Elevated risk of high blood pressure: climate and the inverse housing law

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Background In previous work the authors identified an ‘inverse housing law’ in Britain such that housing quality tends to be worse in areas of harsh climate than in areas where the climate is more benign. This study investigates whether an individual’s risk of hypertension is associated with such a ‘mismatch’ between the quality of their housing and the climate to which they have been exposed.

Methods Cross-sectional observational study based on Britain. Data came from the 5663 Health and Lifestyle Survey (HALS) participants for whom all relevant items were available. A two-stage study design was employed. First, the relationship between exposure to colder climate and housing quality was established. Second, the impact on risk of hypertension was determined for level of exposure to colder climate and housing quality.

Results Analysis confirmed that amongst survey respondents, those with greater exposure to colder climate are more likely (1.32, 95% CI: 1.18–1.42) to live in poor quality housing than those with lower exposure to colder climate. This combination of higher exposure to colder climate plus residence in worse quality housing raises significantly the risk of diastolic hypertension (1.45, 95% CI: 1.18–1.77) and, more weakly, systolic hypertension (1.25, 95% CI: 1.01–1.53).

Conclusions There appears to be an ‘inverse housing law’ in Britain, whereby longer term residents of relatively cold areas are also more likely to live in worse quality housing and this combination of circumstances is associated with significantly higher risk of diastolic hypertension. The findings provide an example of how long term exposure to an adverse environment, which may stem from material disadvantage, can damage health.

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health and regional variations in both clothing habits and the
maintenance of a warm home. They also suggest that the
impact of colder weather on winter mortality appears greater in
regions with relatively mild winters than in those with very cold
winters. This study develops their ideas by focussing on the
ability to maintain a warm home in relation to the prevailing
climatic regime the home must cope with. The research
examined long term exposure to relatively colder and warmer
environments within the comparatively mild British climate.

McCarron et al.15 demonstrate that elevated blood pressure in
young and mid adulthood is closely related to high blood
pressure in older adulthood. This makes the need for lifelong
control of hypertension paramount.16,17 Together, the
literature on hypertension and cold, and life-long risks of
hypertension raise questions about the differential impact of
long term residence in a relatively cold area and the influence
of housing as a potentially protective factor.

Data Sources and Methods
The analysis combined data describing climate, individual
circumstances (including housing quality) and measures of
hypertension.

Study participants
The sample population, aged 18+ and living in private house-
holds, was drawn from The Health and Lifestyle Survey (HALS).
This has been described elsewhere.18 The survey was carried
out between 1984 and 1985 and is both socially and spatially
representative. This analysis is based on the 5663 respondents
for whom valid data were available (2564 men, 3099 women).
Exclusion of those without valid data on all measures did not
render the sample unrepresentative.

Exposure to colder climate
Climate data were obtained from the Climatic Research Unit
(CRU)19 in the form of a 10 km² grid model (Figure 1). All
climatic variables were measured at mean elevation above sea
level. A variable was derived to represent each respondent’s
degree of exposure to a colder climate. This variable was a
combination of the physical climate prevailing in their area of
residence and the length of time they had been resident there.

A geographical information system20 was used to match the
residence and the length of time they had been resident there.
This has been described elsewhere.20 The survey was carried
out between 1984 and 1985 and is both socially and spatially
representative. This analysis is based on the 5663 respondents
for whom valid data were available (2564 men, 3099 women).
Exclusion of those without valid data on all measures did not
render the sample unrepresentative.

A dichotomous measure of housing quality was calculated.
HALS contains four items of information relevant for this
purpose; access to an inside WC and sharing basic amenities
(taken as proxies for house age and physical condition), a
measure of carbon monoxide in the air, and a measure of
heating efficiency (taken as proxy for quality of the heating
system). The ability of a house and its heating system to keep
occupants warm enough, regardless of outside temperature, is
taken as a marker of appropriate housing quality. Although
outside temperature was not recorded by the HALS process,
there was no seasonal bias in the data collection.

