cold is important and needs to be considered in the context of this review. Vulnerability to cold is widely distributed throughout the population and is recognised to be a fluid concept; a 'state' which people, through various stages in their life, may move into and move out of. It is also a multifactorial concept and not necessarily confined to individual characteristics such as health status or age alone.[25] Instead, many factors come into play including low income, social networks and the interaction with these factors on systems of provision and governance.[25]

Aim

To review systematically the literature on the health impacts of cold indoor temperature thresholds to provide evidence-based recommendations for minimum home temperature thresholds to help reduce harm to health from cold home environments.

Objectives

1. Conduct a systematic literature review to look at the evidence on indoor temperature thresholds and their impact on human health.

2. Use the findings of the literature review and consultation with key experts in the field of cold weather and health to develop final recommendations that are applicable in practice.

Scope

This review focuses on minimum indoor temperatures of the domestic environment in the period of operation of cold weather alerts in the Cold Weather Plan (November to March). The reviewers acknowledge the important impact that overheating has on occupant health, but this review does not seek to establish maximum indoor temperature thresholds for health.

Methods

A systematic literature review was conducted to identify peer reviewed papers on the health impacts of cold indoor temperatures, where the health impacts of specific indoor temperature(s) were assessed. The preliminary results were then presented to a number of experts at the National Cold Weather Plan seminar 2014. The feedback and opinions from this event were then considered when reaching the conclusions of this review and finalising the recommendations.

The literature search

The literature search was carried out in February 2014 and aimed to identify peer-reviewed, primary research papers. The following five medical databases were searched: PubMed, OVID, Medline, EMBASE (Excerpta Medical Database Elsevier), and CINAHL (Cumulative Index to Nursing and Allied Health Literature). Table 1 details the search terms and Boolean operators used.

Table 1: Search terms

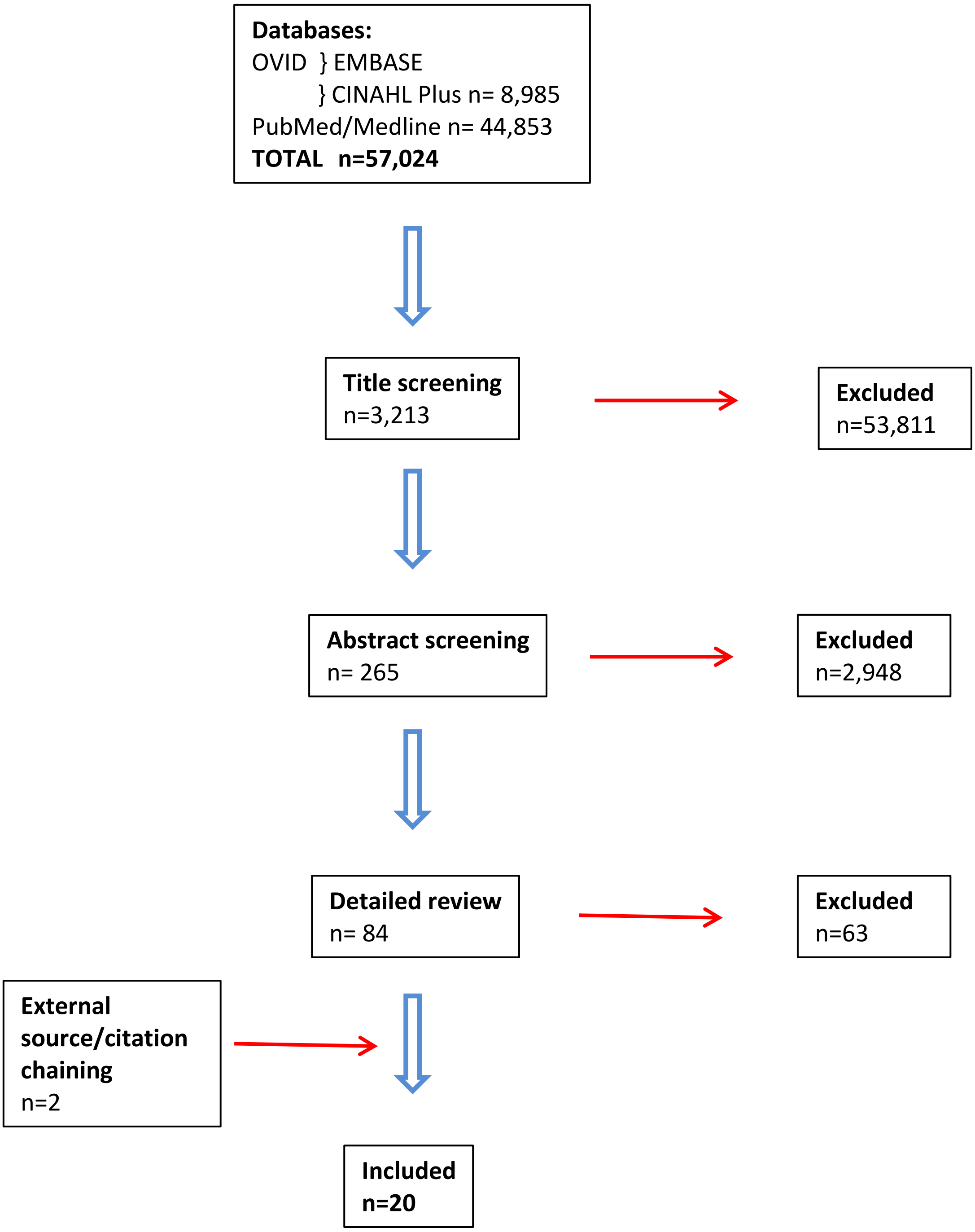
Primary Search Term	Secondary Search Term
Cold AND	OR weather OR ambient OR winter OR seasonal OR low OR cold threshold OR temperature OR environment OR thermal comfort
Indoor AND	OR room OR home OR dwelling OR lounge OR dayroom OR day-room OR bedroom OR house OR inside OR housing
Health AND	Or myocardial infarction OR coronary OR heart attack OR stroke OR angina OR blood pressure OR hypothermia OR COPD OR chronic obstructive pulmonary disease OR influenza OR flu OR asthma OR bronchitis OR respiratory disease OR dementia OR fall OR accident OR injury OR mental health OR depression OR morbidity OR mortality OR excess winter deaths OR health OR wellbeing OR vulnerability OR elderly OR infirm OR older people

Inclusion and exclusion criteria (table 2) were discussed with experts in the field to increase likelihood of capturing all relevant published work. Figure 2 documents the process of the literature search to identify suitable articles for review.

Table 2 Inclusion and exclusion criteria

Inclusion criteria	Exclusion Criteria
- Primary research - Human - All ages - All years - References to specific temperatures or thresholds - English - All physical and mental health effects	- Secondary research - Non-English papers - Air quality - Social effects - Heat or over heating - Outdoor temperatures - Workplace/industrial environment - Housing standards - No reference to health effects - No reference to specific temperature/threshold - Perception of temperature/thermal comfort - Effects of energy efficiency measures/interventions (insulation etc.)

Figure 2 – Search process



A total of 57,024 titles were identified from which 3,213 abstracts were checked for suitability and a total of 265 were selected, after application of inclusion and exclusion criteria. A total of 63 papers were then discarded after reading in full. A further two papers were identified for inclusion by citation chaining. Policy documents and reports [4,12,14] were also checked for citations to ensure peer review articles relevant to the question were captured. A total of 20 papers were included.

Weighting the evidence

The majority of studies meeting the inclusion criteria were observational/cross sectional studies and were graded using the National Institute for Health (NIH) grading system, which includes checklists for this type of study design as well as randomised studies, case control and cohort studies.

Other frameworks were considered, such as the Scottish Intercollegiate Guidelines Network (SIGN) which although appropriate for the consideration of evidence which will lead to guidance and recommendations for heath, do not include tools for evaluating evidence from cross-sectional studies. In addition, the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system was considered, however, one of the limitations of using the GRADE system for this particular review is that the framework was primarily designed to address questions about alternative management strategies, interventions, or policies in terms of individual-level clinical interventions. The European Centre for Disease Prevention and Control suggest that there are other challenges in using GRADE for use in public health with some categories of studies which cannot be assessed by GRADE.[26]

The NIH checklists enabled the reviewers objectively to account for the methodological quality of individual studies alongside the weight of evidence and consistency of findings to support evidence-based recommendations. Two reviewers independently classified study design, completed a methodology checklist, made a quality rating of each study and assigned a grade. The grades were then compared and if there was a disparity the reviewers discussed the paper and assigned an agreed grade. The results were then discussed with a two further members of the reviewing team for finalised grading.

A total of 20 papers were included in the review. These were discussed with experts in the field and cross checked with recently published evidence reviews to ensure that no other work (published or emerging) was overlooked.

Results

The results are presented below and organised by population group (general, older people, those with chronic illness and young people). A detailed critique of each paper can be found in each accompanying table.

General adult population

For the purposes of this review, the general adult population is defined as adults between the ages of 16 and 64 years.

A total of 12 papers examined the impacts of indoor temperature thresholds on the general population. Health outcomes included blood pressure, body mass index, haematological and biochemical markers, and changes to core and skin temperature. The 12 studies are: one small randomised controlled trial of adults without relevant pre-existing disease;[27] four large population-based studies;[28,29,30] (where levels of pre-existing disease are not always clear); and seven very small, laboratory-based studies of healthy adults.[32,33,34,35,36,37] These laboratory-based studies used small sample sizes and volunteers, often with levels of activity and clothing that are unlikely to be experienced in day to day life. Although consistent in their findings, they lack external validity (ie the extent to which the results of a study can be generalised to other situations and to other groups of people) and therefore provide only weak evidence which is supportive rather than conclusive.

Table 3 shows a detailed summary of all papers examining health effects on the general, adult population.

