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# Exposure to indoor mouldy odour increases the risk of asthma in older adults living in social housing

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## Abstract

**Background**: Indoor dampness is thought to affect around 16% of European homes. It is generally accepted that increased exposure to indoor dampness and mould contamination (e.g. spores and hyphae) increases the risk of developing and/or exacerbating asthma. Around 30% of people in the Western world have an allergic disease (e.g. allergy, wheeze and asthma). The role of indoor mould contamination and risk of allergic diseases in older adults is yet to be fully explored. This is of interest because older people spend more time indoors, as well as facing health issues due to the ageing process, and may be at greater risk of developing and/or exacerbating asthma as a result of indoor dampness.

**Methods:** Face to face questionnaires were carried out with 302 participants residing in social housing properties located in the South West of England. Self-reported demographic, mould contamination (i.e. presence of mould growth and mouldy odour) and health information were linked with the asset management records (e.g. building type, age and levels of maintenance). Multivariate Logistic regression was used to calculate the odd ratios and the confidence interval of developing and/or exacerbating asthma, wheeze and allergy with exposure to reported indoor mould contamination. We adjusted for a range of factors that may affect asthma outcomes, which include age, sex, current smoking, presence of pets, education, building type and age. To assess the role of mould contamination in older adults, we compared younger adults to those aged over 50 years.

**Results:** Doctor-diagnosed adult asthma was reported by 26% of respondents, 34% had current wheeze while 18% had allergies. Asthma was common among subjects exposed to reported visible mould (32%) and reported mouldy odour (42%). Exposure to visible mould growth and mouldy odour were risk factors for asthma, but not to wheeze or allergy. Exposure to mouldy odour increased the risk of asthma in adults over the age of 50 years (OR 2.4 95% CI 1.10-5.34) and the risk was higher in females than in men (OR 3.5 95% CI 1.37-9.08). These associations were modified by a range of built environment characteristics.

**Conclusion:** We found that older adults living in social (public) housing properties, specifically women may be at higher risk of asthma when exposed to mouldy odour, which has a number of implications for policy makers and practitioners working in the health and housing sector. Additional measures should be put in place to protect older people living in social housing against indoor damp and mould contamination.

## 1. Introduction

Asthma is a complex heterogeneous disease with variable severity, pathogenesis and treatment (1). The nonspecific symptoms of asthma can be similar to symptoms of diseases like chronic obstructive pulmonary disease (COPD) and can therefore make it difficult to estimate or diagnose in adults (2). According to World Health Organisation (WHO), about 235 million people worldwide are asthmatic and an estimated 383,000 people died in 2015 due to asthma (3). In the United Kingdom (UK), 4.3 million adults currently receive treatment for asthma (4). The rapid rise in asthma and other allergic diseases (e.g. eczema and allergy) over the last several decades cannot be explained by genetic factors alone, which has led to an increased focus on environmental exposures. For example, asthma cases are expected to rise to 400 million globally by 2025 (1) due to increased exposure to air pollution, climate change, change in immune responsiveness, urbanisation and changes in lifestyle (1, 5). It is thought that exposure to pollutants in the home may have a more pronounced impact on asthma because populations living in developed countries spend up to 90% of their time in the indoor environment, with approximately 69% spent in the residential indoor environment (6).

Significant progress has been made towards understanding the different factors in the indoor environment that can lead to the development and/or exacerbation of asthma and other allergic diseases. For example, exposure to combustion by-products such as those arising from environmental tobacco smoke, heating and cooking can contribute significantly to indoor exposure to diverse physical and chemical agents (7, 8). Exposure to indoor dampness and fungal contamination has been associated with a 30% to 50% increased risk of asthma (9-12). Other predictors of mould contamination (e.g. presence of a mouldy odour) have been associated with a two-fold increased risk of asthma in an adult population (13). With regard to fungal growth, common mould genera such as *Aspergillus, Alternaria, Candida, Cladosporium, Fusarium, Penicillium* that dominate in the indoor environment have been associated with asthma and other respiratory disorders (14-16). Increased exposure to indoor dampness (e.g. rising damp, water penetration, leaks and condensation) and therefore mould is a significant public health in Europe concern with around 16% of homes suffer from indoor dampness in Europe (17).

