

A randomized trial of dehumidification in the control of house dust mite

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Summary

Background House dust mites (HDM) are sensitive to humidity. Few studies have adequately examined the potential of dehumidification in reducing HDM numbers.

Objective The study examined the effect of portable domestic dehumidifiers, and a behavioural programme to reduce humidity, on HDM counts and HDM allergen levels.

Methods A randomized controlled trial was undertaken. A total of 76 homes were allocated to three groups that received a portable domestic dehumidifier, a behavioural programme, or no intervention. Humidity, temperature, HDM counts (trap and vacuum samples), HDM allergen, and other details of the home environment were measured on four occasions over a period of 1 year. Interventions and measurements were concerned predominantly with one bedroom.

Results There was a reduction in relative humidity in the dehumidifier group, but not the behavioural group. A decline in HDM trap counts was observed for all three groups. Change scores did not indicate that the dehumidifier group had a greater decline than the other groups. A secondary analysis examining presence or absence of HDM showed a shift from households having HDM at baseline to households not having HDM in the final round for some trap measures. Change score analysis indicated that this shift was greater in the dehumidifier group compared with other groups. The dehumidifier group did not show a greater decline in HDM allergen than that seen in the other two groups.

Conclusion Neither the dehumidifier nor the behavioural intervention had a major effect on HDM counts or allergen levels. However, the study did have a number of limitations relating to size, timing of intervention, and running of the dehumidifiers. The secondary data analysis may indicate some effect of dehumidification, but clearly this effect was small. There is a need for more information on the effects of reducing ambient humidity on the distribution of HDM within their habitats.

Keywords: asthma, house dust mite, humidity

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Introduction

Humidity is a critical factor in the development and survival of the house dust mite (HDM) [1,2]. Despite this, few

studies have examined the potential of humidity reduction in the home in HDM control. Some studies have evaluated behavioural mite avoidance programmes, which incorporate humidity reduction, but any effects of humidity reduction per se have been hard to disentangle from the overall programmes that are often multifaceted [3,4]. The success of one study in reducing HDMs by using electric blankets was attributed to the reduction in humidity achieved through

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the heating of the beds [5]. The use of mechanical ventilation systems, which can both reduce humidity and improve air quality, is being investigated, but studies are small, and few have been published [6,7].

There are a number of studies that have examined the potential role of dehumidifiers in HDM control in a variety of climatic areas, some of which might be more amenable to the dehumidification process than others. Four studies appear to have been undertaken, and of these, only one indicated statistically significant results. This study took place in the Canary Islands [8], and involved 10 homes, in which a comparison of allergen levels was made between two bedrooms. One bedroom in each home had a dehumidifier that had been in operation for at least 3 months before the start of the study, and for the duration of the study (5 months). Bedrooms were also cleaned. Here, a significant difference was observed between dehumidifier and control bedrooms at the end of the study period. However, this appeared to be a cross-sectional comparison with no baseline measures of allergen, and although attempts were made to match bedrooms, there was no guarantee that, for example, experimental bedrooms did not have lower rates of colonization at the start of the study.

The remaining studies show no significant impact on allergen levels. In one study in Japan [9] (abstract only), the authors report large reductions in mites in an unoccupied house where dehumidifiers were run continuously for 2 weeks, and where cleaning occurred every 2 to 3 days. However, no effects were observed in occupied houses where dehumidifiers were run for at least 10 h a day for 2 months. A study in the UK, which lasted 3 months [10] showed no significant reductions in HDM or Der p 1 for six houses that were running a portable dehumidifier (connected permanently to the mains, and turned to maximum dehumidification on the humidistat), compared with six control houses. A 5 month study in Spain [11], compared allergen levels before and after installing dehumidifiers in the homes of a group of 10 patients. A reduction in humidity was observed, but taking the results overall, there was no significant reduction in HDM allergen levels.