Table 3 – Summary of studies on the general adult population

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
27	Saeki, K., Obayashi, K, Iwamoto, J., Tanaka, Y., Tanaka, N., Takata, S., Kubo, H., Okamoto, N. Tomioka, K., Nezu, S., Kurumatani, N., 2013. *Influence of room heating on ambulatory pressure in winter: a randomised controlled study.*	To determine whether intensive room heating in winter decreases ambulatory BP as compared with weak room heating resulting when sufficient clothing and bedclothes are available. Parallel group, assessor blinded, simple randomised controlled study with 1:1 allocation.	GOOD	**146** adults with no chronic cardiovascular illness, diabetes or kidney disease aged **18-60** yrs. from the Nara prefecture in **Japan** where winter temperatures average about **3 to 5 °C**	Intensive heating group: **11h** over night at **22°C**. Weak heating group : **11h** over night at **12°C**	**Primary outcomes:** Evening BP (**2h** prior to going to bed), night-time BP (mean **whilst in** bed), morning BP (**2h** after getting up) and morning BP surge **Secondary outcomes:** Mean skin temperatures, bed temperatures, and subjective sleep quality	Morning and evening BP measurements were found to be lower in those in an intensively heated room **(22°C)** compared to those in a room heated to only **12°C**. Morning systolic was lower by **5.8mmHg** (95% CI 2.4-9.3mmHg p=<0.01) and diastolic by **5.1mmHg** (95% CI 2.3 - 7.9mmHg p=<0.01). Morning BP surge was supressed to two thirds of that observed in the colder room (sleep trough BP surge 14.3 (SD 8.7) vs 21.9 (SD 10.9) mmHg p=<0.01); pre-waking BP surge, 9.7 (SD 8.4) vs 14.9 mmHg (SD 9.6) p=<0.01). No statistically significant difference in night-time BP and authors suggest this is due to the increased use of bedclothes and blankets. Authors suggest that intensive heating to **22°C** may reduce clinical stroke by **25.5%** and haemorrhagic stroke by **12.4%** and all-cause mortality by **12.4% in the elderly,** although the sample were adults aged 18-60.	Confounders controlled for include age, gender, BMI and smoking, but not alcohol consumption or other medication use such as those for thyroid. Participants were blinded to allocation until testing began. They were randomly assigned to their group by an allocator using random sequencing. The participant supervisor and data analyst were blinded to exposure. BP, body and room temperature were measured using automated devices and measurements were masked. This blinding of participants, supervisor and analyst is considered a major strength of this study. Primary outcomes were calculated using only BP and demographic data by analyst blinded to temperature measurements. No information was given about how the sample was recruited and there is a risk of selection bias with issues of external validity. Although the study is in Japan, the area where the study took place has a climate similar to the UK.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
28	Daly, M., 2014. *Association of ambient indoor temperature with body mass index in England.*	To test the hypothesis that those living in homes where the ambient temperature is above the thermal neutral zone (~23°C) will have a lower body mass index than those living in cold conditions. Cross-sectional analysis of existing data set of the Health Survey for England	GOOD	**100, 152** adults aged **≥ 16 years.** Mean age **47.6** years (**SD=17.7**). 44.53% had a long standing illness. 4.43% reported 'bad health' and 1.16% reported 'very bad health'. Subjects participated in 13 independent annual surveys with identical measures. Nationally representative sample. Sub-sample of **34,052** examined separately to evaluate effects of additional control variables.	room temperatures **19°C - 20.5°C** **20.5°C – 21.5°C** **21.5°C – 23°C** **Over 23°C**	**Primary outcomes:** Body mass index	In **100,152** English adults ,high indoor ambient temperatures of **23°C**+ predicted lower BMI levels(b=-0.233, SE=-.053, P<0.001), compared with temperatures of <19°C in analyses adjusted for participant age, gender, social class, health and the month/year of assessment . . The intermediary temperature quintile groups (ie, 19–20.5°C; 20.5–21.5°C; 21.5–23°C) did not differ in their BMI levels from those residing below 19°C. Author suggests this may be due to the fact that excess energy expended to maintain thermal homeostasis at low temperatures is counterbalanced by increased calorific intake.	The data used are from a very large, population based study and is highly likely to be a representative sample of the population of England. The analysis uses 13 years of cross sectional data. Considers long term effects of exposure to indoor temperatures. Unclear as to whether the increased BMI meant that this equated to 'obese' status (BMI ≥ 30) but the mean BMI of 26.68 is outside of the 'normal-healthy range' (BMI 19-25). The exposures overlap by 1°C in each of the 4 exposure groups which may affect the results. Whether this has any practical application in clinical terms as weight loss intervention is questionable on the basis of this one study. Effects of clothing and body fat were not considered. Study considered effect of vigorous activity levels, but not normal daily activity levels in the home environment.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
29	Shiue, I. & Shiue, M., 2014. *Indoor temperature below 18°C accounts for 9% population attributable risk for high blood pressure in Scotland*	To examine the relationship of indoor temperature and risk of high BP at a population level. Cross-sectional analysis of existing data set of the Scottish Health Survey	GOOD	From a study cohort of **17,253** data on room temperature and BP were available for **2,047** adults aged **16-95** years**.** The Scottish Health Survey is a country-wide, population based survey.	Single temperature measurement in subject's home. Mean room temperature: **20.1°C** (**SD 2.4**) **0°C** -28.2**°C** .	**Primary outcome:** Systolic and diastolic blood pressure	Households heated to below **18°C** had a higher risk of high BP (OR 2.08, 95% CI 1.12-3.43, **P=0.004**) and a further increase in risk if heated to below **16°C** (OR 4.92, 95% CI 1.97-12.24, **P=0.001**). Population attributable risk of hypertension due to an indoor temperature of less than 18°C was 9.3% and 16°C a further 4.5% risk. Authors concluded that 9% of hypertension can be prevented as a result of low indoor temperatures of below 18°C.	Data extracted from a large, country-wide, population level survey, sample highly likely to be representative. Results are from a single survey with measurements typical of a cross sectional study and does not seek to establish a trend. Confounders adjusted for in analysis do not include pre-existing disease or disability, (although whether subject had high blood pressure was recorded), daily activity levels, medication use and smoking, which is a factor known to influence cardiovascular risk factors such as blood pressure, there is likely to be some residual confounding that might explain the findings. Unclear as to whether this population is healthy or have pre-existing illnesses.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
30	Bruce, N., Elford, J. Wannamethee, G. Shaper, A. G., 1991. *The contribution of environmental temperature and humidity to geographical variations in blood pressure*	To assess the potential contribution of room temperature at time of BP measurement and outdoor temperature and humidity to geographic variations in BP. Analysis of existing data set from British Regional Heart Study (BRHS). Second, smaller cross sectional study to examine regional variations specific to this hypothesis (Nine Towns Study)	FAIR	BRHS cohort: **7,735** males **40 - 59** years living in 24 towns across in Britain. Nine Towns Study: **2,610** males and females aged **25-29**, **40-44** and **55-59**.	In the BRHS and NTS studies a single room temperature was recorded - in a clinical setting only. In the Nine Towns Study (NTS) this was immediately prior to BP measurement. No information is given on duration of exposure to room temperature. Mean room temps (°C): British regional Heart Study: **21.1±1.89°C** Nine Towns Study males: **19.8 ± 1.58°C** females: **19.9 ± 1.76°C.** Range of mean between towns in NTS given as **17.1°C** and **24.2°C**	**Primary outcomes:** Systolic (sBP)and diastolic BP (dBP). Mean arterial pressure. **Secondary outcomes:** skin temperature, external temperature and humidity.	Evidence of negative association for sBP and dBP with room temperature.(British regional Heart Study: 21.1±1.89°C) (Nine Towns Study males: 19.8 ± 1.58°C females: 19.9 ± 1.76°C). Adjusting for age, on an individual level for each rise in room temperature of **1°C** an effect equivalent to **0.5mmHg** decrease in sBP and dBP is seen and these findings are significant for both (**p=<0.001**). However, this reduction in BP is no longer significant when town is adjusted for. Authors suggest indoor temperatures cannot account for regional differences in blood pressure.	The original BHRS study is a large population study. Care was taken to ensure all regions in the UK were represented as far as possible but this may have affected the results through selection bias. The NTS states that 9 towns were selected from 24 in the BRHS but does not state how selection took place and this may have affected the external validity of the results. Standardised methods of recording outcomes were used to reduce inter-operator variance. Temperature was recorded once in the clinic room and duration of exposure is unclear. Other confounders such as smoking or medication use prior to measurement were not accounted for.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
31	Bo, S., Ciccone, G. Durazzo, M., Ghinamo, L., Villois, P., Canil, S., Gambino, R., Cassader, M., Gentile, L., Cavallo-Perin, P., 2011. Contributors to the obesity and hyperglycaemia epidemics. A prospective study in a population based cohort.	To investigate the possible associations of sleep restriction, **house temperature**, hours of television watching, consumption of restaurant foods, use of aircon, use of antidepressants/ antipsychotic drugs and the risk of obesity and hyperglycaemia Population-based prospective cohort study.	FAIR	1,645 Caucasian subjects aged 45-64 years selected from 6 GP practices in the Asti province in northern Italy. Where winter temperatures average about 3 to 5 °C, Subjects with obesity or hyperglycaemia were excluded at baseline, but no further information on health status of participants	Mean home temperature over autumn and winter recorded in the subject's homes. Measured at the beginning of the study and at the 6 year follow up. baseline characteristics according to obesity development at follow-up: mean house temp of participants who were not obese: 19.4°C ± 1.6°C mean house temp of participants who were obese: 20.8°C ± 2.1°C Tertiles of temperature used in analysis: 1st tertile ≤18C 2nd tertile >18C <20C 3rd tertile ≥ 20°C	**Primary outcomes:** Incident obesity and incident hyperglycaemia	Incident obesity: 8% of subjects at follow up had become obese (BMI ≥ 30) with high values of BMI and other variables including higher home temperatures. Being in the highest tertile of home temperature (≥ 20°C) was independently associated with incident obesity (OR 2.06, 95% CI 1.02 - 4.16, p=0.04) after adjusting for sex, BMI, diet and metabolic factors, TV hours, antipsychotic/antidepressant use, aircon, sleep hours and educational attainment. Incident hyperglycaemia: 17.8% of subjects at follow up had developed hyperglycaemia. These were more frequently male and had higher values of other variables including higher home temperatures. Being in the highest tertile of home temperature (≥ 20°C) was independently associated with incident hyperglycaemia (OR 1.95, 95% CI 1.17 – 3.26, p=0.01) after adjusting for variables above with an additional variable of glucose. Study found a non-linear relationship between indoor temperature and body mass index and fasting glucose levels and a two fold increase in risk for incident obesity and incident hypoglycaemia estimated in subjects living at temperatures above 20°C.	The sample in this study is small and recruited from a small number of physician's practices in northern Italy, although the climate is similar to that in the UK. No information was given as to how the GP practices were selected. The sample are from a specific geographical area, largely rural and the age range is that outside of the population most at risk of the harmful effects of cold. It is unclear whether this is a healthy population or whether participants had chronic illness. Use of medication for psychological disorders was considered. The effect of socio-economic status was not analysed and could be a potential confounder, but educational attainment was accounted for. No information was given on the recording and reporting of 'home' temperatures or which rooms were monitored. Self reporting of diet and lifestyle factors may lead to reporting bias in subjects and under or overestimation of these factors. Impaired glucose fasting and diabetes were grouped under one heading of 'incident hyperglycaemia' and there is no further information. No

