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Old and cold? Findings on the determinants of indoor temperatures in English dwellings during cold conditions

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ABSTRACT

Indoor temperatures during winter conditions play an important role in influencing the comfort and health of households, space heating energy demand and peak heating power. The role that physical dwelling features and household characteristics have on wintertime indoor temperatures has been examined among low-income households, but not across English households in a systematic manner. This paper examines determinants of indoor air temperatures during wintertime conditions to examine how temperature conditions vary with, for example, dwelling age or household socio-economic conditions. Using a cross-sectional survey of English dwellings that included monitoring of indoor air temperatures from January 2011 to February 2012, this study examines the determinants of indoor temperatures during wintertime conditions within a representative sample of English dwellings (N = 821). The study analysed indoor temperatures standardised to outdoor air temperatures of 0 °C, 5 °C and 10 °C within the study sample and the influence of physical dwelling features (type, age, size), household characteristics (tenure, income, composition, benefit receipt) and energy performance (loft and wall insulation, heating system and performance rating levels). The analysis finds that as dwelling age decreased (i.e. newer), so did indoor air temperatures in both the living room and bedrooms, after adjusting for a selection of dwelling and household characteristics. Compared to the lowest income quintile, households with higher incomes kept warmer temperatures, but this was not a linear increase and the highest incomes were not on average the warmest. There appears, however, to be little change in the dwelling temperature trends when looking at lower or higher outdoor air temperature conditions (i.e. 0 °C and 10 °C). In designing policies to improve indoor thermal conditions, policymakers will need to consider underlying energy performance of the dwelling alongside the socio-economic conditions of the household, for example when providing fuel support payments to at risk households.

1. Introduction

Exposure to wintertime indoor temperatures remains an important determinant of health for English households. Exposure to low indoor wintertime temperatures is associated with being in fuel poverty and poverty more generally [1,2], and a higher risk of cardio-respiratory illness [3]. England has a large burden of excess winter mortality (EWM), i.e. number of deaths during winter periods (i.e. December to March) compared to the mean of non-winter period, with approximately 18,200 additional deaths in 2013/14 (and 31,280 in 2012/13), and most of this burden is due to deaths attributable to circulatory and respiratory disease (63% in 2011/12) [4]. EWM is above average in England and Wales compared to much of Europe, which is a trend exhibited among other countries with milder winter weather [5]. EWM has been attributed to inadequate protection from cold temperatures which can be related to: inadequate clothing, poor dwelling thermal efficiency, and low indoor temperatures (i.e. <18 °C) [6]. Exposure to low indoor temperatures has been associated with higher rates of EWM from cardiovascular disease in England [7] and may be attributable for 9% of the risk for high blood pressure in Scotland. In addition to the implications for health, indoor temperature demand is an important driver of space heating demand, which is estimated to account for 54% of the annual average dwelling energy demand in England [9].

The risks associated with living in cold homes and the implications for health and wellbeing more broadly make understanding the determinants of indoor exposure to cold an important area

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for policy action. Therefore, the objective of this study is to determine the variation in wintertime indoor temperatures associated with dwelling features, household characteristics, and measures of energy performance. A further objective is to determine how wintertime indoor temperatures vary with outdoor temperature, with a particular focus on 'cold periods' and outdoor temperature cold thresholds. The research questions asked were:

1. Are older (and presumably less efficient) homes colder than newer homes?
2. Are households of lower levels of socio-economic status colder than those of higher economic status?
3. Do these relationships change during colder periods? and
4. How do retrofits modify the exposure to indoor temperature?

A cross-sectional survey dataset of English dwellings with monitored indoor wintertime temperatures over a 13-month period during 2010 and 2011 was used to investigate the association between household and dwellings characteristics and indoor wintertime temperatures. The temperatures of the homes are standardised to a common external temperature to enable comparison across the sample and with a focus on living room and bedroom temperatures as indicators of likely exposure conditions. In the following section provides a background on past studies conducted in England followed by a description of the data sets and analysis method used to address the research questions.

2. Background

There is a growing interest in better understanding the relationship that indoor thermal conditions have on a range of outcomes, such as heating or cooling energy demand [10,11], levels of activity [12], and of health outcomes such as COPD and cardiovascular disease [13]. Indoor temperatures are influenced by a range of factors, including regional climate, social practices, building energy performance, and fuel prices to name a few. This means that determinants of indoor temperatures will be reflective of local contextual drivers, for example, a recent study of indoor thermal conditions in China found a tendency of very low average indoor wintertime temperatures (e.g. 13 °C) and were influenced by income, presence of children and heating system type [10].

