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Higher energy efficient homes are associated with increased risk of doctor diagnosed asthma in a UK subpopulation

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ABSTRACT

Introduction: The United Kingdom (UK) has one of the highest prevalence of asthma in the world, which represents a significant economic and societal burden. Reduced ventilation resulting from increased energy efficiency measures acts as a modifier for mould contamination and risk of allergic diseases. To our knowledge no previous study has combined detailed asset management property and health data together to assess the impact of household energy efficiency (using the UK Government's Standard Assessment Procedure) on asthma outcomes in an adult population residing in social housing.

Methods: Postal questionnaires were sent to 3867 social housing properties to collect demographic, health and environmental information on all occupants. Detailed property data, residency periods, indices of multiple deprivation (IMD) and household energy efficiency ratings were also investigated. Logistic regression was used to calculate odds ratios and confidence intervals while allowing for clustering of individuals coming from the same location.

Results: Eighteen percent of our target social housing population were recruited into our study. Adults had a mean age of 59 (SD $\pm$ 17.3) years and there was a higher percentage of female (59%) and single occupancy (58%) respondents. Housing demographic characteristics were representative of the target homes. A unit increase in household Standard Assessment Procedure (SAP) rating was associated with a 2% increased risk of current asthma, with the greatest risk in homes with SAP > 71. We assessed exposure to mould and found that the presence of a mouldy/musty odour was associated with a two-fold increased risk of asthma (OR 2.2 95%; CI 1.3–3.8). A unit increase in SAP led to a 4–5% reduction in the risk of visible mould growth and a mouldy/musty odour.

Discussion: In contrast to previous research, we report that residing in energy efficient homes may increase the risk of adult asthma. We report that mould contamination increased the risk of asthma, which is in agreement with existing knowledge. Exposure to mould contamination could not fully explain the association between increased energy efficiency and asthma. Our findings may be explained by increased energy efficiency combined with the provision of inadequate heating, ventilation, and increased concentrations of other biological, chemical and physical contaminants. This is likely to be modified by a complex interaction between occupant behaviours and changes to the built environment. Our findings may also be confounded by our response rate, demographic and behavioural differences between those residing in low versus high energy efficient homes, and use of self-reported exposures and outcomes.

Conclusion: Energy efficiency may increase the risk of current adult asthma in a population residing in social housing. This association was not significantly modified by the presence of visible mould growth, although further research is needed to investigate the interaction between other demographic and housing characteristic risk factors, especially the impact of fuel poverty on indoor exposures and health outcomes.

Study implications: A multidisciplinary approach is required to assess the interaction between energy efficiency measures and fuel poverty behaviours on health outcomes prior to the delivery of physical interventions aimed at improving the built environment. Policy incentives are required to address fuel poverty issues alongside measures to achieve SAP ratings of 71 or greater, which must be delivered with the provision of adequate heating

Abbreviations: BMI, body mass index; ERMI, environmental relative mouldiness index; ETS, environmental tobacco smoke; IAQ, indoor air quality; IMD, index of multiple deprivation; ISAAC, International Study of Asthma and Allergies in Childhood; LARES, the large analysis and review of European housing and health status; MSqPCR, mould specific quantitative polymerase chain reaction; SAFS, severe asthma with fungal sensitization; SAP, standard assessment procedure; SES, socio-economic status; SW, south west of England

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and ventilation strategies to minimise indoor dampness. Changes in the built environment without changes in behaviour of domicile residents may lead to negative health outcomes.

1. Introduction

Household energy efficiency is measured by the Government's Standard Assessment Procedure (SAP) in the United Kingdom (UK), which aims to assess how much energy a dwelling will consume. Increasing energy efficiency is one of the mitigation strategies (Haines et al., 2009) now necessary for meeting energy and climate change targets. Energy efficiency measures are being used as a policy to reduce the domestic carbon footprint, protect against temperature-related morbidity and mortality, and to alleviate fuel poverty (Wilkinson et al., 2007) by reducing property running costs (Kelly et al., 2012). Fuel poverty is a significant problem (Hills, 2011) that affects 2.4 million UK households (Department of Energy and Climate Change, 2014a) leading to poor hygrothermal conditions, increases in winter deaths (Liddell and Morris, 2010; Oreszczyn et al., 2006) and elevated risk of indoor dampness (Sharpe et al., 2014b). Around 40% of UK homes have received energy efficiency upgrades as a result of regulatory and governmental incentives (Hamilton et al., 2014). As a result, energy efficiency rates have increased significantly over the last two decades with the greatest improvements in the social housing sector, which have higher rates of energy efficiency compared to privately owned and privately rented residences (Department for Communities and Local Government, 2014a). Populations residing in social housing live in properties that have been draft-proofed to prevent heat loss, with simultaneous improvements to insulation and heating systems. Reduced ventilation may have unwanted repercussions on indoor air quality (IAQ) (Lavergea et al., 2011) and has been found to modify indoor mould contamination and risk of allergic symptoms (Bornehag et al., 2005; Hägerhed-Engman et al., 2009). This occurs when household air changes per hour (ACH) falls below the European standard of 0.5 ACH (Dimitroulopoulou, 2012). Few studies have assessed long-term trends in household energy efficiency (i.e. sealing up human domiciles, improving insulation and heating systems), and its impact on adult respiratory health. Also populations residing in social housing has been under-represented in health studies, predominantly as they have proved difficult to access.