Although these studies may indicate that the use of dehumidifiers does not have an effect on HDM, there are a number of other reasons why they may not have shown significant results. (1) The sample sizes were small; (2) in the UK study, the dehumidifier used was less powerful (in terms of extraction rate) than others that are currently available, and the positioning of the dehumidifier in the home (in halls or landings) would not have maximized its effect in the tested rooms (bedroom and living room); (3) on the whole, the interventions were of short duration, and it has been shown that interventions that last for more than 6 months are more likely to succeed in reducing HDM levels [12].

Materials and methods

Study sample and recruitment

A village near Cambridge, representing a range of housing types, was chosen as the study site. Households were selected at random from the electoral register. One bedroom was picked as the test bedroom within the home, usually one of the main occupied bedrooms. Where households contained individuals with respiratory complaints, general practitioners were informed of their involvement; asthma sufferers were offered a simple advice sheet.

Study design

A randomized controlled trial involving 75 households was planned, with three different groups. (1) The dehumidifier group (DG) which would receive a portable dehumidifier to run in the test bedroom; (2) the behavioural programme group (BPG) which would receive a simple written protocol aimed at reducing humidity in the home, with an emphasis on one bedroom and; (3) the control group (CG) which would receive no intervention.

Interventions

After an examination of the available machines, the Matsui DH200 (Dixons Group plc, London, UK), which appeared to have the best extraction rate, was used for the study. Hour meters (RS Components, Corby) were fitted especially for the study (Mastercare Laboratory, Currys-Dixons, Hemel Hempstead, UK). These monitored actual dehumidifying time. As the machines were considered too noisy to run at night, households were supplied with Smiths timer switches (Smiths Industries Environmental Controls Co. Ltd, London, UK). Most homes also required extension leads which were made up by an electrician (Collacotts and Co., Cambridge, UK). For safety, all dehumidifiers were given an extension lead with an RCD plug (PowerBreaker, Harlow, UK), and earths in the sockets to be used were tested by the electrician. All equipment was tested prior to use in accordance with Ethics Committee requirements. Participants in the DG were given copies of documentation for the various pieces of equipment, and an instruction sheet covering the study needs (e.g. that dehumidifiers should be run on 'constant', and bed covers should be left back during the day). Dehumidifiers were installed at the beginning of February 1995, and were to be run until September-October. An evaluation sheet was completed by DG participants at the end of the intervention period.

The humidity reduction programme consisted of an A3 sheet with a series of simple measures to reduce humidity in the home (e.g. airing the bed, keeping doors closed where moisture is being produced in a room). Details of the

programme are available from the authors. A member of the research team went through the instruction sheet with BPG participants at the start of the intervention period (February 1995). At the end of the intervention, participants were requested to fill in an evaluation sheet.

The CG were instructed to carry on as before. No groups were asked to refrain from other 'antimite' measures during the intervention period. However, if these were undertaken, they were recorded in the questionnaire (see below).

Data collection and measurements

There were four rounds of data collection during the study period: September–October 1994, February–March 1995, June–July 1995, and September–October 1995. September–October was chosen as the baseline and final monthly measurement period as these months are where the highest mite counts would be expected in the year.

The first 75 households were randomly allocated to three groups prior to baseline (groups were allocated interventions later). A 76th and final household responding to the invitation to take part in the study was also included. For pragmatic reasons, it was allocated to the control group. During the baseline data collection, one household per group was visited each day. This was important as the data collection spanned several weeks, during which a range of weather conditions could be experienced, which in turn, could influence internal hygrothermal conditions. For rounds 2–4, data collection was also organized to ensure that, wherever possible, one household per group was visited each day. The order of visits was kept as similar as possible in each data collection round. Households were visited twice, one week apart, for each data collection round.

Questionnaire

A questionnaire was designed to cover: (a) structural aspects of the home environment (including bedding) which may affect humidity and/or mite numbers; (b) behaviour of occupants which may affect humidity and/or mite numbers and (c) characteristics of the household. No health measures were taken. Questions concerning the structure of the house and household were asked only at the beginning of the study (and checked for change at the end). Behavioural questions relating to the previous 3 months were asked at each measurement period.