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
								statistically significant effect was detected at <20°C and so unable to establish trend. No information was given on the recording and reporting of 'home' temperatures or which rooms were monitored
32	Leppäluoto, J Korhonen, I Hassi, J., 2001: *Habituation of thermal sensations, skin temperatures and norepinephrine in men exposed to cold air.*	To establish whether the thermal sensations, body temperatures, blood pressure and hormonal responses become habituated to repeated cold air exposures. Cross sectional study	GOOD	**6** healthy Caucasian males mean age 20.5 ± 0.2 yrs. Volunteers. Study took place in Finland in August where temperatures range from 8°C-22°C in that period.	Indoor room temperatures Subjects exposed to **30mins at 27-28°C** for baseline observations then **120 mins at 9.78 - 10.08°C. 2 hour** exposure repeated on **11** consecutive days. All subjects wearing shorts and sat for duration of exposure on netting chairs.	**Primary outcomes:** rectal and skin temperatures, cold sensations, oxygen consumption, blood pressure	Thermal habituation of the face was complete in all subjects by day 11 (ie: people get used to 'feeling' cold) Systolic BP increases significantly during first 5 minutes; diastolic at 120 mins with a brief transient habituation effect on days 4 and 6. A reduction heart rate was observed. Increased plasma norepinephrine denoted activation of the sympathetic nervous but reduced at day 5 and 10. Haemoconcentration was observed indicated by an increase in blood cells and serum proteins on day 0 and 5 but not day 10 suggesting that proteins do not become concentrated in response to repeated cold stimuli. When cold exposures were repeated daily - thermal sensations are habituated first	Sample size very small and only healthy males. Not clear how findings apply to wider population, females, children, older people and those with chronic illness. Clothed only in shorts and in experimental cold room so unlikely to be represent conditions in the homes. Only looks at effect of short term exposure. Study took place in August not in winter. Effects observed consistently across all subjects in study and findings should not be considered conclusive but suggestive. Measurement methods robust to reduced inter-operator variability but no blinding in subjects (not achievable) or researchers.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
33	Mercer, J.B., Osterud, B. Tveita, T., 1999: *The effect of short-term cold exposure on risk factors for cardiovascular disease*	To establish whether alterations in the haemostatic system following exposure to cold could be responsible for increased winter risk of cardiovascular disease. Cross sectional, study	FAIR	**11** healthy men from Norway aged **24 - 27** years.	**2 exposures** each day over **5 day period.** Each exposure lasts for **1h**. First exposure **11°C** Second exposure 26°C. Wearing shorts only and sat on camping stool for duration of exposure.	**Primary outcome:** Subjective self assessment of thermal stress, blood parameters (cell differentiation, coagulation, fibrinolytic inflammation)	1 hour exposure to cold caused an inflammatory response in all subjects and a tendency for a state of hypercoagulability. Statistically significant increase in erythrocyte count and plasma fibrinogen when exposed to **11°C** and decrease in lymphocytes. Increased erythrocytes are usually associated with increased plasma viscosity. No increases in platelets found after cold exposure. Large cold induced increase of potent vasoconstrictor.	Small sample size of healthy males only. Not clear how this would apply to females, children, older people and those with chronic illness. Not clear as to time of year experiment was carried out, this may affect results. Short term effects only measured. Subjects clothed only in shorts and in experimental room which is not representative of the home environment. The cold exposure occurred prior to warm exposure in all subjects and it is unclear how this has affected the results. Measurements consistent and robust to reduce inter-operator variability and bias. Participants and investigators not blinded.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
34	Neild, P.J. Syndercombe-Court, D. Keatinge, W.R. Donaldson, G.C. Mattock, M., Caunce, M., 1994: *Cold induced increases in erythrocyte count, plasma cholesterol and plasma fibrinogen of elderly people without a comparable rise in Protein C or Factor X*	To establish whether cold induces haematological changes in elderly people. Cross sectional, study	FAIR	**12** healthy volunteer subjects from the UK, **6** male, **6** female evenly split between each group. **6** in older group (**66-71 yrs**) **6** in young group (**20-23 yrs**)	Indoor temperature Subjects studied **twice** with an interval of at least **one week** between studies. All subjects had **90 mins** stabilisation in **control** environment at **22±1°C** wearing T-shirt and shorts recumbent with 2 blankets. Then exposed to a further **2 hours** at **control** temperature or to **2 hours at 18±0.5°C** on net bed with blankets removed.	**Primary outcomes:** changes in temperature and metabolic rate, changes in erythrocyte parameters, changes in fluid and electrolytes	Two hour exposure causes little change in body temperatures. Exposure to cold increases erythrocyte count and cholesterol concentrations in both groups p. Decrease in skin temp observed in both groups, with quicker recovery in younger compared with older group. Increased water loss was observed in both groups.	Unclear as to what time of year study was conducted and the possible effects of exposure to home/outdoor temperatures. Short term exposure to cold only. Minimum one week interval, maximum not reported. Small sample size of healthy volunteers. Unclear as to how findings apply to those over or under the age ranges and those with chronic illness. No blinding of researchers to exposures. Measurements consistent and robust to reduce bias. Clothing and experimental setting does not reflect home environment and behaviours.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
35	Wagner, J. A., Horvath, S. M. Kitagawa, K., Bolduan, N. W., 1987: *Comparisons of blood and urinary responses to cold exposures in young and older men and women*	To describe the blood and urinary responses that we observed while attempting to derive further insight into the physiological responses to cold in young and older groups of men and women. Cross sectional, study	FAIR	**10 male, 10 female** volunteers from California, USA Young group: Men **22 ± 1** yrs Women **24 ± 1** yrs Older: Men **64 ± 2** yrs Women **61 ± 3 yrs**	All participants exposed, semi reclining in minimal clothing for **2 hours** to each of 4 randomly ordered thresholds: **10°, 15°, 20°, 28° C**	**Primary outcome:** Haemoglobin, haematocrit and total plasma protein levels. Blood lactate and free fatty acid levels. Urine volume post exposure. Plasma volume and blood glucose levels.	All participants showed an increase in haemoglobin, haematocrit and plasma protein levels over time exposed to cold, suggesting haemoconcentration. These effects occurred earlier in women than men, but effect greater in men except plasma protein levels, which older women had highest levels. Plasma volume decreased in all subjects and effects greater at **10°** and **15°C** than at **20°C** - effects greater in women. Lactate levels increased at higher temperatures in men (**15°C**) when compared to women (**10°C**). Increase in urine volume with decreasing temperature in young men. Young women did not have significant diuresis until **10°C**. Older women were more able to control their temperature better than all other groups due to metabolic advantages and body fat.	Small sample. Not clear as to whether participants are healthy. Unclear how findings applicable to children and those with chronic illness. Unclear as to what time of year this study took place. Exposures due to home and outdoor temperatures not adjusted for or considered in the findings. Minimal clothing not defined. Experimental environment not reflective of home environment. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
36	Collins, K.J., Easton, J.C. Belfield-Smith, H., 1985: *Effects of age on body temperature and blood pressure in cold environments*	To examine thermoregulatory and cardiovascular responses of young and older volunteers in a range of temperatures. Cross sectional, study	FAIR	**9** healthy subjects from the UK. **5** older people: **63-70yrs** **4** young people: **18-24yrs**	Subjects exposed for **4 hours** per day over **7-10 days**. First **4hr** exposure was at **9°C** then subsequent **4 hr** exposures to **6°C**. All subjects sat wearing 1.5 clo. After **2 hours**, subject sat for **1 hr** in **23°C** then returned to cold. Following this an additional **2hr** exposure to **6°C, 12°C, 15°C** and **23°C**.	**Primary outcomes:** Body temperatures, heart rate and blood pressure.	Statistically and clinically significant increases in systolic BP with greatest increase in older group (**24 ± 4mmHg/13 ± 4mmHg**) at **6°C** and a significant, but less marked effect at **12°C** (mean measurement not stated) compared to younger group. Steady decrease in heart rate at **6°C and 12°C** in older men, with decrease at **6°C** in younger group. No evidence of acclimatisation over time/repeat cold. **6°C** still depressed core temperature in both groups (more in older group - **0.4 ± 0.1°C**). These observations were consistently observed on **7-10** different days in every subject at **6°C and 9°C.** Authors conclude that it is likely old age related changes to intrinsic thermoregulatory system; reflected in reduced vasoconstriction response. Cold extremities and lowered core temperatures may lead to short-term increases BP. BP responses to cold in old age occur significantly more slowly but reactions more marked than in young - **15°C** suggested as minimum level at which older people should live.	Small sample. Not clear as to whether participants are healthy. Unclear how findings applicable to children and those with chronic illness. Unclear as to what time of year this study took place. Exposures due to home and outdoor temperatures not adjusted for or considered in the findings. Experimental environment not reflective of home environment. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
36	Inoue, Y., Nakao, M. Araki, T., Ueda, H., 1992: *Thermoregulatory responses of young and older men to cold exposure*	To examine age related differences in thermoregulatory responses to cold air. Cross sectional, study	FAIR	**19** healthy active male volunteers from the UK**.** **10 older men**: range **60-71**yrs **9 younger men**: range **20-25**yrs	Two studies in summer and winter: **60 mins 28°C** acclimatisation for all subjects at both summer and winter studies. **60mins at 17°C** in summer study. **60 mins at 12°C** in winter study.	**Primary outcomes:** Oxygen uptake, rectal and skin temperatures and blood pressure. **Secondary outcomes:** Body fat and room temperature	Significant effects on BP at **17°C** in both groups, but greater effect in older people at **12°C**. Different thermoregulatory responses to cold stress in older group observed in summer and winter, compared to younger group - suggests ageing associated with decreased ability to maintain core temp during cold. Older men showed greater increase in BP and decrease in core and skin temperature than younger group. Effects may be more striking in more sedentary older men. Suggest that cold stress produces greater strain on cardiovascular system in older men to effect thermoregulation. Age is a limiting factor for development of cold tolerance, suggesting a decrease in adaptive temp range with age.	Small sample. Unclear how findings applicable to children and those with chronic illness and more sedentary lifestyle. Experimental environment not reflective of home environment. Season accounted for in experimental design. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.
37	Collins, KJ. Hoinville, E., 1980: *temperature requirements in old age*	To determine thermal comfort preferences in groups of old and young subjects by exposing them to controlled temperature environments. Cross sectional, study	FAIR	**32 healthy subjects** **16 Older people:** **68-8 7**yrs **16 Younger adults**: **19-39** yrs In controlled, laboratory conditions.	**2 hours** per day over **5** separate **days** at **12°C, 15°C, 18°C, 21°C, 24°C**. Randomly ordered exposures. Subjects sitting in armchairs in cold room for 1.5hrs then light activity permitted.	**Primary outcomes:** Skin, oral, aural and urine temperatures, thermal comfort (using Bedford Scale) and temperature discrimination . **Secondary**	**Physiological effects:** Urine temperature in all subjects unaffected. likely that core temperatures maintained even at **12°C**. Skin temperature fell progressively with ambient temperature and slightly lower in older group at all exposure levels. Oral temperature stable in both groups at **24°C**. Oral temperature fell more quickly in older group than younger group at **15°C** and **12°C**. **Thermal comfort:** Preferred	Small convenience sample with individuals all in good health. Unclear how findings applicable to children and those with chronic illness. Unclear as to what time of year this study took place. Exposures due to home and outdoor temperatures not adjusted for or considered in the findings. Experimental environment not reflective of home environment. Short term exposure only. No

Ref. No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
					Subject wore own clothing to provide 1.0 clo of insulation - same ensemble for every exposure.	**outcomes:** heart rate	temperatures for both old and young persons after sitting for **2 hours** wearing 1.0 clo is **21.1°C**. With **17°C** being comfortably cool and **12°**C too cold. The average comfortable temperature for sedentary older people and younger adults wearing 1.0 clo is **21.1°C ±** 2.9**°C**. Moderate activity and heavy winter wear could see this drop to **16°C**. **Thermal discrimination:** Fingertip temperature discrimination less precise in the older group. Discrimination deteriorated in both groups as skin temperature decreased in colder environments. Mean thermal comfort temperatures for healthy older people: **Sitting at rest:** 1.0 clo (normal indoor wear in winter) 23.2 1.5 clo (heavy winter wear) 20.6 **Sitting, reading, occasional light activity**: 1.0 clo 21.1 1.5 clo 18.4 **Light domestic work**: 1.0 clo 19.8 1.5 clo 16.2	blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

Evidence summary – general adult population

Cardiovascular effects

The evidence from the small number of epidemiological studies identified suggests an association between raised blood pressure with exposure to indoor temperatures of around 18°C or colder.

Shiue and Shiue [29] (NIH rating Good) found that among 2047 Scots aged 16-95, those living in households with temperatures below 18°C had a higher risk of increased blood pressure than those who had household temperatures maintained above 18°C (OR 2.08, 95% CI 1.12-3.43, P=0.004) and a further increase in risk with temperatures below 16°C (OR 4.92, 95% CI 1.97-12.24, P=0.001). They estimate that 9% of hypertension could be prevented as a result of keeping indoor temperatures above 18°C, although these data and analysis are not presented.

Saeki et al [27] (NIH rating Good), in their study of 146 Japanese adults, demonstrated significantly lower morning systolic blood pressures of 5.8 mm Hg (95% CI 2.4 to 9.3) and smaller sleep-trough morning blood pressure surges (14.3 against 21.9 mm Hg; p<0.01) in people who spent the nights in rooms heated to 22°C, compared with those in rooms at 12°C. The authors suggest that such intensive room heating may reduce clinical stroke, haemorrhagic stroke and all-cause mortality.

Bruce et al [30] (NIH Grade Fair) found a statistically significant decrease in systolic and diastolic blood pressure with increasing room temperature in around 10,000 British adults, but this decrease was no longer significant once town was taken into account. These are findings are more difficult to interpret since ambient room temperature was measured in clinic settings, with no indication of duration of exposure.

The small laboratory studies support the findings that exposure to cold temperatures increases blood pressure and risk of blood clotting in healthy people who are sedentary and wearing minimal clothing. Neild et al [34] (NIH rating Fair) suggests the threshold at which these effects start to occur is 18 (+/-0.5)°C; effects include increases in erythrocyte count and fibrinogen both of which are important for thrombus (blood clot) formation.

Metabolic effects

There is a hypothesis that indoor temperatures may be linked with obesity, but the evidence is not conclusive. One study of over 100,000 English people by Daly [28] (NIH rating Good) showed that BMI levels of those living in temperatures of 23°C were significantly lower than in those who live at <19°C (b=-0.233, SE=-.053, P<0.001). However, this was not supported by Bo et al [31](NIH rating Fair) who studied 1,645 Italian subjects aged 45-64 and found that having obesity (BMI ≥ 30) and hyperglycaemia (impaired fasting glucose and diabetes) at a follow-up assessment 6 years later were associated with higher indoor temperatures.

Older people

For the purposes of this paper, ‘older people’ are defined as those over 65 years. Within this age group there will be healthy active individuals free of chronic illness as well as people who are less mobile and have chronic illnesses. Not all the papers considered used this age cut-off to define older people.

A total of 11 papers examined the impacts of indoor temperature thresholds on the older population. Health outcomes included blood pressure, respiratory symptom score, haematological and biochemical markers, and changes to core and skin temperature, as well as considerations of thermal perception and comfort. The 11 studies are: one large population-based study that has already been considered in the context of the general adult population;[29] three epidemiological studies in older people (aged 60 and above); [5,38,39] one cross-sectional study of adults with chronic obstructive pulmonary disease;[40] and six very small, lab-based studies of healthy adults and older people.[34,35,36,37,41,42] As before, these lab-based studies are characterised by their small sample sizes and use of volunteers, often with levels of activity and clothing that is unlikely to be used in day to day life. Although consistent in their findings, they lack external validity and can therefore only provide weak support to the evidence base.

Table 4 summarises the findings and detailed critique of the papers examining the effects of cold indoor temperature thresholds on older people.