The rise in asthma prevalence throughout the 20th and into the 21st century has been well documented in worldwide childhood epidemiological studies (Asher et al., 2006; Pearce et al., 2007). Fewer studies have addressed a corresponding rise in prevalence of allergic diseases into adulthood. The United Kingdom (UK) has one of the highest prevalence of doctor diagnosed asthma affecting around 10% of the adult population (Netuveli et al., 2005), representing a heavy economic and societal burden (Takaro et al., 2011). The rise in prevalence of allergic diseases has occurred more rapidly than can be explained by genetic factors alone, suggesting that environmental factors are important determinants (Osborne et al., 2010). Researching potential causal pathways has led to investigations into environmental exposures, including indoor dampness and increased exposure to mould contamination. Previous population studies demonstrate that dampness, mould growth (the microbial profile), and odour caused by the production of microbial volatile organic compounds (mVOC) (Weschler and Nazaroffc, 2008), are consistently associated with multiple allergic and respiratory health effects (Mendell et al., 2011). Exposure to elevated concentrations of *Aspergillus*, *Penicillium*, *Alternaria* and *Cladosporium* is associated with increased risk of asthma (Sharpe et al., 2014a). This is a public health concern because an estimated 6.5 million people globally have severe asthma with fungal sensitization (SAFS) and up to 50% of adult asthmatics attending secondary care have fungal sensitization (Denning et al., 2014). There is a need to better understand the potential health effects resulting from increased energy efficiency and its impact on dampness and mould contamination.

Trends in increasing energy efficiency are continuing without assessing long-term health implications (Bone et al., 2010). This is a public health concern because of the predicted increases in outdoor relative humidity levels resulting from climate change, particularly in damp mild climates such as the South West of England (SW) (Kosanic et al., 2014), which promote indoor mould contamination (Mudarri, 2010). Social housing properties have been a specific target for improved energy efficiency to alleviate fuel poverty. From a public health angle, targeting social housing has the potential to benefit occupants residing in 3.7 million households equating to 17% of the total housing stock in the UK (Department for Communities and Local Government, 2014a). To our knowledge, no study has assessed the role of energy efficiency rates on asthma outcomes of adults residing in social housing. In this study, we assess whether 1) improvements to energy efficiency increase the risk of current adult asthma, 2) determine if mould contamination increases the risk of current adult asthma, and 3) whether energy efficiency modifies the likelihood of mould contamination.

2. Methodology

2.1. Study population

Ethical approval for this cross sectional study was granted by the University of Exeter Medical School, application number 13/02/013. This study focuses on a population residing in social housing in Cornwall, SW. The target population resides in properties owned and managed by a medium-sized Social Housing Association. In the UK, Social Housing Associations are not-for-profit organisations responsible for the provision of affordable housing to low income populations (Government, 2013). Cornwall is a predominantly rural county and home to some of Europe's most deprived communities (Cornwall Council, 2014). It is influenced by a strong maritime climate that is dominated by mild temperatures, strong wind speeds and wet winters (Kosanic et al., 2014). Social housing properties are maintained according to the UK Government's Decent Homes standard, which is the statutory minimum standard for housing (Department for Communities and Local Government, 2006).

Study participants were recruited from 3,867 postal questionnaires sent out to each tenancy holder (134 addresses did not have a contact name, and questionnaires were addressed to home holder). The postal questionnaires were conducted in four phases during August 2012, October/November 2013 and January 2014 to reduce the potential impact on customer services. Written consent was obtained using a form containing a series of scripted questions concerning participant involvement in various elements of the study. Response rates were maximised by sending out awareness letters, newsletters, working with community group leaders, reminder post cards, free post return envelopes and a prize draw (vouchers worth £5). The project was titled the Cornish Health project and we omitted the use of key words such as indoor dampness and mould, with the exception of questions relating to mould contamination, which were printed on the last page in an effort to reduce reporting bias.

2.2. Questionnaire data

Questionnaires were designed using a closed questioning technique. They were designed to collect data on all occupants, which included demographic and environmental exposures thought to influence the risk