To date, much of the available evidence on the role of indoor damp and asthma concerns children(18-21) with much less work investigating the relationship between indoor mould and asthma and other allergic disease in adulthood, particularly among older adult populations. This is despite, exposure to indoor mould potentially having a higher risk on adults' asthma due to normal or pathological aging, underlying disease, social economic status (SES), diet, physical activity, and social background(22). The limited research that has been conducted on adult populations found that exposure to mould contamination has been associated with doctor-diagnosed asthma, asthma symptoms, and bronchial hyperresponsiveness (23-25) and new onset asthma in adult (26). Furthermore, this association has been found to be more pronounced for women and in those with multi-sensitisation, and in particular mould sensitisation (26).

Within this context, this study investigates the level of indoor mould exposure and associated risk of asthma in older adults (i.e. greater than 50 years) living in social (public) housing in Cornwall, South West of England. This is of interest because the impact of indoor dampness and related agents in older age is yet to be fully explored within a residential setting. This is relevant given current trends towards ageing societies who may spend more time indoors at home. Additionally, social housing in the UK generally support older and lower income households who experience greater problems with indoor dampness and mould contamination (13). The paper is structured as follows. Section 2 presents the methodology, including discussion of the design of the study and questionnaire. Section 3 presents the results of statistical analysis. Section 4 presents a discussion of the results and gives some conclusions.

## 2. Methodology

*Study Background*

This study forms part of the Smartline project, funded by the European Regional Development Fund. Smartline is a partnership project led by the University of Exeter, involving Coastline Housing (an independent, not-for-profit housing association), Cornwall Council and Volunteer Cornwall (a charity aiming to develop individuals and communities through voluntary action). Smartline has recruited over 300 households in properties owned and managed by Coastline Housing and has conducted a range of activities to better understand the health and wellbeing of individuals in these homes. Activities include the use of questionnaire surveys, qualitative interviews and the collection of sensor data on indoor environments. Ethical approval for the Smartline project was granted by the University of Exeter.

*Study area / population*

This study focuses on a population residing in social housing in Cornwall, South West of England (SW). Cornwall has a strong maritime climate characterised by mild temperatures, strong wind speeds and wet winters (13, 27). The area is largely rural with dispersed settlement patterns and experiences high levels of deprivation (13, 28). The county is ranked 95 out of 326 local authorities in England for overall deprivation and 121 out of 326 in terms of income deprivation in the 2015 Indices of Multiple Deprivation (29). A quarter of our target population current reside in neighbourhoods considered to be the most deprived 20% in England (28). The Smartline sample resides in properties owned and managed by Coastline Housing, a medium-sized not-for-profit Social Housing Association. In the UK, social housing associations are responsible for the provision of affordable housing to low income populations (13). In Cornwall, Social Housing Associations are responsible for around 8% of the total housing stock (29), which represents approximately 12% of the population (30). These homes are maintained according to UK Government's Decent Homes Standards, 2006 (13, 31), which means that properties are maintained and have slightly higher energy efficiency levels (13).

*Questionnaire data*

The questionnaire was designed using a closed questionnaire technique and administered by trained researchers over the period January 2018 to June 2018. The overall survey lasted for about 45 minutes and included questions relating to demographic information, health and wellbeing, volunteering activity, use of technology and data on the use of the home. In total, 302 households were surveyed.