Heating was described as inefficient when it was recorded as
being switched on but room temperature was recorded at below
15°C. Although room temperature was measured in the living
room, this was taken as a reasonable proxy for ‘living space’
temperature. The Eurowinter group14 found that houses with a
warm living room were highly likely to be warm elsewhere too.
Following Blane et al.1 these measures were summed for each
HALS respondent and then dichotomized to give a ‘better’ or
‘worse’ housing indicator. About 30% of the respondents were
in the ‘worse’ housing category.

Combination of exposure to colder climate and
housing quality
These two variables (exposure to colder climate and housing
quality) provided the means by which the ‘inverse care law’
was tested. Our hypothesis regarding the ‘mis-match’ between
housing and climate combined the two dimensions, therefore
we specified a categorical variable defining a respondent group
who had experienced both lower housing quality and exposure
to colder climate. This variable is described in Table 1.

We refer to this combination of climate and housing quality
as ‘environmental risk’ throughout the rest of the paper. The
environmental risk variable allowed testing of our hypothesis
that only the specific combination of higher exposure to colder
climate and worse quality housing would be associated with an
elevated risk of hypertension. Other combinations of housing
quality and exposure to colder climate were not expected to be
associated with hypertension.

Outcome variables
The outcome variables were dichotomous measures of systolic
diastolic blood pressure. HALS recorded four measures of
both diastolic and systolic blood pressure. Measurement was
made by a trained nurse in the respondent’s home, using an
‘Accutorr’ automatic instrument. The four measurements were
made at one-minute intervals. The mean of the last two
measures was dichotomized such that readings greater than
90 mmHg were labelled as diastolic hypertension and those
greater than 140 mmHg were labelled as systolic hypertension.
This is congruent with both the WHO Hypertension Guidelines
and those from the British Hypertension Society.5,21 About
22% of the sample included in the analysis were in the diastolic
hypertensive category, about 27% were in the systolic
hypertensive category, and 18% were in both. Blood pressure
was dichotomized because the study was interested in
differences that represent a presence or absence of clinical risk
(as defined by globally accepted standards) rather than small-
scale differences in blood pressure without clinical implications.
Figure 1 Geographies of climate, exposure, housing quality and diastolic hypertension

*: See text
Table 1 Combination of exposure and housing variables to represent ‘environmental risk’

<table>
<thead>
<tr>
<th>Risk score</th>
<th>Housing and exposure characteristics</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lower exposure to colder climate, in better housing</td>
<td>2461</td>
</tr>
<tr>
<td>2</td>
<td>Higher exposure to colder climate, in better housing</td>
<td>1502</td>
</tr>
<tr>
<td>3</td>
<td>Lower exposure to colder climate, in worse housing</td>
<td>941</td>
</tr>
<tr>
<td>4</td>
<td>Higher exposure to colder climate, in worse housing</td>
<td>759</td>
</tr>
</tbody>
</table>

Confounding variables

Several potentially confounding variables were included. Age (measured continuously in years), sex, body mass index, social class, room temperature (which has an influence on the measured blood pressure), consumption of alcohol (units in the previous week), taking anti-hypertensive medication and smoking status were all controlled for. Squared measures of body mass index and room temperature were also tested but made no difference to substantive model results. The models shown here therefore contain linear terms. By including a measure of room temperature in the model there was, arguably, ‘over-control’ for aspects of housing quality since the balance of temperature and heating provision formed part of the assessment of housing quality. However, since room temperature has a powerful impact on blood pressure measurement, its inclusion was appropriate. Models were re-run without including room temperature and no substantive difference in results was observed. In any case, including room temperature in the model was likely to make the results conservative, thus strengthening the conclusions.

