

Reduction in humidity as a method of controlling mites and mite allergens: the use of mechanical ventilation in British domestic dwellings

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Summary

Background Low humidity is an important limiting factor for mite population growth. Reducing humidity can therefore be used as a method to control mites within the home.

Objective This study investigated the effect of mechanical ventilation heat recovery (MVHR) units on house dust mites and mite allergen Der p 1 in typical homes in the North-West of England.

Methods Mite counts and Der p 1 levels were measured at 3-monthly intervals over a period of 1 year in 18 houses (nine with MVHR units and nine architecturally matched control houses). Paired dust samples were collected using a vacuum cleaner with an air-flow rate 45 l/sec, adapted to collect the sample onto a preweighed filter paper. A 1 m² area of bedroom carpet, living room carpet and mattress was sampled for 2 min. Indoor temperature and relative humidity (RH) levels were recorded for a period of 1 week before and after the winter period (November and February: 3 and 6 months data sets). The environmental questionnaire was completed at the beginning and at the end of the study.

Results No difference in either Der p 1 concentrations or mite counts in any of the sampling sites at 3, 6, 9 and 12 months as compared with the baseline values was found, both within and between the groups ($P > 0.1$). The measured levels of RH performed in autumn and winter were found to be lower in the MVHR houses compared to the architectural controls. The indoor temperature during each period did not differ between the groups. Questionnaire data showed that the severity of condensation improved in the MVHR homes, whilst during the winter period, the severity of condensation had increased in the architectural control group.

Conclusions The MVHR unit does not reduce indoor humidity to levels capable of retarding mite population growth and decreasing mite allergens in the type of houses predominantly found in the mild and humid climate of the North-West of England.

Keywords house dust mites, Der p 1, avoidance, mechanical ventilation, humidity

Clinical and Experimental Allergy, Vol. 26, pp. 1051–1056. Submitted 20 December 1995; revised 13 February 1996; accepted 28 March 1996.

Introduction

House dust mite allergens are a major cause of asthma world-wide and 45–85% of patients with asthma in the

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UK show skin test reactivity to mites, as compared with 5–30% in the general population [1]. The benefit of mite allergen avoidance in mite allergic patients has been clearly demonstrated, with improvement in symptoms and a reduction in airway hyperreactivity and in medication [2–9].

The abundance of mites in dwellings has been related to a number of environmental factors. Among them, the effects of temperature and humidity have been studied in detail (summarized in ref.10). The occurrence of mites in homes is largely determined by the level of air humidity [11], and indoor humidity is the decisive factor for the growth of mites [12]. Active life stages require relatively high indoor humidity for their survival, but a desiccation-resistant protonymph can survive longer periods at low humidities [13].

Dust mites are able to extract water vapour from unsaturated air by passive and active absorption, the amount of passive gain being directly proportional to the humidity of the environment [13]. The uptake of water vapour from the air is facilitated by the hygroscopic properties of a hyperosmotic solution secreted by a small supracoxal gland [14]. The lowest relative humidity at which the passive and active uptake combined compensate for water loss under fasting conditions is known as the critical equilibrium humidity (CEH) [15,16]. Humidity below CEH can dehydrate and kill mites, but will threaten the mite population only if sustained long enough, i.e. for several days [10]. This is more difficult to obtain in mite microhabitats (carpet, mattress and upholstery) than in the room air. The feeding rate of mites is directly influenced by the ambient humidity [17].

A reduction in indoor humidity has been suggested as a method to control mite populations within the home. However, we have shown that a single dehumidifier does not lower humidity sufficiently to suppress mite growth [18]. Mechanical ventilation heat recovery (MVHR) units have been suggested as a means to reduce mite numbers in homes by reducing indoor humidity [19–21]. These units exchange humid indoor air for dry outdoor air, recovering heat from the outgoing air in the process (i.e. the system itself does not actively dry the air). This study investigated the effect of MVHR units on indoor humidity, house dust mites and mite allergen Der p 1 in typical homes in the North-West of England.

Methods

Mite counts and Der p 1 concentrations were measured at 3-monthly intervals over a period of 1 year in 18

houses (nine with installed MVHR units and nine architecturally matched control houses).

Selection of study houses

Mite sensitive asthmatic patients were randomly recruited from the hospital asthma register and their homes were then surveyed by a qualified engineer. Those patients whose homes did not have open fires and had good fitting windows and a suitable loft space were offered the installation of an MVHR unit (Genvex International Ltd, Warwick, UK). The MVHR units consisted of a heat recovery unit and pump, and were sited in the loft. Outside air was ducted into the home and warmed by the heat of outgoing air ducted from the kitchen and bathroom. The two air streams did not mix, and the incoming warmed air was distributed to each room.