The elements of the survey relating to asthma risks were designed based on an earlier study on social housing (13) and collected information on all occupants including demographic and environmental exposures thought to influence the risk of asthma. Questions included participant age, sex, height, weight; smoking status; employment; cleaning regimes; number of rooms carpeted; pets; health data on asthma, allergy and chronic bronchitis or emphysema; heating/ventilation regimes and whether participants thought damp/mould impacted their family's health (13). Asthma in this study was defined as doctor-diagnosed asthma where participants confirmed they had seen a doctor and /or taken medication for asthma' in the last 12 months. Wheeze is defined as adults who have answered 'yes' on having wheezing or dry coughing in the chest in the preceding 12 months. Allergy is defined as participants who have answered 'yes' on having allergy and seen a doctor in the last 12 months for allergy. The exposure variables for mould contamination were defined as the presence of visible mould (Yes, No) and mouldy odour anywhere in the house (Yes, No). Questionnaire data were merged with property records from Coastline Housing's asset management and stock condition data (December 2018) using a unique household identifier. Data variables used in this study to account for the built environment included building age (Pre 1930s, 1930-1965, 1965-1980s, 1980s onwards) and building type (house, bungalow, flat).

*Statistical Analysis*

Descriptive analysis was used to describe the participants' representativeness and household demographics differences. The outcome data (asthma, wheeze and allergy) were analysed as separate dependent variables against the dichotomous mould exposures (reported visible mould, and mouldy odour). Univariate analyses were performed using logistic regression to assess the association between the variables of interest and asthma outcomes. Multivariate logistic regression analyses were used to estimate the relationship between reported mould exposures and asthma, wheeze, and allergy, adjusting for gender, age, smoking status, education, presence of pets, building type and building age. To evaluate the association of mould contamination and asthma across the life course, the asthma model was further stratified by age with a specific focus on adults aged 50 years plus. Associations are expressed as odd ratios (OR) with a 95% confidence interval (CI). All statistical analyses were performed using STATA /SE 15.0 (Stata Corporation, college station, Texas, USA).

## 3. Results

Table 1 presents descriptive statistics for the sample population. The average age of participants is 57 years (range 18-93 years). Sixty-nine percent of the survey participants are female, 39% are current smokers. 35% of the participants are retired while 27% are on long time illness. Much of the population, 71%, only completed formal primary and secondary (4-16 years) levels of education. Twenty-six percent of the adult participants have had asthma and seen a doctor for asthma in the last 12 months while 34% reported having a wheeze in the preceding 12 months. Eighteen percent of adult participants reported having allergy in the preceding 12 months. Forty-five percent of the participants (47% female compared to 40% male) reported visible mould in different rooms in their homes. Eighteen percent of respondents reported having a mouldy odour in different rooms. Fifty-four percent of the participants live in flats compared to 37% in single storey houses and 35% of participants reside in properties less than 40 years old.

**Table 1. Descriptive Statistics of Smartline Participants**

| Socio-demographic characteristics | Study Participants | |
|---|---|---|
| | Percentage (%) | Number (n=302) |
| Percentage male | 30 | 91 |
| Percentage female | 69 | 208 |
| Mean adult age (≥18 years) = 57, range =18-93 years | | |
| **Smoking status** | | |
| Non-smoker | 24 | 72/302 |
| Ex-smoker | 37 | 113/302 |
| Current smoker | 39 | 116/302 |
| Smoke< 5 times a day | 15 | 44/302 |
| Smoke 5-15 times a day | 34 | 102/302 |
| Smoke more than 15 times a day | 27 | 81/302 |
| Smoke inside house | 34 | 101/299 |
| **Respiratory Health** | | |
| Adults with a wheeze or dry cough in ≤12 months, | 34 | 104/302 |
| Have asthma and seen a doctor in ≤12 months, for asthma | 26 | 78/302 |
| Allergy | 18 | 55/302 |
| Emphysema or chronic bronchitis | 13 | 39/302 |
| **Education** | | |
| GCSE/O level or lower (including no formal qualification) | 71 | 212/302 |
| A level or equivalent | 25 | 74/302 |
| Degree level or equivalent | 4 | 13/302 |
| **Participants providing employment status** | | |
| Employed | 18 | 55/302 |
| Unemployed | 0 | 0 |
| Actively looking for work | 2 | 7/302 |
| Retired | 35 | 107/302 |
| Long-time illness | 27 | 82/302 |
| Housekeeper / carer | 14 | 42/302 |