Table 4 – summary of studies on older people and indoor temperatures

Ref No	Study/ author/year	Aim of study & design	NIH Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
29	Shiue, I. & Shiue, M., 2014. *Indoor temperature below 18°C accounts for 9% population attributable risk for high blood pressure in Scotland*	To examine the relationship of indoor temperature and risk of high BP at a population level.	GOOD	From a study cohort of 17,253, data on room temperature and BP were available for **2,047** adults aged **16-95** years**.** The Scottish Health Survey is a country-wide, population based survey.	Single temperature measurement in subject's home. Mean room temperature: **20.1°C** (SD 2.4) Range 0°C -28.2°C .	**Primary outcome:** Systolic and diastolic blood pressure	Households heated to below **18°C** had a higher risk of high BP (OR 2.08, 95% CI 1.12-3.43, P=0.004) and a further increase in risk if heated to below **16°C** (OR 4.92, 95% CI 1.97-12.24, P=0.001). Population attributable risk of hypertension due to an indoor temperature of less than 18°C was 9.3% and 16°C a further 4.5% risk. Authors concluded that 9% of hypertension can be prevented as a result of heating homes to above 18°C.	Data extracted from a large, country-wide, population level survey, sample highly likely to be representative. Results are from a single survey with measurements typical of a cross sectional study and does not seek to establish a trend. Confounders adjusted for in analysis do not include pre-existing disease or disability, (although whether subject had high blood pressure was recorded), daily activity levels, medication use and smoking, which is a factor known to influence cardiovascular risk factors such as blood pressure, there is likely to be some residual confounding that might explain the findings. Unclear as to whether this population is healthy or have pre-existing illnesses.

40	Osman, L. M. Ayres, J. G. Garden, C., Reglitz, K. Lyon, J.; Douglas, J. G., 2008: *Home warmth and health status of COPD patients*	To explore whether health status of patients with chronic obstructive pulmonary disease (COPD) was associated with the number of hours when homes reached recommended standards or indoor warmth in living rooms and bedrooms. Cross-sectional study	GOOD	206 homes of COPD patients who had been admitted to Aberdeen Royal Infirmary with an exacerbation of COPD between January 2003 and October 2004. **Mean age 69** (SD 8.2)years, 55% female. 18 patients had mild COPD, 91 moderate COPD and 39 severe COPD. 58 smokers, 90 non-smokers.	Exposure over **1 week** of monitoring: Living room (LR) hours at **21°C**: Median **46** IQR **8-119** Bedroom (BR) **hours** at **18°C**: Median **126** IQR **56-164** Number of **days** with living room at **21°C for 9 hours**: Median **2** IQR **0-7** Number of **days** with bedroom at **18°C** for **9 hours**: Median **5** IQR **0-7**	**Primary outcomes:** SGRQ (St Georges Respiratory Questionnaire) scores for symptoms of COPD, impact of COPD and activity limitations of COPD. EQVAS (Euroquol Visual Analogue Scale) to measure level of thermal comfort. **Secondary outcomes:** hours of warmth, smoking and health and health status.	**9 hours** of LR warmth of **21°C not achieved** in more than **50%** of homes. 8 subjects had LR temperature at 5pm of below 18°C and two below 14°C. BR was more likely to be maintained at recommended levels. Better health status was associated with more hours of indoor warmth at and above **21°C** (p=0.01). Days with bedroom temperatures of at least 9 h at 18°C showed a trend to association (p = 0.04). Greatest effects were observed in those who smoke compared with non-smokers.	The sample are taken from a population of those who were admitted to hospital with complications of their illness and so may not be representative of the total COPD population as effects may be smaller in those with milder disease. In addition, less than 50% of the eligible population took part in the study and there is not a comprehensive examination of how this population differed from those who took part other than deprivation scores. Therefore this population may not be representative of those with severe COPD. In terms of recommendations for indoor temperatures, findings from this study are most applicable to smokers where the effects were greater compared with non-smokers.
41	Collins, KJ. Hoinville, E., 1980: *temperature requirements in old age*	To determine thermal comfort preferences in groups of old and young subjects by exposing them to controlled	FAIR	**32 healthy subjects** from the UK **16 Older people:** 68-87yrs **16 Younger adults**:	**2 hours** per day over **5** separate **days** at **12°C, 15°C, 18°C, 21°C, 24°C**. Randomly ordered	**Primary outcomes:** Skin, oral, aural and urine temperatures, thermal comfort (using Bedford Scale) and	**Physiological effects:** Oral temperature stable in both groups at **24°C**. Oral temperature fell more quickly in older group than younger group at **15°C** and **12°C**. Urine temperature in all subjects unaffected. likely that core temperatures maintained even at **12°C**. Skin temperature fell	Small sample and all but one participant is healthy. Unclear how findings applicable to children and those with chronic illness. Unclear as to what time of year this study took place, which may affect exposures and results. Exposures due to home and outdoor

		temperature environments. Cross sectional, study		19-39 years In controlled, laboratory conditions.	exposures. Subjects sitting in armchairs in cold room for 1.5hrs then light activity permitted. Subject wore own clothing to provide 1.0clo of insulation - same ensemble for every exposure.	temperature discrimination. **Secondary outcomes:** heart rate,	progressively with ambient temperature and slightly lower in older group at all exposure levels. **Thermal comfort:** Preferred temperatures for both old and young persons after sitting for **2 hours** wearing 1.0 clo is **21.1°C**. With **17°C** being comfortably cool and **12°**C too cold. The average comfortable temperature for sedentary older people and younger adults wearing 1.0 clo is **21.1°C ±** 2.9**°C**. Moderate activity and heavy winter wear could see this drop to **16°C**. **Thermal discrimination:** Fingertip temperature discrimination less precise in the older group. Discrimination deteriorated in both groups as skin temperature decreased in colder environments. Mean thermal comfort temperatures for healthy older people: **Sitting at rest:** 1.0 clo (normal indoor wear in winter) 23.2 1.5 clo (heavy winter wear) 20.6 **Sitting, reading, occasional light activity**: 1.0 clo 21.1 1.5 clo 18.4 **Light domestic work**: 1.0 clo 19.8 1.5 clo 16.2	temperatures not adjusted for or considered in the findings. Experimental environment not reflective of home environment. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

38	Fox, R. H. Woodward, P. M. Exton-Smith, A. N. Green, M. F., Dennison, D. V. Wicks, M. H., 1973a: *Body temperatures in the elderly: A national study of physiological, social and environmental conditions*	To ascertain the incidence of low body temperatures in the elderly at home during three winter months and to relate the body temperatures (hand, mouth, core) to the environmental temperatures (room and external) and living conditions. To identify the categories of elderly people particularly at risk of developing hypothermia. Longitudinal study	FAIR	**1,020** subjects aged **65** and over living in UK. 391 males, 629 females. Local sample surveyed in London Borough of Camden, but size of sample and other characteristics not stated.	**2** measurements over **24 hours** in the home setting: National sample mean **AM temp**: **15.97°C** ± 3.38 **PM temp** **18.16°**C ± 3.27	**Primary outcomes:**, body temperature. **Secondary outcomes:** Comfort votes, socioeconomic circumstances, hypothermia/low body temperature	**75%** of rooms heated to below **18.3°C** and **54%** below **16°C** . Low indoor temperatures lead to reduced hand and mouth temperatures, but no relationship with core temperature. Relationship between hand and all other temperatures reflects role of peripheral body parts in thermoregulatory control. Characteristics of those with low deep body temperatures: Living alone, single/widowed, no heating in bedroom, no central heating, lacking hot water.	The study sample was recruited by random probability sampling and comprised 1,020 subjects over 65 years of age. Comparisons with census data showed that the sample was representative for age and sex. Measurements uniform/consistent to reduce bias. No consideration given to behaviours such as heating home prior to nurse visit which could affect results. Study took place over the winter months of January and February and spring moth of March. No visits took place in November or December which are the period of interest for this study.

39	Fox, R.H. MacGibbon, R., Davies, L. Woodward, P.M., 1973b: *Problem of the old and the cold*	To measure the mouth, urine and hand temperatures of a group of elderly people living at home and to investigate their relation to living conditions and environmental temperatures. Cross sectional, study	FAIR	Sample drawn from participants of previous study. **72** subjects **65-91** (mean **77 yrs**) yrs in receipt of 'meals on wheels' living in UK city of Portsmouth.	Recorded living area temperature on 2 occasions over 24 hours. Range : 9-23 C	**Primary outcomes:** mouth, hand and urine temperatures **Secondary outcomes:** environmental temperature, thermal comfort votes, weather conditions.	81.3% of subject's rooms were heated below **18°C** and 57% were at below **16°C**. 7 subjects had low recorded oral temperatures below 35°C. These subjects were found to be less aware of being cold in winter and did not think they have to wear excessive clothing. Lower warmth and cold thresholds in some combined with low indoor temperatures and a reduced safety margin of heat to lose before hypothermia sets in puts older people especially at risk.	These studies were carried out in the homes of participants to reflect living conditions. Single sample group comprising 72 subjects all in receipt of 'meals on wheels' and were concentrated in one city in the UK and were chosen to participate following their participation in a previous study and therefore are likely not be representative of the general population as convenience sampling is likely to be biased. Vulnerable older people are a target group for affordable warmth interventions and so the findings may be applicable to this target group. Not clear as to whether subjects are healthy or what mobility status is given they are receiving meals on wheels. Measurement by nurse on two separate occasions steps to reduce bias. But this can affect results as subjects may have heated home knowing visit from nurse and purpose of visit. Survey took place in winter.

5	Collins, KJ., Dore, C. Exton-Smith, A. N. Fox, RH., MacDonald, I.C. Woodward, P.M., 1977: *Accidental hypothermia and impaired temperature homeostasis in the elderly*	To clarify the physiological basis of the ageing process in thermoregulation and to try to identify by physiological means those members of an elderly population sample living at home who seem likely to be at risk of developing hypothermia. Cross sectional study	FAIR	**47** older people, 19 male, 28 female**.** Studied in 1972 and again in 1976. Of original sample of 120, only 47 had data available for both studies. Age range **69-90.** Mean **70 ± 4** (1972 group) Mean **74 ± 4** (1976 group) **30** young healthy adults under the age of **45 years** (1972) **10** young healthy adults under the age of **45 years** retested in 1976.	2 measurements over 24 hours. 1972 mean **AM temp 17.38 °C** ± 2.80/ **PM temp 19.42°C** ± 3.14 1976 mean **AM temp 17.74 °C** ± 2.69/ **PM temp 19.00°C** ± 2.81	**Primary outcomes:** oral, urine and hand temperature. **Secondary outcomes:** indoor, outdoor, comfort vote.	Thermal perception between young and older groups very different. Ageing is associated with a decline in autonomic nervous function which leads to impaired thermoregulatory capacity in a high proportion of older people. Although comparisons were made between older people in one group and young people in a second group exposed to cold both groups were healthy and none of the participants had any chronic illnesses. Those at the highest risk of death in cold weather in the UK ie: those over 75 years are not represented in the sample groups in this study. .	Results lack external validity and may not be generalisable to those with chronic illnesses, or the very young. The study took into account activity levels when considering the results. The sample were a sub-sample of a randomly selected population, recruited into a large-scale indoor temperature survey. Tests were carried out in a hospital setting so difficult to apply findings to home environment. However loss to follow up was 61% largely due to illness or death, which, in the older population being studied is not unexpected, even in light of the short follow up time. No explanation given as to why there was such a large drop-out rate for younger subjects. Measurements uniform/consistent to reduce bias. No consideration given to behaviours such as heating home prior to nurse visit which could affect results. Study took place over the winter months of January and February and spring moth of March. No visits took place in November or December which are the period of interest for this study.

42	Saeki, K., Obayashi, K. Iwamoto, J., Tone, N. Okamoto, N., Tomioka, K. Kurumatani, N., 2014: *The relationship between indoor, outdoor and ambient temperatures and morning BP surges from inter-seasonally repeated measures*	To assess the relationship of indoor, outdoor and ambient temperatures with morning BP surges (MBPS), independent of physical activity in elderly individuals living at home. Cross sectional survey.	FAIR	192 older people aged **60 years** and over. Mean 69.9 (SD 6.3) 50% smokers 42.2% subjects were on antihypertensive, prevalence of diabetes was 13% and dyslipidaemia 37.5%. Study took place in the Nara prefecture in Japan where winter temperatures average about 3 to 5 °C, and 25 – 28 °C in the summer with highest reaching close to 35 °C.	**48h** monitoring in winter and again in spring or autumn. Morning mean temperature (SD): **Bedroom** morning temperature mean **10.3°C** (4.0) (winter) **20.2°C** (4.7)(spring/ autumn) **Living room morning** mean: **14.1°C** (4.6)(winter) - **20.4°C** (4.1) (spring/autumn) Night time temperature: **Bedroom** mean **10.9°C** (3.9) (winter)- **20.8°C** (4.6) (spring/autumn)	**Primary outcome:** ambulatory blood pressure, physical activity **Secondary outcome**: and blood parameters (plasma glucose, lipids and haemoglobin)	On winter mornings where living room temperatures were 6.3°C lower than corresponding temperatures in spring/autumn and night time bedroom temperatures were 9.9°C lower; morning sBP increased by 3.0mmHg(95% CI 0.9-5.2, p=<0.01), sleep-trough MBPS increased by 4.9mmHg (95% CI 2.7-7.3, p=<0.01), pre-waking MBPS increased by 5.2mmHg (95% CI 2.9-7.4, p=<0.01) . This is statistically and clinically significant. Multivariate analysis adjusted for potential confounders identified that a 1°C decrease in living room, outdoor and ambient temperatures was significantly associated with a 0.46mmHg (95% CI -0.68, -0.24 p=<0.01) increase in sleep-trough MBPS and an increase of 0.56mmHg (95% CI -0.78, -0.34 p=<0.01) in pre-waking MBPS	Participants were recruited by non-random sampling and therefore limits the generalisability of this study. Study considered seasonal variations and controlled for important confounders such as physical activity, socio economic status, presence of chronic illness smoking and drinking and medication use. Measurements of blood pressure were consistent and ambulatory but temperature measurement was fixed and so exposure outside of home environment was not accounted for.