To ensure a 'tight' environment additional loft insulation and draught proofing around doors was carried out. Control houses were selected in the immediate neighbourhood and architecturally matched with homes in the active group.

Dust sample collection, allergen assay, mite counts and questionnaires

Paired house dust samples were collected using a Medivac vacuum cleaner with an air-flow rate 45 l/sec, adapted to collect the sample onto a preweighed filter paper (Whatman GFF, pore size 0.7 µm). A 1 m² area of bedroom carpet, living room carpet and mattress were sampled for 2 min. Der p 1 was determined using a commercial ALK ELISA as previously described [22]. Extracts were initially assayed in duplicate at 5-, 25-, and 125-fold dilutions. For concentrations lying off the sloping portion of the standard curve, the assays were repeated at an appropriate dilution. Paired samples were rejected if they differed by more than 5% (restricting intra-assay variation to this level).

The number of mites, as well as their sex, species and developmental stage in every dust sample were documented as previously described [18]. The results were expressed as number of mites/gram of dust.

The environmental questionnaire which documented the type of house and housing conditions, including the type of windows, insulation and heating, the location and age of carpets, mattresses and upholstered furniture, and any problems with condensation and dampness, was completed by the house owner at the beginning and at the end of the study. The occupiers of the homes in the MVHR group were requested to keep their windows closed.

Temperature and humidity measurements

Temperature and relative humidity (RH) levels were recorded in a selected bedroom of each house. A squirrel meter logger (Grant Instruments, London, UK) recorded both dry and wet temperatures at hourly intervals for a period of 1 week. All measurements were performed before and after the winter period (November and February; 3 and 6 months data sets). RH and temperature data were plotted on the psychrometric chart to calculate absolute humidity.

Statistical analysis

Mite counts and Der p 1 data were found to follow a log-normal distribution; the results are thus reported as geometric means. Changes over the study period both within and between groups were examined using a two factor analysis of variance (ANOVA) with repeated measures. The computations were carried out using the GLIM 3.77 computer program. Statistical significance was set at the 5% level.

Results

The general description and details of the domestic dwellings in each group are summarized in Table 1. Tumble dryers were either fitted with external extraction or internal condensers. The proportion with central heating and double glazing reflects the current trend of housing in the Manchester area (personal communication, Manchester City Council).

Table 1. Characteristics of study houses

	MVHR	Control
Type of house:		
Semi-detached	5	6
Detached	2	1
Terraced	2	2
Windows:		
Double glazed	4	6
Secondary	1	0
Single	4	3
Central heating	8	8
Fitted carpets:		
Living room	9	9
Bedroom	8	9
Tumble dryer	5	4
Visible mould	1	2
Pets	2	5

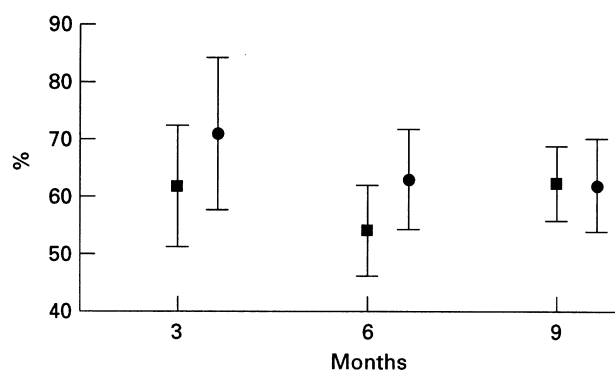


Fig. 1. Relative humidities in the mechanically ventilated and control houses during the course of the study. ■ = MVHR; ● = Controls.

Temperature and humidity

The measured levels of RH performed in autumn and winter were significantly lower in the MVHR houses compared to the architectural controls (Fig. 1). The indoor temperature during each period did not differ between the groups (Table 2).

The reporting of condensation in the bedroom over the study periods demonstrated an improvement in those homes using the MVHR unit compared to the control houses (Table 2). Questionnaire data showed that the severity of the condensation in the bedroom improved in the MVHR homes, whilst during the winter period the severity of condensation had increased in the architectural control group (Table 2).

Mite counts

The geometric means of logged values for mite counts (mites/gram of dust) in the dust samples from mattress, bedroom carpet and living room carpet are shown in Figures 2–4. Although there were some differences in the baseline mean levels of mite count between the groups, these were not statistically significant. There were no significant differences in mite counts both within and between groups in any of the sampling sites at 3, 6, 9 and 12 months, as compared with the baseline values. Similar results were obtained when the results were expressed as mites/area sampled.