Temperature and humidity

For all households, relative humidity (RH) and temperature were measured for 1 week, during each round of data collection, using clockwork thermohygrographs (Casella

CEL Ltd., Bedford, UK), calibrated prior to each round using a digital thermohygrometer (Jenson 2000, ETI, Worthing, UK). Twelve Envirolog V 632 precalibrated dataloggers (Envirolog Measurement Ltd, Hatton, UK) were made available to the study allowing some continuous monitoring in 12 households from April 1995 onwards. A convenience sample of households was selected to have a datalogger, and these data were used to validate the thermohygrograph data.

Average weekly RHs and temperatures were calculated based on 4-hourly readings, and minimum and maximum RHs and temperatures were recorded from the whole reading. A good estimate of absolute humidity (AH) was calculated [13] by using the mean RH and mean temperature for each household at each data collection period.

HDM and HDM allergen (Der p 1) ascertainment

Dust sampling

During each data collection period, at the first visit to a household, a vacuum dust sample was taken from (a) the tested bedroom carpet, using a 1 m² quadrant placed as near to the bed as possible, and (b) the whole top mattress surface (bedding removed).

Vacuum samples were taken using a Dirt Devil Handy Model, 180 W (Royal Appliance, Cleveland, USA). Dust was vacuumed directly into a filter bag that was removed after sampling and sealed within a polythene bag. To avoid contamination of samples, the vacuum was blown out (through an open window) between carpet and mattress samples and between household visits and attachments were wiped carefully between households. The dust was stored initially (for at least 24 h) in a freezer to kill the mites, after which, where space constraints existed, they were stored in a refrigerator (4–8 °C).

Dust samples were used for two measures. First, for HDM allergen ascertainment, using Enzyme Linked Immunosorbent Assay (ELISA) tests (ALK, Hørsholm, Denmark). Dust samples from mattresses (left over after dust required for the ELISA test was removed) were also used for a mite count, using a modified high flotation technique. This was undertaken externally by Central Science Laboratories (CSL, Slough, UK) for baseline and final mattress samples for the DG and CG only. CSL were blind to the experimental groups.

HDM trap counts

A second mite count was undertaken using a trap method derived from Bischoff *et al.* [14]. This type of sampling can trap mobile mites up to 30% of a biotope. This compares favourably to the flotation technique which has an extraction rate of 2–10% [14]. Moreover, the mites trapped are likely to be live mites. This approach involved making 'mite traps', 20 cm by 22.5 cm rectangles, from transparent

sticky back plastic (Web International Ltd, London, UK).

Six traps were laid at the first visit to each household, for each data collection period. After the vacuum dust sample was taken, four traps were laid on the mattress; two traps were placed on the top surface and two on the bottom surface, at the head and foot of the bed. The traps were placed in the middle of single beds, and towards one side on double beds to reflect where the person slept. For the top surface, vacuuming would have removed most of the dead (and possibly some live) mites. Two traps were also placed on the carpet, just under the bed (to prevent participants slipping on them), with blocks on them to keep them stuck down. As the carpet traps were placed under the bed, that is, away from where the vacuum sample was taken, there should have been no effect on the HDM trap count. On a few occasions, however, where the traps could not be put right under the bed, it is possible that there would have been a slight overlap with the vacuumed area. Traps were picked up at the second visit, a week later. The majority of round 1 traps were counted (details available on request) before groups had been allocated interventions, and for rounds 2, 3 and 4, the senior technician and the acarologist involved in this process were blinded to group.

Mite numbers were then multiplied up to give a measure of live, dead and total HDM per metre squared. In the analysis described here, the two top mattress traps were combined to give a top mattress count per m², the two bottom mattress traps were combined to give a bottom mattress count per m² and the two carpet traps were combined to give a carpet count per m².

Data analysis

The following data analyses were undertaken:

- 1 An examination of compliance to the interventions using data from the hour meters and the questionnaire.
- 2 An examination of the impact of the interventions on (a) humidity, (b) HDM counts and (c) HDM allergen levels.
- 3 An examination of potential confounding variables and artefacts.