34	Neild, P.J. Syndercombe-Court, D. Keatinge, W.R. Donaldson, G.C. Mattock, M., Caunce, M., 1994: *Cold induced increases in erythrocyte count, plasma cholesterol and plasma fibrinogen of elderly people without a comparable rise in Protein C or Factor X*	To establish whether cold induces haematological changes in elderly people. Cross sectional study	FAIR	**12** healthy volunteer subjects from the UK, **6 male**, **6 female** evenly split between each group. **6** in older group (**66-71**) **6** in young group (**20-23)**	Subjects studied **twice** with an interval of at least **one week** between studies . All subjects had **90 mins** stabilisation in **control** environment at **22±1°C** wearing T-shirt and shorts recumbent with 2 blankets. Then exposed to a further **2 hours** at **control** temperature or to **2 hours at 18±0.5°C** on net bed with blankets removed.	**Primary outcomes:** changes in temperature and metabolic rate, changes in erythrocyte parameters, changes in fluid and electrolytes **Secondary outcomes:** Long term effects (post 22 hrs)	Two hour exposure causes little change in body temperatures. Exposure to cold increases erythrocyte count and cholesterol concentrations in older people which may indicate a greater risk of thrombosis in this group. Decrease in skin temp greater in elderly who recover slower. Increased water loss in both groups.	Unclear as to what time of year study was conducted and the possible effects of exposure to home/outdoor temperatures. Short term exposure to cold only. Minimum one week interval, maximum not reported. Small sample size of healthy volunteers. Unclear as to how findings apply to those over or under the age ranges and those with chronic illness. No blinding of researchers to exposures. Measurements consistent and robust to reduce bias. Clothing and experimental setting does not reflect home environment and behaviours.

37	Collins, K.J., Easton, J.C. Belfield-Smith, H., 1985: *Effects of age on body temperature and blood pressure in cold environments*	To examine thermoregulatory and cardiovascular responses of young and older volunteers in a range of temperatures. Cross sectional, study	FAIR	**9** healthy subjects from the UK. 5 older people: **63-70yrs** 4 young people: **18-24yrs**	Subjects exposed for **4 hours per day over 7-10 days**. First 4hr exposure was at **9°C** then subsequent 4 hr. exposures to **6°C**. All subjects sat wearing 1.5 clo. After 2 hours, subject sat for 1 hr in **23°C** then returned to cold. Following this an additional 2hr exposure to **6°C, 12°C, 15°C and 23°C.**	**Primary outcomes:** Body temperatures, heart rate and blood pressure.	Statistically and clinically significant increases in systolic BP with greatest increase in older group (**24±4mmHg/13±4mmHg**) at **6°C** and a significant, but less marked effect at **12°C** (mean measurement not stated) compared to younger group. These observations were consistently observed on 7-10 different days in every subject at **6°C and 9°C.** Steady decrease in heart rate at **6°C and 12°C** in older men, with decrease at **6°C** in young group. No evidence of acclimatisation over time/repeat cold. **6°C** still depressed core temperature in both groups (more in old - 0.4 ± 0.1°C). Authors conclude that it is likely old age related changes to intrinsic thermoregulatory system; reflected in reduced vasoconstriction response. Cold extremities and lowered core temperatures may lead to short-term increases BP. BP responses to cold in old occur significantly more slowly but reactions more marked than in young - **15°C** suggested as minimum level at which elderly should live.	Small sample. Not clear as to whether participants are healthy. Unclear how findings applicable to children and those with chronic illness. Unclear as to what time of year this study took place. Exposures due to home and outdoor temperatures not adjusted for or considered in the findings. Experimental environment not reflective of home environment. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

36	Inoue, Y., Nakao, M. Araki, T., Ueda, H., 1992: *Thermoregulatory responses of young and older men to cold exposure*	To examine age related differences in thermoregulatory responses to cold air. Cross sectional, study	FAIR	**19** healthy active male volunteers from the UK**.** **10 older men**: range **60-71**yrs **9 younger men**: range **20-25**yrs	Two studies in summer and winter: **60mins 28°C** acclimatisation for all subjects at both summer and winter studies. **60mins at 17°C** in summer study. **60 mins at 12°C** in winter study.	**Primary outcomes:** Oxygen uptake, rectal and skin temperatures and blood pressure. **Secondary outcomes:** Body fat	Different thermoregulatory responses to cold stress in older group observed in summer and winter, compared to younger group - suggests ageing associated with decreased ability to maintain core temp during cold. Significant effects on BP at **17°C** in both groups, but greater effect in older people at **12°C**. Older men showed greater increase in BP and decrease in core and skin temperature than younger group. Effects may be more striking in more sedentary older men. Suggest that cold stress produces greater strain on cardiovascular system in older men to effect thermoregulation. Age is a limiting factor for development of cold tolerance, suggesting a decrease in adaptive temp range with age.	Small sample. Unclear how findings applicable to children and those with chronic illness and more sedentary lifestyle. Experimental environment not reflective of home environment. Season accounted for in experimental design. Short term exposure only. No blinding of exposures to investigators. Measurement consistent and robust to reduce bias.

35	Wagner, J. A., Horvath, S. M. Kitagawa, K., Bolduan, N. W., 1987: *Comparisons of blood and urinary responses to cold exposures in young and older men and women*	To describe the blood and urinary responses that we observed while attempting to derive further insight into the physiological responses to cold in young and older groups of men and women. Cross sectional, study	FAIR	**10 male, 10 female** volunteers from California, USA Young group: Men **22 ± 1** yrs Women **24 ± 1** yrs Older: Men **64 ± 2**yrs Women **61 ± 3 yrs**	All participants exposed, semi reclining in minimal clothing for **2 hours** to each of 4 randomly ordered thresholds: **10°, 15°, 20°, 28° C**	**Primary outcome:** Haemoglobin, haematocrit and total plasma protein levels. Blood lactate and free fatty acid levels. Urine volume post exposure. Plasma volume and blood glucose levels.	All participants showed an increase in haemoglobin, haematocrit and plasma protein levels over time exposed to cold, suggesting haemoconcentration. These effects occurred earlier in women than men, but effect greater in men except plasma protein levels, which older women had highest levels. Plasma volume decreased in all subjects and effects greater at 10° and 15°C than at 20°C - effects greater in women. Lactate levels increased at higher temperatures in men (15°C) when compared to women (10°C). Increase in urine volume with decreasing temperature in young men. Young women did not have significant diuresis until 10°C. Older women were more able to control their temperature better than all other groups due to metabolic advantages and body fat.	All participants showed an increase in haemoglobin, haematocrit and plasma protein levels over time exposed to cold, suggesting haemoconcentration. These effects occurred earlier in women than men, but effect greater in men except plasma protein levels, which older women had highest levels. Plasma volume decreased in all subjects and effects greater at **10°** and **15°** than at **20°C** - effects greater in women. Lactate levels increased at higher temperatures in men (**15°C**) when compared to women (**10°C**). Increase in urine volume with decreasing temperature in young men. Young women did not have significant diuresis until **10°C**. Older women were more able to control their temperature better than all other groups due to metabolic advantages and body fat.

Evidence summary – older people

Cardiovascular effects

One epidemiological study from Japan explores the relationship between temperatures and blood pressure in 192 participants aged 60 and over [42] (NIH rating Fair). They found that in winter, when the mean bedroom, living room and ambient temperatures were lower than the corresponding spring/autumn temperatures (mean (SD) winter temperatures 10.3°C (4), 14.1 (4.6) and 13.1 (4.6)) statistically significant increases in various measures of blood pressure occurred (table 4). As indicated previously, Shiue and Shiue [29] (NIH rating Good) found that occupants aged 16-95 of houses with temperatures below 18°C had a higher risk of increased blood pressure than those who had households heated to above 18°C (OR 2.08, 95% CI 1.12-3.43, P=0.004) and a further increase in risk if temperatures were below 16°C (OR 4.92, 95% CI 1.97-12.24, P=0.001). They did not restrict analysis to the older age group.

The very small laboratory-based studies that included older people, many of which have already been presented in the general adult section, support the findings that exposure to cold temperatures increases blood pressure and risk of blood clotting in healthy adults and older people who are sedentary and wearing minimal clothing. The studies show fairly consistently that the physiological effects of cold are more marked and occur more quickly in older people and may recover more slowly. Neild et al [34] (NIH rating Fair) suggests the threshold at which these effects start to occur is 18°C (+/-0.5°C); effects include increases in erythrocyte count and fibrinogen both of which are important for thrombus formation, as well as increases in cholesterol.

Respiratory effects

Osman et al,[40] (NIH rating Good) examined the health status of people living with chronic obstructive pulmonary syndrome, mean age 69 (sd 8.2). They found that improved respiratory symptom scores were associated with more hours of indoor warmth (at least nine hours) at or above 21°C in the living room. Nights with bedroom temperatures of at least 9 h at 18°C showed a trend to a similar association (p = 0.04). The greatest effects were observed in those who smoked, compared with non-smokers.

Thermal comfort and perception

The temperature at which older and younger people feel comfortable appears to be similar at 21.1°C ± 2.9°C, where subjects were sedentary and wearing light clothing.[41] (NIH rating Fair). Heavier clothing and moderate activity showed that this comfort level would be achieved at lower thresholds (16.2°C). However several studies also demonstrated reduced thermoregulatory control and thermal perception/discrimination with aging. Collins et al,[5] demonstrated that younger people were able to discriminate very small differences in temperature in a cold environment (0.8°C ± 0.2°C) compared to older people (2.3°C ± 0.5°C), indicating that older people are less likely to be able to respond to cold conditions when needed to (eg turning heating on/up, wearing appropriate clothing etc.).

Two epidemiological studies of older people in the UK demonstrated that in the early 1970s, large proportions of older people had room temperatures less than 18°C. Fox et al [41] (NIH rating Fair) found that older people with low recorded core temperatures were less aware of being cold and did not think they had to wear 'excessive' clothing. Lower cold thresholds in some older individuals combined with low indoor temperatures and a reduced safety margin of heat to lose before hypothermia sets in puts older people especially at risk.

Evidence summary - chronic illnesses

For the purposes of this review the WHO definition of chronic illness (also referred to as non-communicable disease) will be used:

"Non communicable diseases (NCDs), also known as chronic diseases, are not passed from person to person. They are of long duration and generally slow progression. The four main types of non-communicable diseases are cardiovascular diseases (eg heart attacks and stroke), cancers, chronic respiratory diseases (eg chronic obstructed pulmonary disease and asthma) and diabetes." [43]

Four papers documented the effects of low indoor temperatures on people with chronic illnesses. Health outcomes included respiratory effects, thermal comfort and perception and blood pressure. The four studies are: one randomised control trial focusing on 6-12 year olds with doctor diagnosed asthma;[44] one cross-sectional study of adults with chronic obstructive pulmonary disease;[40] and two small, clinically-based observational studies on older people with a range of chronic illnesses.[5,42] As previously mentioned, the results from lab and clinically-based studies should be interpreted with caution when applying findings to the general population. They are characterised by small sample sizes and use of voluntary participants who often have levels of activity and clothing that they wouldn't have in day to day life.

Table 5 summarises the four papers which examine the effects of low indoor temperature thresholds on people with chronic illnesses.