The smoking status variable included any potential impact of passive smoking by scoring a non-smoker in a non-smoking household as 0, a non-smoker in a smoking household as 1 and a smoker as 2. Although Registrar General’s Social Class (I–V) was included in the model development process, it does not feature in any results shown here because it made no significant contribution to any model.

Analysis

Analysis was divided into two sections. Stage 1 sought to confirm that the general relationship between exposure to colder climate and worse quality housing conformed to the ‘inverse housing law’. The second stage employed multivariate logistic regression to determine the relationships between environmental risk and odds of hypertension. Models were run in SPSS and the same sample was used in each. Since all these data were held at the individual level, multilevel modelling was not appropriate. However, model residuals were examined for systematic regional variation which might have indicated a systematic regional or county-level bias in measurement (observer is known to be an important influence on blood pressure measurement). No such variation was found.

Results

Stage 1: Demonstrating the ‘Inverse Housing Law’

Figure 1 presents a sequence of maps showing the aggregate level relationships between the distribution of colder climate, longer term exposure to cold, and worse quality housing. It also illustrates the geography of diastolic hypertension within the HALS survey.

Map (a)—top left—illustrates the grid-based surface climate model from the CRU data. It depicts the distribution of average number of days with ground frost in Britain for each 10 km² of land. Map (b)—top right—combines the information in map (a) with data describing the length of residence amongst survey respondents to give an exposure score. The boundaries are counties. Counties with no shading had no HALS respondents living in them. The other counties are shaded according to the proportion of the HALS sample who were categorized as having longer term exposure to colder climate. Note the concentration of respondents categorized as having high exposure to cold in the north east of England, Midlands, central southern England and Scotland. Map (c)—bottom left—illustrates the distribution of the HALS sample living in worse quality housing. Note the concentrations in north east England, east central Scotland and the southern portion of England’s Midlands. Map (d)—bottom right—illustrates the distribution of HALS participants with diastolic hypertension within the sample. The map is shaded using an index standardized to the age and sex of the HALS sample used in this analysis. Areas with values below 100 have a prevalence of hypertension below the sample average, areas with values above 100 have a prevalence above the sample average.

The first three maps presented indicative evidence for an ‘inverse housing law’ in that they suggested those areas where climate is worse, tend also to be those where housing is worse. Chi-square tests were carried out to formally test this visual association. Table 2 illustrates the relationship between higher exposure to colder climate and the chances of also living in a worse quality house.

The Table shows that a significantly higher proportion of those with higher exposure to colder climate are resident in worse quality housing compared to those with lower exposure to colder climate. Analysis confirmed that those with higher exposure to colder climate and living in worse quality housing had significantly colder homes than those with all the other possible combinations of exposure to colder climate and housing quality (P < 0.001). Together, Figure 1 and Table 2 demonstrate evidence for an ‘inverse housing law’.

Stage 2: The relationship between ‘environmental risk’ and hypertension

Table 3 shows the unadjusted odds of hypertension for each category of the environmental risk variable.

The table illustrates significantly elevated odds of both systolic and diastolic hypertension for those with higher exposure to colder climate (in both better and worse quality housing).

Table 2 Demonstrating the ‘inverse housing law’

<table>
<thead>
<tr>
<th>Proportion of sample in worse housing</th>
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<tbody>
<tr>
<td>Lower exposure to colder climate</td>
<td>27.7%</td>
<td>3402</td>
</tr>
<tr>
<td>Higher exposure to colder climate</td>
<td>33.6%</td>
<td>2261</td>
</tr>
</tbody>
</table>

P < 0.001.
The effect of living in worse quality housing and having higher exposure to colder climate on risk of diastolic hypertension seems to be greater than the effect on risk of systolic hypertension.

Logistic regression models were used to control for potential confounders. Two sets of multivariate models are presented (Table 4), one set for systolic hypertension (models 1 and 2) and one for diastolic hypertension (models 3 and 4).