For 2(b), a secondary analysis was undertaken to compare round one and round four in terms of the proportion of households for which no HDM were retrieved. HDM counts were therefore categorized into 'no HDM' (scored '0') and 'some HDM' (scored '1'). This was considered necessary as there were a large number of households for which no HDM were retrieved. For example, for total HDM/m², by round four, the proportion of homes with zero HDM ranged from 40.9% to 81.8% amongst the various groups sampling rates.

Statistical analyses were undertaken using SPSS for Windows [15], using the following tests, where they were relevant: the chi-squared test (with continuity correction

where applicable), Fisher's Exact test (2-tailed), ANOVA, Kruskal–Wallis one-way ANOVA, the *t*-test, Mann–Whitney *U*-test, the McNemar test, and Wilcoxon matched pairs signed ranks test. Non-parametric tests were used where data were non-normal. For the purposes of displaying the data, geometric mean differences have been calculated and are shown alongside nonparametric statistical tests. Change scores were calculated where relevant (by subtracting the values at round four from those at round one, a positive score therefore indicating change in the hypothesized direction). Statistical significance throughout was taken at $P < 0.05$.

Results

Recruitment, response rates and withdrawals

In total, 341 invitations were sent to households, of these, 76 were happy to take part, giving an overall participation rate of 22.3%. Of the 76 households recruited, four withdrew during the study period. Withdrawals were included where data were available, but counted as missing once they had dropped out. For the third round of data collection only, one household was unavailable. For this round therefore the household's data were counted as missing.

Reliability of measurements

Data for the HDM counts and allergen levels were largely complete, however, some problems were experienced in the processing of the dust samples for ELISA tests (e.g. insufficient dust for satisfactory tests). Thermohygrograph readings were largely complete although a few problems of reliability were experienced. Datalogger data were available for comparison with 13 thermohygrograph traces. This indicated that although the thermohygrograph temperature readings were comparable to those obtained using the dataloggers, the thermohygrograph RH readings were consistently higher, and varied in degree according to the machine.

Characteristics of study homes

A large amount of information was gathered relating to the characteristics of the homes involved in the trial. For most variables, the three groups appeared to be similar to each other, indicating the success of the randomization process.

Compliance with interventions, and feedback on them

On the whole, the DG complied well, with 87.5% households running the dehumidifier for an average of 6 or more hours per day; and 62.5% running it for an average of 8 or

Table 1. Mean (and SD) for relative humidity (RH) absolute humidity (AH) and temperature by group and data collection round

Reading	Round 1 (baseline)	Round 2	Round 3	Round 4 (final)
Mean RH (%)	(n = 76)	(n = 74)	(n = 70)	(n = 70)
DG	57.0 (4.9)	47.4 (6.8)***	55.3 (6.1)***	57.2 (5.9)†††
BPG & CG	55.9 (5.3)	54.8 (8.4)	61.4 (6.3)	70.3 (4.5)
Mean temperature (°C)	(n = 75)	(n = 74)	(n = 68)	(n = 68)
DG	19.7 (2.1)	17.7 (2.5)*	22.8 (2.3)	21.7 (2.3)***
BPG & CG	20.0 (1.8)	16.2 (2.5)	21.6 (2.3)	19.6 (1.7)
Mean AH (g/kg)	(n = 75)	(n = 74)	(n = 68)	(n = 66)
DG	8.2 (1.0)	6.0 (0.9)	9.6 (1.1)	9.4 (1.0)*
BPG & CG	8.3 (0.9)	6.3 (0.9)	10.0 (1.4)	10.1 (1.2)

* $P < 0.05$ (t -test); *** $P \leq 0.001$ (t -test); ††† $P < 0.001$ (Mann–Whitney U -test).

more hours per day. Householders complied fairly well with behavioural requests to maximize the dehumidifier's effect, such as airing the bed. At the end of the study, the two main problems reported whilst using the dehumidifiers were those of noise and heat.

A great deal of information was collected on household behaviour, so that compliance in the BPG could be assessed. Here, there was evidence of fairly modest behavioural change. Respondents made some comments concerning the programme, but on the whole, found it fairly easy to follow.