Table 5 – Summary of studies on participants with chronic illnesses

Ref. No	Study/author/year	Aim of study & design	Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
44	Pierse, N. Arnold, R. Keall, M. Howden-Chapman, P. Crane, J. Cunningham, M., 2013: *Modelling the effects of low indoor temperatures on the lung function of children with asthma*	To determine how the short term effects of temperature can best be modelled to show maximum association with changes in lung function of children with asthma. Randomised control trial with half of households randomised to receive a new heater before the winter and the control group who were given new heaters at the end of the study.	FAIR	Home based study of **409** children in New Zealand aged 6-12 years with doctor-diagnosed asthma. Study during winter months (June - October)	hourly temperature in bedroom and living room over 128 days. Bedroom temperatures from 21:00 - 08:00 (mean temp: **14.4°C**) Living room temperatures from 16:00 - 20:00 (Mean temp: **16.53°C**) Over period of 128 days	**Primary outcomes:** self recorded, forced expiratory volume (FEV), peak expiratory flow rate (PEFR) with indicator of validity of blow: morning and evening.	Small changes in indoor temp are associated with small changes in the lung function of asthmatic children. Exposure to temperatures **<12°C** had the greatest effect on lung function. Models demonstrated that for every 1ºC increase in temperature below 9ºC, Peak Expiratory Flow Rate (PEFR) improves by 0.010L/s (morning) and 0.008L/s (evening). Likewise, for each 1ºC increase in temperature below 12ºC, Forced Expiratory Volume (FEV) would improve by 10.06mL (morning) and 12.06mL for each 1ºC increase below 10ºC (evening). These effects were detectable at lags up to 14/7. Bedroom exposure was shown to have stronger association with asthmatic children's lung function than living room exposure.	This study was conducted in New Zealand where types of housing and climate differ from the UK. Measurements took place in the home so findings are more relevant to domestic temperature thresholds and study took place in winter. Methods of measuring were consistent and robust and steps taken to avoid introducing bias. Effect of damp, housing quality and other potential confounders which could account for effects observed were not stated as having been adjusted for. Whether there was a smoker in the household was ascertained, but not whether the child was exposed to smoke. Severity of exposure examined but not severity of asthma. Study examined which metric has strongest association rather than size of effect. With such a specific sample group it would need to be considered as to whether these findings are applicable to other asthmatics outside of population of interest. Considerable challenges in quantifying individual exposures and study does not account for exposure elsewhere. Behavioural considerations are crucial to understanding exposures, neither of which are accounted for in their statistical analysis.

40	Osman, L. M. Ayres, J. G. Garden, C., Reglitz, K. Lyon, J.; Douglas, J. G., 2008: *Home warmth and health status of COPD patients*	To explore whether health status of patients with chronic obstructive pulmonary disease (COPD) was associated with the number of hours when homes reached recommended standards or indoor warmth in living rooms and bedrooms. Cross-sectional study	GOOD	206 homes of COPD patients who had bee admitted to Aberdeen Royal Infirmary with an exacerbation of COPD between January 2003 and October 2004. Mean age 69 (SD 8.2)years, 55% female. 18 patients had mild COPD, 91 moderate COPD and 39 severe COPD. 58 smokers, 90 non-smokers.	Exposure over **1 week** of monitoring: Living room (LR) hours at **21°C**: Median **46** IQR **8-119** Bedroom (BR) **hours** at **18°C**: Median **126** IQR **56-164** Number of **days** with living room at **21°C for 9 hours**: Median **2** IQR **0-7** Number of **days** with bedroom at **18°C** for **9 hours**: Median **5** IQR **0-7**	**Primary outcomes:** SGRQ (St Georges Respiratory Questionnaire) scores for symptoms of COPD, impact of COPD and activity limitations of COPD. EQVAS (Euroquol Visual Analogue Scale) to measure level of thermal comfort.	Median LR temperatures at 5pm were 21°C. 8 subjects had LR temperature at 5pm of below 18°C and two below 14°C. 9 hours of LR warmth of 21°C not achieved in more than 50% of homes. BR was more likely to be maintained at recommended levels. Better health status was associated with more hours of indoor warmth at and above **21°C**. Days with bedroom temperatures of at least 9 h at 18°C showed a trend to association (p = 0.04). Greatest effects observed in those who smoke compared with non-smokers.	The sample are taken from a population of those who were admitted to hospital with complications of their illness and so may not be representative of the total COPD population as effects may be smaller in those with milder disease. In addition, less than 50% of the eligible population took part in the study and there is not an examination of how this population differed from those who took part, other than deprivation scores. Therefore this population may not be representative of those with severe COPD. In terms of recommendations for indoor temperatures, findings from this study are most applicable to smokers where the effects were greater compared with non-smokers.

42	Saeki, K., Obayashi, K. Iwamoto, J., Tone, N. Okamoto, N., Tomioka, K. Kurumatani, N., 2014: *The relationship between indoor, outdoor and ambient temperatures and morning BP surges from inter-seasonally repeated measures*	To assess the relationship of indoor, outdoor and ambient temperatures with morning BP surges (MBPS), independent of physical activity in elderly individuals living at home. Cross sectional observational survey.	FAIR	192 older people aged **60 years** and over. Mean 69.9 (SD 6.3) 50% smokers42.2% subjects were on antihypertensive, prevalence of diabetes was 13% and dyslipidaemia 37.5%. Study took place in the Nara prefecture in Japan where winter temperatures average about 3 to 5 °C, and 25 – 28 °C in the summer with highest reaching close to 35 °C.	48h monitoring in winter and again in spring or autumn. Morning mean temperature (SD): Bedroom morning temperature mean 10.3°C (4.0) (winter) 20.2°C (4.7)(spring/autumn) Living room morning mean: 14.1°C (4.6)(winter) - 20.4°C (4.1) (spring/autumn) Night time temperature: Bedroom mean 10.9°C (3.9) (winter)- 20.8°C (4.6) (spring/autumn)	**Primary outcome:** ambulatory blood pressure, physical activity **Secondary outcome**: blood parameters (plasma glucose, lipids and haemoglobin)	Multivariate analysis adjusted for potential confounders identified that a 1°C decrease in living room, outdoor and ambient temperatures was significantly associated with a 0.46mmHg (95% CI -0.68, -0.24 p=<0.01) , 0.23mmHg (95%CI 0.09-0.36) and 0.44mmHg (95%CI 0.23-0.65) increase respectively in the sleep-trough MBPS (independent of confounders).	Participants were recruited by non-random sampling and therefore limits the generalisability of this study. Study considered seasonal variations and controlled for important confounders such as physical activity, socio economic status, presence of chronic illness smoking and drinking and medication use. Measurements of blood pressure were consistent and ambulatory but temperature measurement was fixed and so exposure outside of home environment was not accounted for.

Respiratory effects

The randomised controlled trial by Pierse et al [44] (NIH rating Fair) modelled the effects of low indoor temperature on lung function of 409 (doctor diagnosed) asthmatic 6-12 year olds. Their results show that indoor temperatures have a small, but significant association on lung function variation over a short period of 0-14 days. Bedroom temperatures showed the strongest association between low indoor temperature thresholds and lung function. Their models demonstrated that for every 1ºC increase in temperature up to 9ºC, Peak Expiratory Flow Rate (PEFR) improves by 0.010L/s (morning) and 0.008L/s (evening). Likewise, for each 1ºC increase in temperature up to12ºC, Forced Expiratory Volume (FEV) would improve by 10.06mL (morning) and 12.06mL for each 1ºC increase up to 10ºC (evening). Although this study reports significant (small) results, this is a very specific population which makes generalising results challenging.

The study by Osman et al [40] (NIH rating Good) examined the health status of people living with chronic obstructive pulmonary disease (ranging in severity) with a mean age of 69 (sd 8.2). They demonstrated that better health status was associated with more hours of indoor warmth (at least nine hours) at and above 21°C in the living room. Nights with bedroom temperatures of at least 9 h at 18°C showed a trend to association ($p = 0.04$). The greatest effects were observed in those who smoked, compared with non-smokers.

Thermal perception

The cross sectional study by Collins et al [5] (NIH rating Fair) focused on a population of over 69 years (range 69-91) with multiple co-morbidities. The study demonstrated that thermal perception was very different between the younger and older groups, but no explanation as to how the co-morbidities may have affected the results. For example, the younger sample were able to discriminate very small differences in temperature in a cold environment (0.8°C ± 0.2°C) compared to the older sample (2.3°C ± 0.5°C), which suggests that older people are less likely to be able to respond to cold conditions when needed to (eg turning heating on/up, wearing appropriate clothing etc.). One explanatory factor is that ageing is associated with a decline in autonomic nervous function which leads to impaired thermoregulatory capacity. Findings confirm the results of other studies' which suggest that thermoregulation decreases with age. This illustrates the difficulty in differentiating population groups and highlights issues with co-vulnerabilities.

Cardiovascular effects

The small cross sectional study conducted by Saeki et al [42] (NIH rating Fair) has already been summarised in the previous section. It is also covered here since many of the 192 older aged participants had co-existing chronic illnesses. The researchers examined the relationship between temperatures and morning blood pressure surges (an increased morning BP surge has been previously shown to be a risk factor for cardiovascular disease.[45]) Their multivariate analysis was adjusted for potential confounders and showed that a 1°C decrease in living room, outdoor and ambient temperatures was significantly associated with a 0.46mmHg (95% CI -0.68, -0.24 $p=<0.01$), 0.23mmHg (95%CI 0.09-0.36) and 0.44mmHg (95%CI 0.23-0.65) increase respectively in the sleep-trough morning blood pressure surge.

Evidence summary - children

For the purposes of this review, children are defined as persons from birth to 15 years of age inclusive.

Three studies examined the effects of low indoor temperatures on children. Health outcomes included; respiratory effects and body mass index. The three studies included: one randomised control trial [44] (also included in the chronic disease section as the sample population were children with doctor diagnosed asthma), one longitudinal observational study [46] and one case control study.[47]

Table 6 summarises the findings of the papers which examine the effects of low indoor temperature thresholds on children.

Table 6 – summary of studies on children and low indoor temperatures

Ref. No	Study/author/year	Aim of study & Design	Grade	Population & setting	Exposure	Outcomes measured	Results	Strengths and Limitations
44	Pierse, N. Arnold, R. Keall, M. Howden-Chapman, P. Crane, J. Cunningham, M., 2013: *Modelling the effects of low indoor temperatures on the lung function of children with asthma*	To determine how the short term effects of temperature can best be modelled to show maximum association with changes in lung function of children with asthma. Randomised control trial with half of households randomised to receive a new heater before the winter and the control group who were given new heaters at the end of the study.	FAIR	Home based study of **409** children in New Zealand aged 6-12 years with doctor-diagnosed asthma. Study during winter months (June - October)	Bedroom temperatures from 21:00 - 08:00 (mean temp: **14.4°C**) Living room temperatures from 16:00 - 20:00 (Mean temp: **16.53°C**) Over period of 128 days	**Primary outcomes:** self recorded, forced expiratory volume (FEV), peak expiratory flow rate (PEFR) with indicator of validity of blow: morning and evening.	Small changes in indoor temp are associated with small changes in the lung function of asthmatic children. Exposure to temperatures **<12°C** had the greatest effect on lung function. These effects were detectable at lags up to 14/7. Bedroom exposure was shown to have stronger association with asthmatic children's lung function than living room exposure. Their models demonstrated that for every 1ºC increase in bedroom temperature below 9ºC, Peak Expiratory Flow Rate (PEFR) improves by 0.010L/s (morning) and 0.008L/s (evening). Likewise, for each 1ºC increase in bedroom	This study was conducted in New Zealand where types of housing and climate differ from the UK. Measurements took place in the home so findings are more relevant to domestic temperature thresholds and study took place in winter. Methods of measuring were consistent and robust and steps taken to avoid introducing bias. Effect of damp, housing quality and other potential confounders which could account for effects observed were not stated as having been adjusted for. Whether there was a smoker in the household was ascertained, but not whether the child was exposed to smoke. Severity of exposure examined but not severity of asthma. Study examined which metric has strongest association rather than size of effect. With such a specific sample group it would need to be considered as to whether these findings are applicable to other asthmatics outside of population of interest. Considerable challenges in quantifying individual exposures and study does not account for exposure elsewhere. Behavioural considerations are crucial