| | | |
|---|---|---|
| Student | 2 | 5/302 |
| Other | 1 | 4/302 |
| **Presence of pets in the house** | | |
| Cat | 31 | 93/302 |
| Dog | 36 | 110/302 |
| **Reported visible mould contamination** | 45 | 135/302 |
| **Reported Mouldy odour** | 18 | 54/292 |
| **Household occupancy (mean 2, range 1-7)** | | 302 |
| 1- single occupancy | 42 | 128/302 |
| 2- double occupancy | 31 | 93/302 |
| 3- triple occupancy | 13 | 40/302 |
| 4+ multiple occupancy | 14 | 41/302 |
| **Build age of properties (1929-2016, mean=45 years)** | | 302 |
| Pre 1930 | 3 | 9 |
| 1930-1965 | 41 | 124 |
| 1965-1980 | 20.5 | 62 |
| 1980+ | 35 | 107 |
| **Build Type** | | 273 |
| House | 37 | 101 |
| Bungalow (single storey house) | 9 | 24 |
| Flat (apartment) | 54 | 148 |

The average age of those who reported having asthma and seen doctor in the last 12 months was 54.7 years old compared to 57 years old for those who do not have asthma. Forty three percent of those exposed to mouldy odour and 21% of those exposed to visible mould have current asthma. Reported asthma was more common among ex-smokers / current smokers and those in multiple occupancy. Asthma was also prevalent in those that have had wheeze or dry cough (55%), allergy (62%), and seen a doctor for chronic bronchitis, emphysema or COPD (49%).

*Association between behavioural and indoor exposure covariates to asthma*

Younger adults (OR 1.0 95% CI 1.00-1.10) and women (OR 2.7 95% CI 1.4-5.1) were more likely to have asthma (Table 2). In terms of smoking, risk of having doctor diagnosed asthma is higher for current (OR 1.3 95% CI 0.7-2.85) and ex-smokers (OR 1.4 95% CI 0.69 -2.80) compared to participants who never smoked, while participants who smoke inside the home had a positive relationship with asthma. However, these relationships are not statistically significant. There was also no clear relationship between vaping in the home and risk of asthma in this population. Those who vacuum their house less than 5 times a month were more likely to have asthma than those who vacuum more than 5 times a month. There are positive relationships between cat or dog ownership and asthma, but the relationship is statistically stronger in dog ownership (OR 2.0 95% CI 1.20-3.44) and not in cat ownership (OR 1.6 95% CI 0.92 -2.73). Asthma was more common among those that have had wheeze or dry cough in the preceding 12 months (OR 14.55 95% CI 1.83-116.05), had an allergy (OR 7.4 95% CI 3.94- 14.02), or seen a doctor for chronic bronchitis, emphysema or chronic obstructive pulmonary disease (COPD) (OR 3.3 95% CI 1.64-5.63).

**Table 2: Univariate Analysis between covariates and asthma**

| Covariates | Current Asthma | |
|---|---|---|
| | % (n/d) | OR (95%CI) |
| **Participants age (mean=54.7)** | | |
| ≤50 years | 32(33/103) | 1.0 (1.00-1.10) |
| >50 years | 23(45/197) | 0.98(0.95-1.01) |
| **Gender** | | |
| Male | 14(13/91) | Ref |
| Women | 31(64/208) | 2.7(1.4-5.14) ** |
| **Smoking history** | | |
| Never smokers (ref) | 22(16/72) | Ref |
| Ex-smokers | 28(31/112) | 1.4(0.69-2.80 |
| Current smokers | 28(31/113) | 1.3(0.70-2.85) |
| **Smoke inside house** | | |
| No | 25(49/198) | Ref |
| Yes | 28(28/100) | 1.2(0.68-2.04) |
| **Home Vape** | | |
| No | 26(66/254) | Ref |
| Yes | 26(11/43) | 0.98(0.47-2.05) |
| **Vacuum house (n per month quartiles)** | | |
| 0-5 times | 29(22/77) | 1.2(0.42-3.21) |
| 5-15 times | 23(21/92) | 0.89(0.31-2.52) |
| 15-30 times | 28(29/104) | 1.2(0.42-3.21) |
| >30 (ref) | 25(6/24) | Ref |
| **Household occupancy** | | |
| 1-Single occupancy | 23(30/128) | Ref |
| 2-double occupancy | 23(21/93) | 0.95(0.50-1.80) |