Model 1 shows the relationship of the potential confounding variables to systolic hypertension before including the environmental risk variable. Female sex and having blood pressure measured in a warmer room were associated with a significantly lower risk of systolic hypertension. Participants with higher body mass index, consuming additional units of alcohol and taking anti-hypertensive medication showed a significantly higher risk of hypertension. It was also associated (but not significantly) with being a smoker.

Environmental risk was entered in model 2. When compared to those with lower exposure to colder climate, in better quality housing, the odds of systolic hypertension were raised in all other groups. This excess risk was significant and greatest amongst those for whom higher exposure to colder climate was combined with worse quality housing, i.e. those experiencing the ‘inverse housing law’. However, although the confidence intervals for those with higher exposure to colder climate but better housing did straddle 1.0, whilst those for the group experiencing the inverse housing law did not, there was no significant difference between the parameter estimates for these groups. Thus, evidence for an association between increased risk of systolic hypertension and the ‘inverse housing law’ is rather weak.

Results for diastolic hypertension are shown in models 3 and 4. In model 3, with only the confounding variables present, female sex and having blood pressure measured in a warmer room were associated with significantly lower odds of diastolic hypertension, with higher body mass index and higher alcohol consumption associated with significantly higher odds of diastolic hypertension. Again, smoking and taking anti-hypertensives were associated with higher odds, but not significantly. Whilst
counter-intuitive, the non-significant relationships with smoking in both the systolic and diastolic models are congruent with some other studies.22 Given that about 40% of those taking anti-hypertensive drugs were not classified as having diastolic hypertension (presumably because their medication was successfully controlling the condition), the absence of a significant statistical relationship between medication and outcome was expected. In addition, the HALS data were gathered during an era in which diastolic hypertension was regarded as of greater clinical significance and the medication received may well have been aimed more at tackling diastolic hypertension, than systolic.

The environmental risk variable was added in model 4. When compared to those with lower exposure to colder climate, in better quality housing, the odds of diastolic hypertension were raised in all other groups. This excess risk was significant and greatest amongst those for which higher exposure to cold was combined with worse quality housing, i.e. those experiencing the ‘inverse housing law’. Their odds of diastolic hypertension were about 45% greater than for those with lower exposure to cold, who lived in better housing.

**Discussion**

Data from a representative survey of the British population were augmented through integration with climatic variables known to be related to the behaviour of the cardiovascular system. Aggregate analyses demonstrated that respondents who live in the relatively cold parts of Britain tend also to live in worse housing (Figure 1, Table 2). If the quality of housing was matched to the ‘demands’ placed upon it by climate, this relationship should be reversed. Following earlier work,1,2 it seems reasonable to label this an ‘inverse housing law’, in the same way that the inverse care law marks the lack of health care services in areas where need is greatest.

The second stage of analysis demonstrated that respondents with higher exposure to colder climate (i.e. living in a colder area for a long period of time) and living in worse quality housing had significantly greater odds of diastolic hypertension, relative to those with lower exposure to colder climate, living in better quality housing. Although the direction of association between environmental risk and increased odds of systolic hypertension was similar, evidence for an impact of the ‘inverse housing law’ on systolic hypertension is weak in comparison to that presented for diastolic hypertension.

**Blood pressure**

The greater increase in odds, and the most robust distinction between those experiencing the ‘inverse housing law’ and those in the other categories environmental risk, was for diastolic hypertension. We suggest that since diastolic pressure reflects the structure of musculature in the arteriolar wall it is, arguably, the component of arterial pressure which better reflects longer term processes, including long term exposure to cold. Although systolic blood pressure is also sensitive to environment it does not reflect arteriole structure in the same way and is therefore less likely to reflect long term exposure to cold through elevation. The weaker evidence for elevated odds of systolic hypertension amongst those experiencing the ‘inverse housing law’, relative to others, was thus as expected.