							temperature below 12ºC, Forced Expiratory Volume (FEV) would improve by 10.06mL (morning) and 12.06mL for each 1ºC increase below 10ºC (evening).	to understanding exposures, neither of which are accounted for in their statistical analysis.
46	Scheffers, F. Bekkers, M. Kerkhof, M., 2012: *The association between indoor temperature and body mass index in children: the PIAMA birth cohort study*	To further explore the association between ambient temperature and adiposity, specifically the association between indoor temperature (living room and bedroom) and body mass index (BMI) in a cohort of children followed from birth up to the age of 11 years. Birth cohort study	FAIR	Baseline study population of **3,963** children from **birth to 11** years of which 3,343 had data available for analyses. Home based study from The Netherlands. .	Self-reported living room temperature: Range **10°C-30°C**; Mean **20.3°C** Self-reported bedroom temperature: **Range** 4°C-28°C; Mean **17.4°C** Objectively measured bedroom temperatures: Range **9.0°C-21.4°C**; mean **17.5°**C	**Primary outcomes:** Body mass index	99.7% of children lived in home where LR was heated, 68.1% slept in a bedroom which was heated. No association found between room temperatures and body mass index in children between the ages of 3 months and 11 years. Few significant age-specific differences found in children who did and did not have heating in their bedrooms: higher BMI score in boys of 1 year old who had heating in bedroom compared to those who did not. Reverse effect in girls of 5,6 and 7 years who had lower BMI scores	Study was undertaken in the Netherlands, but has similar climate to UK, however, difference in housing quality may affect applicability of findings. Large, longitudinal study looking at long term trends and effects of indoor temperatures on body mas index. Larger sample relied on self-reported temperatures - no details of method of taking or recording temperatures. Likely to have introduced bias. Small subset of 104 subjects had temperatures objectively measured in bedroom. A 0.1°C difference in mean of self reported and objectively measured temperatures was observed. Results adjusted for most major confounders but exposure to other environmental factors such as outdoor/school temperatures and dietary

							compared to girls who slept in bedroom where heating was not used.	factors other than breastfeeding status not considered.
47	Ross, A. Collins, M. Sanders, C., 1990: *Upper respiratory tract infection in children, domestic temperatures, and humidity.*	To seek an association with measurements of domestic temperature and humidity with measurements of upper respiratory tract infection (URTI) that were available and feasible. Case control study	FAIR	**297** children aged 24-59 months from a single GP practice in North Staffordshire. Home based study.	Mean **living room** temperatures (°C) +/- reported URTI **16.5 /16.7** +/- recorded URTI **16.6 /16.8** +/- recorded AOM **16.7 /16.7** Mean **bedroom** temperatures (°C) +/- reported URTI **14.1 /14.4** +/- recorded URTI **14.0 /14.7** +/- recorded AOM **14.3 /14.2**	**Primary outcomes:** Reported URTI (Incidence of URTI reported on questionnaire) Recorded URTI (incidence of URTI recorded in child's medical records) Recorded acute otitis media (AOM) (Incidence of AOM recorded in medical notes)	No uniformly consistent results. Key findings show that when compared to the 34.7% of children in the group without URTI, bedrooms of children with URTI tended to be cooler overnight, but this a very small difference which could be accounted for by differences in measurement technique /equipment. A greater proportion of the homes of children who wheezed had fires rather than central heating. Non-wheezers tended to have radiators in their bedroom. Wheezers tended to sleep in bedrooms which were cooler. Authors conclude that this suggests	This is a small home based study from a single GP practice in North Staffordshire and it is unclear as to how this population compares to other areas. The age range is very specific and it is unclear as to how the findings from this group are applicable to other population groups. Although numerous measurements (144 per child) were made, these took place over a 6 day period during December to March and does not establish long terms effects of exposure on acute respiratory disease. No measurements were taken during November, a month for which we would seek to make recommendations. The authors suggest that a limited period of measurement will present challenges and question whether these findings can be extrapolated over the remaining months where cold weather is problematic. Potential confounders such as heating methods, smoking and other socio

							that cooler bedroom temperatures may be a relevant factor in wheezing in children. Overall, the study did not show any association between URTI and indoor temps of any significant degree in practical terms.	economic factors and housing type were taken into account but other exposures such as school not accounted for. It is unclear as to whether the children had existing chronic respiratory disease, such as asthma. Outdoor conditions were adjusted for to control for effects of seasonal variation. Individual exposure is challenging to quantify and behavioural considerations are crucial to understanding exposures, neither of which are accounted for in their statistical analysis. Methods of taking and recording temperatures were robust and steps were taken to limit bias. and location no consideration of other factors such as outdoor, school or other potential confounders were taken into consideration. possible evidence of reporting bias with unusually high number of reported URTO cases

Respiratory effects

The randomised controlled trial by Pierse et al [44] (NIH rating Fair) modelled the effects of low indoor temperature on lung function of 409 (doctor diagnosed) asthmatic 6-12 year olds. Their results show that indoor temperatures have a small, but significant association on lung function variation over a short period of 0-14 days. Bedroom temperatures showed the strongest association between low indoor temperature thresholds and lung function. Their models demonstrated that for every 1ºC increase in bedroom temperature below 9ºC, Peak Expiratory Flow Rate (PEFR) improves by 0.010L/s (morning) and 0.008L/s (evening). Likewise, for each 1ºC increase in bedroom temperature below 12ºC, Forced Expiratory Volume (FEV) would improve by 10.06mL (morning) and 12.06mL for each 1ºC increase below 10ºC (evening). Although this study reports significant (small) results it is unclear if the results can be generalised across the whole population..

Ross et al [47] (NIH rating Fair) examined whether low indoor temperatures and subsequent high humidity levels influence the incidence of upper respiratory tract infection (URTI) in a sample of children aged three to five years. Compared to the children who did not have a URTI, those that did have URTI tended to have cooler bedrooms, but this difference is small and could be accounted for by variance in instruments used to measure temperature.

Body Mass Index

Scheffers et al [46] (NIH rating Fair) examined the link between indoor temperature and body mass index (BMI) using data from the Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study. The sample consisted of 3,963 children who took part from birth to 11 years of age. They found that the mean reported living room temperature was 20.3ºC and the bedroom temperature 17.4ºC. Results showed no evidence for an association between indoor temperatures (living room and bedroom) and body mass index of children aged 3 months to 11 year in this real life setting.

Discussion

Whilst there is strong evidence that cold homes have a harmful effect on health, and there are good arguments for making recommendations on home temperature thresholds in winter, the findings of this literature review demonstrate that there is very limited robust evidence on which to base these recommendations. Only two small randomised controlled trials, two cohort studies and one case control study were identified; the remainder were cross-sectional studies of varying sizes and quality. The studies were very heterogeneous. There was a range of methods for measuring the exposure to indoor cold and the analyses often used relatively arbitrary thresholds for exposure, rather than demonstrating a particular threshold at which cold effects occur. A variety of outcomes were explored. The recommendations that emerge from this review, can therefore only be weak recommendations and should be viewed in this context.

The challenges in ascertaining appropriate thresholds, the findings, their implications for recommendations and practical considerations are discussed below.

Challenges in establishing home temperature thresholds for health

Exposure assessment

Accurately measuring exposure to indoor temperatures in observational, epidemiological studies is not straightforward. Most studies used a single temperature measurement taken in the home at the time of other data collection. Whilst this is a pragmatic choice, there was usually little/no information on duration of exposure at that temperature, whether this is the usual temperature of the room/home under day to day circumstances (when not potentially influenced by the presence of a visiting researcher), or of cold exposure outside of the home. There are gradients in temperature within a room (both horizontal and vertical) and within the wider home, and the value recorded will depend on positioning of the thermometer, the time of day, household activities and the number of people present. Although literature exists on modelling the relationship between indoor and outdoor temperatures, the aims of this literature review required the reviewers to look specifically at studies which had taken individual level temperature measurements.

The experimental and laboratory-based studies provided more detailed and accurate records of temperature exposure, often placing people in very cold or rapidly cooling environments. In most cases, participants were often semi-clothed and recumbent. However these conditions and behaviours are unlikely to represent most home environments and occupant behaviours.

Outcome assessment

The majority of studies used easily measurable end-points such as blood pressure, BMI or haematological/biochemical measures. These are reasonable approaches, but are only proxies for harder health outcomes such as cardiovascular disease or health service use. One study assessed self-reported symptoms at specific pre-determined temperature thresholds which were based on existing temperature guidance.[40]

All of the studies included in this review concentrated on the direct, physical health outcomes resulting from exposure to various indoor temperature thresholds. Although no studies included in this review quantify the mental health impact of cold indoor temperatures, evaluations of affordable warmth and home energy efficiency policy interventions have demonstrated the positive impact on mental health and anxiety levels from living in a warm home heated to appropriate temperatures.[19,48]

Studies that only assessed thermal comfort/perception were excluded from this review, however, a number of studies included this as one of the outcomes. These studies provide valuable information to suggest that whilst the range of temperatures at which people are comfortable is similar, older people are less able to perceive colder temperatures. Thermal comfort may also be an important factor in mental health, well-being and social outcomes, such as days off work or school.

Other important health outcomes include those associated with risk behaviours in an effort to keep the home warm for example use of flueless gas heaters, inappropriate use of charcoal barbecues indoors. Equally, measures taken to reduce drafts through sealing air vents and leaking windows could impair necessary ventilation and impact on air quality and subsequently the health of occupants.

Confounding

When an association is observed between an exposure and outcome, consideration needs to be given to other possible explanations. Most studies made some attempt to adjust their findings for possible confounders, although certain confounders (eg smoking, pre-existing disease, medication use) were not always measured.

Generalisability of the findings

When applying the results of published studies to another population, an assessment is needed of the degree of similarity between individual study populations and those who will receive the final recommendations. It has been documented that over time people acclimatise to different outdoor temperatures (particularly in relation to hot weather). It is therefore important to consider whether the same is true for indoor temperatures and cold (although the evidence on this is lacking). Many studies included in the review were undertaken in the UK. Most studies conducted in other countries, were carried out in countries which have a similar climate to England (eg New Zealand, Japan) with comparable populations. Therefore, it is reasonable to assume that the findings are largely applicable to the English setting.

Findings

Despite these multiple challenges, the evidence identified supports previous guidance that cold temperatures have physiological and health effects and that these effects start to occur at indoor temperatures around 18°C.

General adult population

The main observed effects of exposure to cold indoor temperatures in the general adult population are increases in blood pressure. This was demonstrated in a randomised controlled trial comparing overnight temperatures of 22°C and 12°C in 18-60 year olds,[27] and in a cross-sectional analysis of a sub-sample of the Health Survey for England (aged 16-95) which showed a significantly increased risk of hypertension in those assessed as living at temperatures below 18°C.[29] To support this, a large population study[49] showed that for each 1°C increase in indoor temperature, mean systolic BP fell by 0.31mmHg. Although a change of this magnitude is unlikely to be considered clinically significant at the individual level, it may have an important effect at population level. The authors of these studies suggested that a substantial proportion of hypertension, stroke and winter mortality might be avoided by increasing indoor temperatures.

The smaller laboratory based studies provided supportive data to indicate cold indoor temperatures increased blood pressure, as well as increasing levels of clotting factors that promote thrombosis, with effects starting at 18°C (+/-0.5°C) in young healthy, recumbent and semi-clothed adults in one study.[34]

There is a growing evidence base exploring the association between exposure to low indoor temperatures and obesity, but the findings are conflicting.[28,31,46] One study included in this review suggested that BMI may be lower in those living at indoor temperatures of 23°C and above compared to those living at <19°C, hypothesising that low indoor temperatures lead to over compensatory comfort eating.[28] However most studies and reviews suggest that high indoor living temperatures in the UK may be contributing to a growing obesity problem.[46] Since the currently available studies are both inconsistent in their methods and results, making recommendations to include the risk of obesity is not possible.

Taken together these studies suggest that there may be a benefit to the cardiovascular and cerebrovascular health of the general adult population of maintaining indoor temperatures to at least 18°C, although the evidence supporting this is not sufficiently robust to be categorical about this.

Older people

Many of the studies in the section on the general adult population included older participants, so the findings are also likely to be applicable to older people as well. It is notable that the changes in outcomes such as blood pressure, clotting factors, cholesterol and in core and skin temperature were more rapid, more profound, or slower to recover, in older compared to younger people.

The ability to regulate temperature declines with age.[5] Older people `(over 60 years of age) who are exposed to cold environments are less able to maintain a core temperature.[5,38,39] This may be exacerbated by a reduction in physical activity since daily activity levels are considered to be an important factor in the maintenance of core body temperature.[50] Studies included in this review and the wider literature also suggest that older adults can lose the ability to discriminate between changes in temperature [51,52,53] and have reported less discomfort in colder environments than younger adults.[53]

As well as a low body fat percentage,[38] comorbidities, chronic conditions and restricted mobility, can additionally affect physiological parameters and temperature perception, increasing vulnerability of older people to cold environments.[54,55]

These findings present powerful arguments for the importance of endeavouring to set minimum home temperature thresholds for health in older people in winter, as opposed to suggesting older people set indoor temperatures solely according to levels of thermal comfort. Two studies suggest that leaving the decision to alter temperature with an older person may result in suboptimal environmental temperature [52] as they may not modify behaviour to reduce or prevent cold.[56]

WHO guidance on indoor temperatures and health recommended an indoor temperature of 18°C, but a temperature 2-3°C warmer in rooms occupied by older people to account for their more sedentary lifestyle.[22] This review has failed to find hard evidence that temperature thresholds above 18°C are required for older people. However, since older people have weaker thermoregulatory systems and have more profound physiological responses to cold, as well as being less able to detect cold or falling temperatures, there is an argument for advising slightly higher indoor temperatures in this age group.