| | | |
|---|---|---|
| 3-triple occupancy | 35(14/40) | 1.8(0.82-3.79) |
| Multiple occupancy (4+) | 33(13/40) | 1.5(0.72-3.42 |
| **Wheeze or dry cough in ≤12 months** | | |
| No | 8(1/13) | Ref |
| Yes | 55(57/104) | 14.55(1.83-116.05) * |
| **Allergy** | | |
| No | 18(44/246) | Ref |
| Yes | 62(34/55) | 7.4(3.94-14.02) *** |
| **Seen a doctor for chronic bronchitis, emphysema or COPD** | | |
| No | 23(59/262) | Ref |
| Yes | 49(19/39) | 3.3(1.64-6.53) ** |
| **Presence of Cat** | | |
| No | 23(48/208) | Ref |
| Yes | 36(30/93) | 1.6(0.92-2.73) |
| **Presence of Dog** | | |
| No | 21(40/192) | Ref |
| Yes | 35(38/109) | 2(1.20-3.44) ** |
| **Home has more than 2-rooms carpeted or rugged** | | |
| No | 30(28/93) | Ref |
| Yes | 35(50/208) | 0.7(0.43-1.27) |
| **Build age** | | |
| Pre 1930 | 29(2/7) | 1.3(0.25-6.88) |
| 1930-1965 | 52(42/81) | 2.4(1.29-4.47) |
| 1965-1980 | 32(15/47) | 1.5(0.69-3.17 |
| 1980+ | 22(19/88) | Ref |
| **Build Type** | | |
| House | 33(6/18) | Ref |
| Bungalow | 43(30/70) | 1.3(0.46-3.56) |
| Flat (apartment) | 33(37/111) | 1(0.37-2.707) |

*Exposure to mould contamination and risk of adult asthma diagnosis*

There were no clear associations between self-reported visible mould growth and mouldy odour and the risk of asthma, wheeze and allergy (Table 3). The presence of visible mould growth may not be a true representation of the extent of contamination within a home, which may partly explain a relationship between the presence of a mould musty odour and asthma. In the unadjusted model, exposed to visible mouldy was not significantly associated with asthma (OR 1.4 95% CI 0.86-2.42) but was for reported mouldy odour (OR 2.7 95% CI 1.46-5.02). After adjusting for our *a priori,* exposure to a mouldy musty odour was associated with a 2-fold increased risk of asthma (AOR 2.7; 95%CI 1.32-5.58; p=0.006) and both allergy and asthma (AOR 2.2; 95% CI 1.11-4.40; p=0.025).

**Table 3. Association between indoor mould contamination and risk of adult asthma, wheeze and allergy**

| Health outcome | Presence of visible mould | | Presence of Mouldy Odour | |
|---|---|---|---|---|
| | **Unadjusted** | **Adjusted** | **Unadjusted** | **Adjusted** |
| | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| **Current Asthma** | 1.4 (0.86-2.42) | 1.02 (0.55-1.89) | 2.7(1.46-5.02) ** | 2.7(1.32-5.58) ** |
| **Wheeze** | 1.3 (0.41-4.18) | 1.2 (0.28-4.91) | 0.7(0.20-2.62) | 0.93(0.18-4.81) |
| **Allergy** | 0.98(0.54-1.76) | 1.04 (0.52-2.09) | 0.97(0.45-2.07) | 0.95(0.40-2.30) |
| **Current asthma & Allergy** | 1.2 (0.77-2.02) | 1.0 (0.6-1.84) | 2.3(1.26-4.18) ** | 2.2(1.1-4.40) * |

In our stratified adjusted model (Table 4), we found adults self-reporting the presence of a mouldy musty odour had a 4-fold increased risk of asthma (OR 4.0: 95%CI 1.4 -11.43, P=0.008). There was no association between mouldy musty odour and asthma among adults aged between 18 and 50 years. To assess the potential effects of demographic characteristics, we also stratified the model by gender. Compared to men, women had a 2-fold increased risk of asthma when exposed to mouldy odour (OR 2.4: 95%CI 1.02 -5.67, P=0.045).