Effect of interventions on humidity

Table 1 shows the mean RH, mean AH and mean temperature by group and data collection round. As no significant

differences in RH, AH or temperature were found for any data collection round between BPG and CG, their data have been combined.

Effect of interventions on trap-based HDM counts

For all the analyses of trap mattress variables, four cases were excluded (e.g. where mattresses had been replaced). For similar reasons, three cases were excluded in the carpet analyses. Other missing values are indicated by the numbers in each analysis.

No significant differences were shown among groups at any of the data collection rounds. A second analysis compared round 1 (baseline) HDM counts with round four (final) HDM counts. These results are shown in Table 2. The direction of the significant results in this analysis

Table 2. Comparison between baseline and final round trap HDM/m²

		Total HDM/m ² Geometric mean diff. (95% CI)	<i>P</i> *	Live HDM/m ² Geometric mean diff. (95% CI)	<i>P</i> *	Dead HDM/m ² Geometric mean diff. (95% CI)	<i>P</i> *
<i>Top mattress</i>							
DG	22	6.4 (1.7, 19.0)	0.0092	5.3 (1.3, 16.3)	0.026	1.4 (0.2, 3.7)	0.028
BPG	23	1.0 (0.009, 3.0)	0.053	0.9 (−0.06, 2.8)	0.066	0.5 (−0.1, 1.6)	0.094
CG	22	1.8 (−1.1, 7.8)	0.044	1.7 (−0.1, 7.4)	0.049	1.3 (0.2, 3.3)	0.028
<i>Bottom mattress</i>							
DG	22	1.3 (−1.1, 5.1)	0.064	1.2 (−0.2, 5.0)	0.064	0.3 (−0.1, 1.0)	0.18
BPG	24	0.04 (−0.3, 0.5)	0.60	0.05 (−0.3, 0.5)	0.40	0.2 (−0.2, 0.8)	0.14
CG	22	0.9 (−0.2, 3.7)	0.13	0.7 (−0.3, 3.3)	0.17	0.8 (0.07, 1.9)	0.043
<i>Carpet</i>							
DG	24	11.6 (4.1, 30.1)	0.0004	8.8 (2.8, 24.2)	0.0011	1.2 (0.2, 2.9)	0.028
BPG	23	0.8 (−0.2, 2.7)	0.019	0.6 (−0.2, 2.4)	0.041	1.3 (0.2, 3.2)	0.018
CG	21	2.6 (0.2, 9.6)	0.0076	2.1 (−1.4, 8.7)	0.013	0.8 (−0.06, 2.5)	0.063

*Wilcoxon matched pairs signed ranks test.

Table 3. Percentage of households with 'no HDM/m²' at round one (R1) and round four (R4)*

Variable	<i>n</i>	Total HDM/m ²			Live HDM/m ²			Dead HDM/m ²		
		R1	R4	<i>P</i>	R1	R4	<i>P</i>	R1	R4	<i>P</i>
<i>Top mattress</i>										
DG	22	31.8	81.8	0.001	36.4	81.8	0.002	72.7	100.0	0.031
BPG	23	52.2	65.2	0.38	56.5	69.6	0.38	78.3	87.0	0.63
CG	22	45.5	63.6	0.39	45.5	63.6	0.39	72.7	100.0	0.031
<i>Bottom mattress</i>										
DG	22	50.0	63.6	0.45	50.0	63.6	0.45	86.4	90.9	1.00
BPG	24	66.7	66.7	1.00	66.7	66.7	1.00	87.5	87.5	1.00
CG	22	31.8	40.9	0.69	36.4	40.9	1.00	72.7	90.9	0.13
<i>Carpet</i>										
DG	24	16.7	66.7	0.0005	25.0	66.7	0.002	75.0	100.0	0.031
BPG	23	43.5	47.8	1.00	43.5	47.8	1.00	69.6	95.7	0.031
CG	21	33.3	47.6	0.38	38.1	47.6	0.69	71.4	90.5	0.22

*The table was derived from the McNemar analysis, and therefore includes only cases for which the variables were valid at both rounds one and four.

indicates that round four counts are in general lower than round one counts.