Der p 1 levels

Baseline Der p 1 levels were higher in the MVHR unit houses compared to the control group, but this difference was not statistically significant. Figures 2–4 show the geometric means (ng/g of dust) for the two groups at each sampling point. No difference in Der p 1

Table 2. Presence and severity of condensation in bedrooms and mean temperature (°C) in the mechanically ventilated and control houses at 3 months (autumn), 6 months (winter) and 9 months (spring)

	3 months	6 months	9 months
<i>MVHR</i>			
Presence of condensation	7 (70.7%)	5 (55.5%)	1 (11.1%)
Severity:			
Severe	1 (11.1%)	1 (11.1%)	0
Often	5 (55.5%)	0	0
Occasional mist	1 (11.1%)	4 (44.4%)	1 (11.1%)
Mean temperature (sd)	16.2 (3.3)	20.6 (2.1)	17.3 (1.7)
<i>Control</i>			
Presence of condensation	8 (88.8%)	8 (88.8%)	8 (88.8%)
Severity:			
Severe	1 (11.1%)	4 (44.4%)	2 (22.2%)
Often	4 (44.4%)	0	0
Occasional mist	3 (33.3%)	4 (44.4%)	6 (66.6%)
Mean temperature (sd)	17.6 (3.5)	20.2 (1.2)	17.6 (2.5)

concentrations in any of the sampling sites at 3, 6, 9 and 12 months as compared with the baseline values was found, both within and between the groups. The same results were obtained when the Der p 1 data were expressed as recovered allergen/area sampled.

Discussion

The results of the current study indicate that although mechanical ventilation reduced indoor humidity, it did not do so sufficiently to affect the survival of mite populations or reduce allergen levels in typical homes

in the mild and humid climate of the North-West of England.

Mite allergen levels have been found to be significantly lower at high altitudes [23], because outdoor humidity is generally lower at high altitude for a given temperature. Seasonal rises in mite population density are also associated with an increase in mean monthly temperature and humidity [11]. Korsgaard and Iversen have suggested that the dust mite population can be eradicated by using ventilation to keep the indoor humidity of homes in Denmark at below 7 g/kg [19]. The indoor humidity can be reduced by dry outdoor air replacing humid indoor air. This is only true for the dry

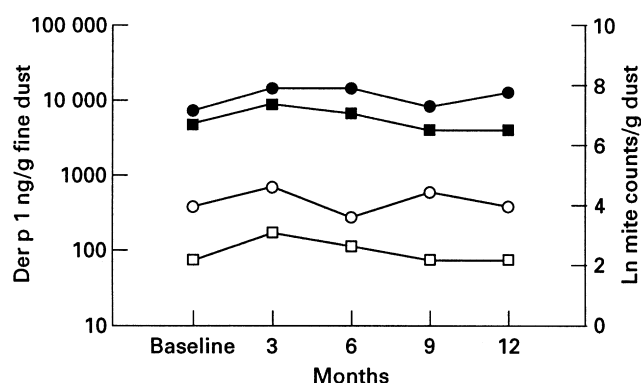


Fig. 2. Bedroom carpet: the geometric means of Der p 1 levels and of logged values for mite counts at baseline and 3, 6, 9 and 12 months after the installation of the MVHR unit. ● = MVHR Der p 1; ■ = Control Der p 1; ○ = MVHR mites; □ = Control mites.

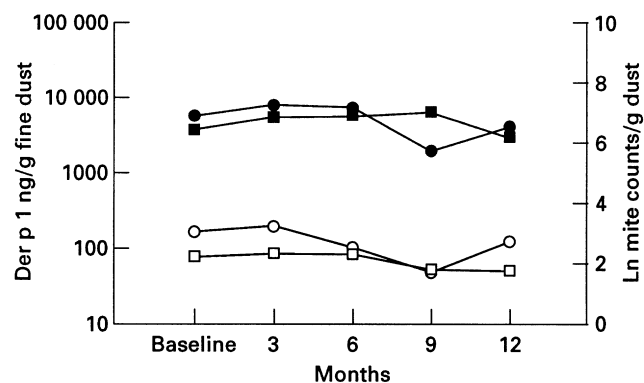


Fig. 3. Living room carpet: the geometric means of Der p 1 levels and of logged values for mite counts at baseline and 3, 6, 9 and 12 months after the installation of the MVHR unit.