**Table 4: Indoor mould and risk of asthma in adult greater than 50 years**

| Mould contamination | Health outcome: Adult Asthma | | | | |
|---|---|---|---|---|---|
| | Percent (n/d) | Unadjusted | | Adjusted 1 | |
| | | OR | 95%CI | OR | 95%CI |
| **Presence of visible mould** | | | | | |
| **≤50 years** | 33(22/62) | Ref | | Ref | |
| **>50years** | 31(19/72) | 1.3 | 0.65-2.53) | 1.02 | 0.50-2.30 |
| **Presence of Mouldy Odour** | | | | | |
| **≤50 years** | 100(13/27) | Ref | | Ref | |
| **>50years** | 38(11/27) | 2.6 | 1.10-6.14* | 4.0 | 1.40-11.14 ** |

## 4. Discussion

This study contributes to existing literature by investigating how exposure to mould contamination influences the risk of asthma in older adults. The study found that older adults were at greater risk of asthma when living in homes with a mouldy musty odour (i.e. a 4-fold increase risk of asthma in adults aged over 50 years). The study also demonstrates that women may also be at greater risk, which may be due to gender differences between the amount of time spent indoors at home. Further research is needed to explore the differences between gender differences and the variability of daily activities and time spent indoors. This will help improve future estimates of the impact of indoor dampness and related biological, chemical and physical air pollutants found in the home.

*Synthesis with existing literature*

It is generally accepted that indoor mould contamination increases the risk of asthma (9, 10, 12) across a range of populations. Other studies have reported significant association with reported visible mould and risk of adult asthma and allergy (13, 24-26, 32, 33). The lack of association between self-reported visible mould growth and asthma and allergy in this study may be due to the sample size of the study and/or sensitivity of this exposure definition for example. Prior research (13, 32) supports our finding that exposure to a mouldy/musty odour has a stronger effect with a 2-fold increased risk of adult asthma. The mechanism by which mouldy odours are associated with asthma may be related to toxic reactions in damp surfaces (e.g. resulting from the degradation of building materials), hypersensitivity reactions and degradation of microbial volatile compounds. Also the presence of a mouldy odour has been found to correspond with high concentration of microbial contaminates and airborne mould concentration in homes (34). While, a mouldy odour can be easily missed and not detected, this represents a strong indicator for poor air quality risk to adults with an allergic and non-allergic disease(33). While, In terms of potential gender differences, other studies have reported similar associations between mould contamination and risk of asthma in men and women (23). However, in contrast to our findings, previous research also indicated that mould contamination had a stronger risk for asthma onset in younger adults (44).

While we were not able to formally test the mechanisms underpinning the reported gender and age results reported here, women and older adults may have increased exposures to indoor mould contamination because of different lifestyle characteristics and spending more time indoors at home. The elderly due to health reasons may be restricted to movements and are likely to spend more time indoors and may live in different housing solutions such as sheltered housing especially in industrialised countries (35). As described in Table 1, many of our participants are older and reported one or more chronic diseases, which in turn may make them more likely to spend time indoors. Women on the other hand generally spend more time in the home, carrying out most of the house chores like cleaning, caring and other activities making them more susceptible to mould exposures. More so, late onset adults' asthma is known to affect women particularly (36) which could also explain the effect in older adults.

From a methodological perspective, the differences observed between this study and previous studies may be a result of different outcome definitions between studies particularly as this study did not assess the risk of asthma onset. However, it is important to note that our topic of interest is complex and is the result of complex interactions between residents' lifestyles, the natural and built environment, which includes both housing conditions but also external environmental conditions, such as outdoor air pollution and access to greenspace. It is also important to consider the impact of other allergens found in the home and interaction with occupant health outcomes. For example, it is thought that the diversity of indoor allergens and allergic sensitisation may play a different role in children and adults (33), which further highlights the complexity of investigating the impact of allergic diseases in older age. It is also likely that the association between COPD and asthma may partly explain our findings.