People with chronic illnesses

A wide range of chronic conditions have been associated with vulnerability to cold. In most settings the major disease groupings show association with low temperature, including cardiovascular disease and major subgroups, respiratory disease (especially chronic obstructive pulmonary disease, COPD), external causes (injuries), and other causes including malignancy. The top three causes of excess winter deaths are respiratory disease, cardiovascular disease and dementia. Whilst most excess winter deaths occur in older people, a substantial number (5,500 in 2012/13) occurred in people under the age of 75.[1]

These data and studies of temperature mortality/morbidity relationships are generally taken to mean that people with chronic conditions are more susceptible to cold. The studies included in this review give indications of the likely pathophysiological pathways of this increased vulnerability. As well as physical vulnerability other factors such as reduced mobility, inability to adapt behaviour in response to cold or difficulties with self care, are likely to play a role.

This review has found only very limited information on the effects of cold indoor temperature thresholds in people with pre-existing disease. Osman et al [40] demonstrated that a better respiratory symptom score was associated with more hours of indoor warmth (at least nine hours) at and above 21°C in the living room in adults with COPD, with the greatest effects in those who smoke, compared with non-smokers. Nights with bedroom temperatures of at least 9 h at 18°C showed a trend to association (P = 0.04). However the choice of these thresholds was based on existing temperature guidance, and it is not clear if other (lower) temperature thresholds might have also demonstrated health benefits. The other studies demonstrated health effects at much lower temperatures in children and adults with pre-existing disease, but it is not clear where the threshold for these effects might be.

The WHO guidance recommended a minimum air temperature of 20°C for "the sick and the handicapped". Although this review did not find firm evidence of the importance of a threshold higher than 18°C in this group, their particular vulnerabilities should be considered when setting recommendations.

Young people

Children are considered to be at risk from poor health outcomes from cold temperatures, particularly those with pre-existing respiratory conditions, but there is limited evidence because of the considerable inherent challenges of studying this population. The literature suggests that there are small, and sometimes statistically significant effects on children's respiratory health from heating and energy efficiency interventions.[57] It has also been reported that adolescents living in cold housing are at a significantly greater risk of developing multiple mental health problems.[12,48,58] Expert testimony shows anecdotal evidence that children may be less exposed to cold indoor temperatures than other vulnerable groups owing to the protective behaviour of their care givers.[57]

For infants, there is an existing recommendation that rooms in which infants sleep should be heated to between 16°C and 20°C. These recommendations are made in conjunction with recommendations for thermal insulation for infants, proportionate to the ambient temperature. This has been decided as a 'general consensus'[59] and recommended largely as an intervention to prevent overheating; although up to 10% of neonatal deaths classified as respiratory or Sudden Infant Death Syndrome (SIDS) related could be as a result of unrecognised cold injury.[60]

There is currently a lack of evidence on which to base separate recommendations for children, but there are well-established recommendations for infants to reduce the risk of SIDS and it is important that these are taken into account when proposing minimum home temperature thresholds in winter.

Setting recommendations

Implications of the findings

There is very limited, robust evidence available on which to base minimum home temperature recommendations. Despite this, there are powerful reasons to attempt to set recommended domestic temperatures, on the currently available evidence. Most notably, older people who form the group most vulnerable to cold, may be less able to perceive cold temperatures and therefore less likely to respond appropriately in dangerously cold environments. This is why we consider it important to provide guidance on minimum home temperatures.

Firstly we must decide whether temperature recommendations should be targeted to vulnerable groups or whether they should be considered applicable to the whole population. We consider that a recommendation about minimum indoor temperature thresholds for the population as a whole as a guide is warranted because:

- the currently available evidence, although limited, demonstrates that the harmful effects to health may start at around 18°C in recumbent healthy young adults with minimal clothing. There is also an indication that there is an increased risk of hypertension at population level in those living at temperatures below 18°C.
- vulnerability to cold is widely distributed amongst the population and there may be a mix of vulnerabilities within households
- many of those who are vulnerable do not view themselves as such
- people may be transiently vulnerable or on the margins of vulnerability.
- there is an opportunity to 'futureproof' by embedding messages and influencing behaviour before people become vulnerable
- delivering a population targeted approach means that messages are kept as simple as possible whilst protecting the health of all

The potential drawbacks of this approach are increased expenditure on fuel and increased carbon emissions, if households with winter indoor temperatures usually below the threshold use more fuel to meet to it. The 2011 Energy Follow Up Survey demonstrated that mean room temperatures recorded during the heating season (October to April) are 19.3°C for the living room, and 18.9°C for the bedroom.[62]

Secondly, a decision is needed on what temperature threshold should be set, and whether this should be a single value or be a range of temperatures. The very limited available evidence suggests that 18°C would be a reasonable minimum threshold. Concern has been raised that the existing recommendation of at least 21°C in living rooms, particularly if widely implemented by the population would result in excessive use of household energy, with resultant high levels of carbon emissions from the domestic sector and high levels of expenditure on fuel, neither of which are desirable from a broad health and wellbeing perspective. After discussing this with experts, considering the limited evidence to support the 21°C threshold, and the importance of producing a simple and clear message, we suggest that a single minimum threshold of 'at least 18°C' is most appropriate for the general population.

However, given the limited evidence to support this threshold, it would not be appropriate to frame this as a 'strong' recommendation. Furthermore the fact that certain groups are particularly vulnerable to cold, and that younger healthy adults may find it easier to increase activity levels and adjust their clothing/bedding, we consider that some nuancing of the message is needed to allow flexibility above and below that threshold respectively, so that action can be tailored by the individuals concerned. Stating clearly what the potential risks to health are in a simple, relevant and accessible way is important, to enable informed choice in heating behaviours and accommodate personal preferences.

Thirdly, given that previous recommendations provided different thresholds for the bedroom and the living room, a decision is needed regarding the parts of the house to which this recommendation applies. A number of studies explored the impact of overnight temperatures on health [27,40,42,44,47] and there are clear indications that night time temperatures are likely to be important. But only one study looked specifically at the impact of different thresholds for living room and bedroom temperatures,[40] meaning that the rationale for setting different thresholds is weak. We therefore propose not to suggest different thresholds for living rooms and bedrooms.

There is a clear need for further research in this area. The majority of studies on the effects on health of cold indoor temperatures are small cross sectional laboratory studies. Whilst these studies support findings of large studies and findings are consistent with other similar small studies; in isolation these studies are not sufficient to make findings generalisable (largely due to recruitment practices and size of sample groups). In addition, a laboratory setting may not be analogous to the domestic environment.

More work is needed on the health impact of bedroom temperatures as well as large longitudinal studies to show the long terms effects and levels of exposure that precipitate illness. Further studies on the role of interventions such as electric blankets and hot water bottles may also be of use. However, there is some face validity to the role of these actions in keeping people warmer at night, despite the room temperature. This might be done through individual level monitoring of exposure to indoor temperatures over a period of time. Studies on the long term effects of low indoor temperatures on obesity are needed in addition to those on the effects on people with chronic illness and children, as the evidence base on these populations is considerably weaker than those on older people and the general population. However, as previously discussed, considerable ethical and practical considerations would need to be taken when developing such studies.

Practical considerations

There is good evidence to show that indoor temperatures in homes have increased steadily in recent decades, with recent estimates suggesting that average indoor temperatures have increased by about 5-6°C since the 1970s to around 17-21°C, depending on the source of the estimate.[61] Much of this is thought due to the increased use of central heating.

Nevertheless despite existing advice recommending thermal ranges in the home for three decades, people's homes are still not always heated appropriately.[13,40] Challenges to taking up advice and changing heating behaviours remain. The cost of fuel may be a barrier to adopting this advice, as well as the thermal efficiency of homes. It is clear that where recommendations are made, people need to be supported and enabled to make changes. Any recommendations should be considered and implemented alongside other related policies.

This review has focused on the evidence to support indoor temperature recommendations for use over the winter period. However, it is acknowledged that indoor temperatures may drop to below 18ºC at other times in the year. This review did not set out to address what temperature to keep rooms at during the warmer months of the year.

Proposed minimum home temperature recommendation for homes in winter

On the basis of the evidence and discussions presented in this review; the following recommendations on minimum indoor temperature thresholds are proposed:

Heating homes to at least 18°C (65F) in winter poses minimal risk to the health of a sedentary person, wearing suitable clothing.

Daytime recommendations

- The 18°C (65F) threshold is particularly important for people **over 65yrs or with pre-existing medical conditions**. Having temperatures slightly above this threshold may be beneficial for health.
- The 18°C (65F) threshold also applies to **healthy people (1 – 64)*.** If they are wearing appropriate clothing and are active, they may wish to heat their homes to slightly less than 18°C (65F)

Overnight recommendations

- Maintaining the 18°C (65F) threshold overnight may be beneficial to protect the health of those **over 65yrs or with pre-existing medical conditions**. They should continue to use sufficient bedding, clothing and thermal blankets or heating aids as appropriate.
- Overnight, the 18°C (65F) threshold may be less important for **healthy people (1 – 64)*** if they have sufficient bedding, clothing and use thermal blankets or heating aids as appropriate.

*There is an existing recommendation to reduce Sudden Infant Death Syndrome (SIDS). Advice is that rooms in which infants sleep should be heated to between 16 – 20 °C (61 – 68F) http://www.lullabytrust.org.uk/roomtemperature

These updated recommendations should be widely disseminated to partners and other agencies working with people in high risk groups, and incorporated into future editions of the Cold Weather Plan for England and Keep Warm Keep Well documents.

Strengths and weaknesses of the literature review and expert consultation

This review was undertaken in response to a number of queries raised following the publication of the Cold Weather Plan in 2013.[4] This demonstrates our commitment to ensuring that our information and guidance is up to date and evidence based. The review aims to provide a balanced approach to a complex issue and takes into consideration the effects of climate change, expenditure on fuel and the issue of protecting and improving health both now and in the future.

This review only considered effects of cold indoor temperature thresholds on health. The social effects were not considered and these may have an effect on wellbeing that is not captured in this review. Papers that were not written in English were not included so we may have missed valuable findings. This language bias has been acknowledged by the reviewers.

In addition to the literature review, we sought to engage with a number of partners to ensure that important issues and expertise had been considered and captured. Traditionally, expert feedback falls low on the hierarchy of evidence. However, the reviewers consider that this consultation process was vital in considering the available evidence, putting the findings into context and setting recommendations that were appropriate in practice and are likely to be able to be adopted in real life.

Conclusions

There is good evidence that cold indoor temperatures are associated with increased morbidity and mortality, but there is limited robust evidence to determine the indoor temperature threshold at which these adverse effects start.

There is good evidence that older people and those with chronic illnesses are more vulnerable to cold and that the ability of the body’s thermoregulatory system to respond to external temperatures declines with age. Older people may be less able to perceive cold temperatures and therefore less likely to respond appropriately in dangerously cold environments. Therefore it is important to provide guidance with regard to minimum home temperature thresholds, whilst acknowledging that the evidence on which this recommendation is based is limited.

A population wide approach to minimum indoor temperature thresholds in winter is warranted for a variety of reasons. The currently available evidence base, alongside expert discussion, suggests that heating homes to at least 18°C poses minimal risk to the health of a sedentary person, wearing suitable clothing. At below 18°C, negative health effects may occur, such as increases in blood pressure and the risk of blood clots which can lead to strokes and heart attacks.

There is a lack of sufficient evidence to define thresholds in different parts of the house, or for those in high risk groups. Emphasis should be placed on keeping the homes of vulnerable people to at least 18°C, but that temperatures up to 21°C may be beneficial. Younger healthy adults may find it easier to increase activity levels and adjust their clothing to keep warm, and may wish to keep indoor temperatures to levels at which they are comfortable, even if this is lower than this threshold.

These updated recommendations should be widely disseminated to partners and other agencies working with people in high risk groups, and incorporated into future editions of the Cold Weather Plan for England and Keep Warm Keep Well documents. However challenges to changing heating behaviours remain, including ability to pay for fuel and the presence of adequate heating and thermal efficiency in homes. It is clear that where recommendations are made, people need to be able to access support to make changes.

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