When developing policies on tackling low indoor temperatures for a specific country or region it is vital to understand the prevalence of those conditions and their determinants across the broader population. A recent review of indoor temperature thresholds for health found that few studies had been undertaken at a population level with sufficient coverage and sample size [6]. The objective of this study is to better understand what dwelling and household characteristics influence wintertime indoor temperatures in England, which is marked by high levels of excess winter mortality and also fuel poverty [4,14]. The following studies are included here due to their specific focus on determinants of indoor temperatures among the English household population.

A study by Vadodaria et al. of indoor temperatures samples in England has shown that indoor living room temperatures have broadly stayed the same over the past 40 years, with most samples used to determine this being within the range recommended by WHO (i.e. above 18 °C) [15]. The study also showed that from a limited number of samples, to achieve thermal comfort satisfaction in the UK, living room temperatures may need to be in the range of 20–22 °C. The study was not, however, able to examine determinants of the indoor temperature.

A study by Wilkinson et al. used survey data on English dwellings from the 1991 Energy Follow-Up Survey (EFUS) linked to postcode level mortality data for a ten-year period (1986–1996) to examine the relationship between indoor air temperature and EWM. The EFUS temperature survey took spot air temperature readings outdoors and indoors in the main living rooms and hall/stairs measured in 4942 dwellings between February and May 1992 [16]. In the Wilkinson study, the internal temperatures were standardised to an outdoor air temperature of 5 °C at 3pm after four hours of heating. The standardisation allowed for comparison over time and for different areas of the country. The study found that older (pre-1900) properties had lower wintertime indoor temperatures than post-1980 (-1.20 °C), that dwellings with no central heating were colder (−1.3 °C) than those with, and households in the highest income quartile had higher temperatures (0.25 °C) than those in the lowest. The study also showed that residents living in older and colder homes had a higher risk of excess winter death caused by cardiovascular disease and other causes.

A study by Oreszczyn et al. used a similar method of analysing temperatures as Wilkinson et al. by standardising indoor temperatures to an outdoor air temperature of 5 °C. The study examined temperatures in low income households in England who were recipients of the government Warm Front programme that provided energy efficiency retrofits to tackle fuel poverty. Using the standardised internal temperature for the living room during the daytime (08:00 to 20:00), they showed that among the low income households higher temperatures were associated with newer dwellings (∼0.53 °C), that detached dwellings were colder than terraced dwellings (−0.17 °C) and flats even colder (−0.30 °C). Dwellings with a higher level of efficiency, measured using the notional dwelling fabric heat loss divided by the heating system efficiency, were 1.37 °C warmer than lower levels. Using the government's standard assessment procedure (SAP) the difference between those dwellings in the most efficient bands (>70) were 2.24 °C warmer than those in the lowest (<42). They also found that older (>60) households were warmer (0.52 °C) and those that had difficulty paying their bills were colder (−0.67 °C). The study also included overnight bedroom temperatures, which showed very similar trends as the living rooms. A notable exception was that dwellings with older occupants had lower night-time bedroom temperatures (−0.79 °C).

A study by Kelly et al. examined 347 homes from across England and used a panel approach to examine the determinants of indoor temperatures at 45 min intervals during an ∼6 month period (22 July 2007–3 February 2008) [17]. They found that households with heating controls had lower average daily temperatures compared to no controls (0.24 °C), that homes with more occupants increased their average daily temperature by 0.25 °C/person, that temperature increased with income (0.085 °C/income bracket), that older households (>64 years) had higher temperatures than younger households (0.37 °C), and that socially and privately rented dwellings had higher indoor temperatures than owner-occupiers. Kelly also found that the presence of gas central heating was associated with lower temperatures than those without (−0.56 °C) and those with electric room heating as much warmer (1.0 °C), while the presence of gas and electric room heaters decreased average daily internal temperatures (−1 °C). Dwelling energy efficiency was also shown to be an important determinant of the variation in daily average indoor temperatures, with increased temperatures associated with increased levels of loft insulation (0.25 °C/25 mm), wall insulation (0.08 °C/U-value band), and proportion of double glazing (0.19 °C/25% of glazing). The detachedness of the dwelling (i.e. a proxy for exposed surface area) also affected temperatures, with detached dwellings being colder than semi-detached and terraced dwellings (−0.7 °C and −0.61 °C respectively), while temperatures increased in newer dwellings with post-2003 dwellings being ∼0.42 °C warmer than pre-1900 dwellings.

The above studies of England show that average wintertime indoor air temperatures are influenced by dwelling age, thermal