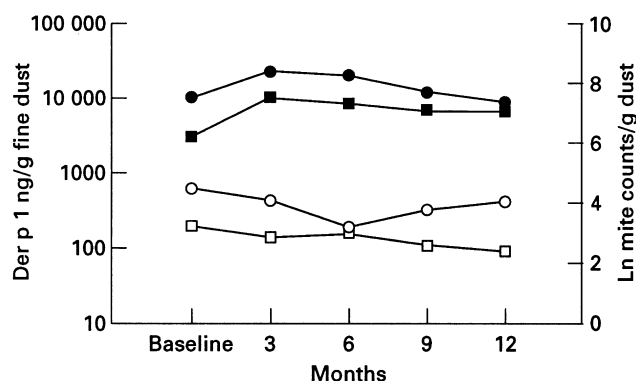


Fig. 4. Mattress: the geometric means of Der p 1 levels and of logged values for mite counts at baseline and 3, 6, 9 and 12 months after the installation of the MVHR unit.

winter season, when the mean outdoor humidity level in Scandinavia is low [24]. Several studies from Scandinavian countries have reported a successful control of house dust mites within domestic dwellings by the use of mechanical ventilation units [19–21]. Wickman *et al.*, have recently reported that the majority of homes with mechanical ventilation in northern Stockholm had absolute humidities below 7 g/kg and significantly lower mite allergen levels than homes without mechanical ventilation [20]. This approach to controlling the mite population has the greatest chance of succeeding in areas with dry cold winters.

Like Scandinavia, the central and northern areas of the USA usually have a prolonged dry period in the winter, which creates poor conditions for mite survival [25]. However, the modern energy efficient housing with external and roof insulation and reduced ventilation was introduced in these areas (the major source of indoor humidity in sealed houses is the water vapour created by human transpiration and domestic activities such as cooking, boiling water, washing and drying of clothes and bathing). The consequent increase in indoor humidity has created favourable conditions for mite population survival throughout the year.

The energy consumption of Swedish houses has been reduced by 18% between 1975 and 1986 by improved insulation [24]. British houses, however, are not tight nor energy efficient. Half of the 18.8 million dwellings in England were built before 1944, and only one quarter have been built since 1964 [26]. Eleven per cent of all dwellings are without loft insulation, and only 14% have either wall insulation or full double glazing [26]. The outdoor humidity is high throughout the year (mean monthly outdoor humidities in South Manchester ranged between 73.6% and 92.1% in 1990–1991) [27]. Outdoor humidity has a major impact on the indoor

humidity level in houses that are not tight and well insulated. In addition to the water vapour produced by different domestic activities, there is a continuous influx of humidity from outdoors to indoors. As a consequence, the temperature and humidity in the indoor environment remain relatively constant and conducive to mite growth throughout the year, and the seasonal variations in exposure to mite allergens are small [27]. The combination of climatic conditions (mild, humid winters) and the type of housing predominantly found in the area (relatively poorly insulated) are probably the reasons why mechanical ventilation has failed to make a significant impact on dust mite densities in the North-West of England. Similarly, we have previously failed to observe any effect of portable dehumidifiers on mite counts and Der p 1 level in the sample of houses, which again reflected the predominant type of housing in the UK [18].

The reduction in RH in mechanically ventilated houses was in the order of 10% (64% versus 54% in the control and active group, respectively) and was most marked during the winter period. Fluctuations in mite population density in some studies show synchrony with fluctuations in relative humidity and in others with absolute humidity. It has been suggested that levels less than 45% RH are required before effective control of mites can be achieved. The absolute humidity above 7 g of water vapour per cubic metre of air has also been quoted as a risk factor for high mite allergen concentration [19–21]. However, Colloff argued that it is inappropriate to use the absolute humidity threshold as an indicator of the dryness of the air that would kill mites, as the water balance and survival of house dust mites is dependent on the interaction between temperature and humidity, and not on the total amount of water in the air alone [16]. RH was often decreased below 45% (and absolute humidity below 6 g/kg), but these low levels of indoor humidity were only sustained for short periods of time.

The recorded bedroom temperatures were almost always within the preferred temperature range of house dust mites of 17–32°C. Furthermore, the minimal temperature recorded in any of the bedrooms was 13°C. At this temperature, with an absolute humidity of 7 g/kg, RH is almost 80%, at which conditions the *D. pteronyssinus* population will survive.

Contrary to Scandinavia and some parts of the USA which may be facing an increase in house dust mite allergen levels as a consequence of exaggerated energy conservation [24], it becomes apparent that in the UK we need tight and energy efficient houses in order to dehumidify sufficiently to decrease the mite allergen concentrations. Allergen avoidance measures should be allergen specific, but

also specific to any particular geographic area, with housing and climate conditions being taken into account.

In conclusion, an MVHR unit is not able to decrease indoor humidity to the level capable of retarding mite population growth and decreasing mite allergens in the type of houses predominantly found in the mild and humid climate of the North-West of England. This confirms the prediction by Colloff that 'it seems unlikely that mechanical ventilation will make a major impact on dust mite control where it is most needed: those places where the outdoor climate makes the indoor environment an ideal breeding ground for mites' [16].

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