*Strengths and limitations*

A strength of this study includes its response rate. After discarding nine invalid / incomplete questionnaires, a comparatively high number of the targeted population (87%) participated in the study. This reduces the risk of bias within this population because the potential of selection bias reduced in response rates above 62% (37). The questionnaires were completed by trained volunteers to ensure questions are explained to participants and reduce the risk of information bias through misunderstanding / misinterpretation of the questions. This also may have led to participants being more engaged hence the increase in study response. The focus on social housing residents means that the project provides a unique insight to this sub population.

However, some limitations do exist. The cross-sectional study design limits the possibility to draw conclusions on causality and sample size reduces our confidence in the effect sizes (resulting in wide confidence intervals). There is the potential for bias resulting from participants believing that indoor damp and/or mould contamination impacts their family's health (13), and the potential for asthmatics being more likely to report dampness related issues (9). As indicated above, it is also possible that a lack of heating and ventilation and elevated dampness may lead to the proliferation of house dust mites and concentrations of volatile organic compounds, which are known risk factors for asthma (38). Our self-report exposure outcomes may also introduce an element of uncertainty, but it is clear that homes with visible mould growth have higher concentrations of microbial exposures (34). While the use of self-reported measures may introduce an element of error, others have found that self-reported asthma has corresponded well with a GP formal diagnosis (39). The prevalence of asthma in our study is high (26%) when compared to UK general population, however, similar prevalent rates have been reported by prior studies assessing risk of asthma in lower income populations (13, 40).

Studies that compared self-reported mould exposures with site visits and / or quantitatively measured microbial exposures have also shown that occupants may underestimate their exposures (41) or may not suspect or detect mould contamination (34). Our findings may also be influenced by other building characteristics not assessed in this study, which may include building type, ventilation type and indoor temperate etc. These factors modify indoor mould concentration and / or risk of asthma. To further our understanding into the impact of indoor environmental exposures, future studies must account for these limitations. This could be achieved through larger scale studies investigating health risks associated with indoor air pollution through the use of air pollution sensors and more detailed information on behavioural and building characteristics.

## 5. Conclusion

Exposure to indoor mould contamination in social housing increases the risk of doctor diagnosed asthma, which appears to be greatest among older adults and women. There is a clear need for housing providers to improve housing conditions in social housing communities, as well as improve occupants' awareness of indoor mould effects and educate them on strategies to reduce mould contamination to help avoid these adverse health outcomes. The findings from this study can be applied to other comparable low-income populations, however it is vital to consider the possible bias in the study when discussing the results or applying the findings to the general population.

**Author Contribution**

Conceptualization, Karyn Morrissey and Richard Sharpe; Data curation, Karyn Morrissey; Formal analysis, Loveth Moses; Funding acquisition, Karyn Morrissey and Timothy Taylor; Methodology, Loveth Moses, Karyn Morrissey and Richard Sharpe; Writing – original draft, Loveth Moses; Writing – review & editing, Loveth Moses, Karyn Morrissey, Richard Sharpe and Timothy Taylor.

**Funding**

This research was supported by funding provided by the European Regional Development Fund (grant number SZ07660) for the SMARTLINE Project.

**Conflict of Interest**

We declare that none of the authors involved in writing this paper have any conflict of interests with respect to the content of this article.

**Acknowledgments**

The European Regional Development Fund is part of the European Structural and Investment Funds Growth Programme 2014–2020. The Ministry of Housing, Communities & Local Government (and in

London the intermediate body Greater London Authority) is the Managing Authority for European Regional Development Fund. Established by the European Union, the European Regional Development Fund helps local areas stimulate their economic development by investing in projects which will support innovation and businesses and create jobs and local community regeneration. For more information visit https://www.gov.uk/european-growth-funding.

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