**Cross-sectional data**

Some caution is required in the interpretation of results since they are based on cross-sectional data. The measurement of blood pressure at one point in time, for example, was not ideal for the classification of respondents as ‘hypertensive’, particularly with regard to any medication which they may, or may not, have been taking. No clinician would classify a patient as hypertensive based on readings taken at one point in time and a degree of ‘white coat hypertension’ can be expected in the readings. However, unless the incidence of white coat hypertension has a geography that closely matches the distribution of cold climate or is related to housing quality, this will not have an effect on the study’s substantive results. The cross-sectional data are likely to be responsible for the apparently high levels of ‘hypertension’ within the study.

By choosing to measure longer term exposure to colder climate, rather than simply including prevailing climate as an independent variable, it was possible to guard against selective migration as a confounder in observed associations between climate, housing and health. However, one disadvantage of this approach is that it grouped those resident in colder parts of Britain for a relatively short period of time together with those who live in warmer parts. However, given our hypothesis that longer term exposure to colder environment might be needed for a clinically damaging response in diastolic blood pressure, the approach adopted represents the best use of available information. Given that hypertension, typically, is asymptomatic for much of its natural history it seems unlikely that it would play any significant role in a selective migration processes.

**Confounding**

Controlling for alcohol consumption, smoking status and body mass index rules out the possibility that these results were due to the higher prevalence of drinking, smoking and/or obesity in areas of Britain which also happen to have a colder climate. However, one possible source of confounding in the relationships described would be a geographical bias in the quality of hypertension treatment which closely matched the geographical distribution of risk as defined in this study. Many of the colder parts of Britain tend to be more remote rural areas in which GP recruitment can be problematic. The HALS data provided a limited opportunity to test this possibility using a proxy for quality of hypertension care in the respondent’s area of residence. A variable was computed to represent the proportion of the sample with no or poor hypertension control in each respondent’s county of residence (no or poor control was defined as presence of hypertension without, or despite, use of anti-hypertensive drugs). There was no correlation (Pearson’s $r = 0.009, P > 0.500$) between environmental risk, through exposure to colder climate and worse quality housing, and this proxy for quality of care. This suggested that geographical variation in quality of hypertension care was not a mediating or confounding factor in the ‘inverse housing law’ explored here.

The absence of an effect of social class suggested that this is a genuine relationship between physical environment and housing circumstances. However, the nature of the housing system means that an inability to correct housing problems, such as inadequate heating or insulation, is likely to be linked
to financial circumstances. The inverse housing law is therefore not seen as an alternative to an effect of income, but rather as one of the ways in which such an effect may operate.

Conclusion
The results suggest that a significant portion of the inequality in the spatial distribution of diastolic hypertension (Figure 1, map [d]) might be explained by the distribution of poor quality housing in Britain, in relation to the climatic environment. As a whole, the results appear to confirm a genuine influence of area of residence on health (via climate)—the so-called 'area effect'.24,25 However, in this case the area effect will primarily influence those for whom longer term exposure to adverse climate is combined with residence in poor quality housing: not all residents of the same area may be affected.

On a population basis, it has been estimated that a reduction in diastolic blood pressure of 2 mmHg would result in a 15% reduction in risk of stroke and transient ischaemic attacks and a 6% reduction in risk of coronary heart disease.26 Coronary heart disease alone costs the NHS about £1600 million a year. Only 1% of this figure is spent on prevention outside of primary care.27 This study provides evidence that the widespread existence of housing of a quality that is inadequate relative to the physical environment is implicated in high levels of hypertension. Britain’s climate cannot be intentionally altered such that it gets warmer in areas of poor quality housing, but investment in housing where its protective role is most needed might yield considerable health benefits.

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KEY MESSAGES
- Longer term residents of Britain’s colder areas tend also to live in poor quality housing.
- People who are both longer term residents of Britain’s colder areas and who live in poor quality housing have significantly higher risk of high diastolic blood pressure.
- The findings provide an example of how long term exposure to an adverse environment, which may stem from material disadvantage, can damage health.

References