This effect is seen in all three groups. In order to determine whether the decline was greater in the DG, a comparison was made between the change scores of (1) the three groups, and (2) the DG, compared to the other two groups combined (as no significant differences were shown between the BPG and the CG for these variables). No significant differences in change scores were observed for these variables.

The secondary analysis examining the shift in proportions of households with and without HDM was tested using the McNemar test (results in Table 3).

A change score analysis of these categorized HDM trap counts indicated no significant difference between BPG and CG for top mattress, bottom mattress or carpet change scores for categorized trap values. They were therefore combined, and compared to the DG using the Mann-Whitney *U*-test. This indicated that the DG was showing a significantly greater shift towards having no HDM than the other two groups combined for top mattress total ($P = 0.029$), carpet total ($P = 0.0033$) and carpet live ($P = 0.014$) HDM/m². The shift in proportions for top mattress live HDM/m² was almost significant ($P = 0.058$).

Effect of interventions on modified high flotation HDM counts

No significant differences were observed between the DG and the CG at baseline or at round four, or over time within groups between round one and round four. The secondary analysis of proportions of homes with and without HDM/g

at rounds one and four showed no statistically significant differences. However, it is interesting to note the differences in the direction of change between the two groups (see Table 4).

Effect of interventions on house dust mite allergen levels (Der p 1)

A number of exclusions had to be made in the Der p 1 analysis, where, for example, the weight of dust available

Table 4. Percentage of households with 'no HDM/g' in rounds one and four*

	% households 'no HDM'/g			
Variable	R1	R4	<i>n</i>	<i>P</i>
<i>Total HDM/g</i>				
DG	15.0	30.0	20	0.45
CG	19.0	14.3	21	1.00
<i>Live HDM/g</i>				
DG	45.0	45.0	20	1.00
CG	38.1	38.1	21	1.00
<i>Dead HDM/g</i>				
DG	25.0	30.0	20	1.00
CG	28.6	19.0	21	0.69

*The table was derived from the McNemar analysis, and therefore includes only cases for which the variables were valid at both rounds one and four.

Table 5. Comparison between baseline and final round trap Der p 1 $\mu\text{g/g}$

	<i>n</i>	Der p 1 $\mu\text{g/g}$ Geometric mean diff. (95% C.I.)	<i>P</i> *
<i>Mattress</i>			
DG	19	2.4 (1.4, 4.1)	0.0033
BPG	19	2.1 (1.0, 4.2)	0.14
CG	20	1.6 (0.8, 3.1)	0.15
<i>Carpet</i>			
DG	17	1.2 (0.6, 2.3)	0.23
BPG	15	0.6 (0.3, 1.2)	0.19
CG	8	1.3 (0.4, 3.8)	0.33

*Wilcoxon matched pairs signed ranks test.

was insufficient to perform an adequate ELISA test. As before, appropriate exclusions were made where changes in the mattresses or carpets had occurred during the study period.

No significant differences among groups in Der p 1 levels were found at any round. However, the DG showed a significant decline in Der p 1 levels between round one and round four for mattress samples, a result not seen in the other two groups, or the carpet samples for any groups (see Table 5). Despite this, it appears from an analysis of change scores that this decline was not significantly greater than any decline seen in the other two groups examined either separately or in combination.

Analysis of potential artefacts and confounding factors

As reported above, some significant results were found for the analysis of the shift in the proportions of households with 'no HDM/m²'. It was important to ascertain whether other factors might be responsible for the results. Data on a large number of potential artefacts and confounding variables were collected from the questionnaire, and whilst samples/measurements were taken. Cases where obvious changes in mattresses/carpets had occurred were recorded and excluded in the analysis. No other substantial changes were recorded in the structural characteristics of the DG during the study period. Behavioural factors that could have influenced the results were examined, using similar approaches to the main analyses.

Measurement artefacts examined were the degree to which traps left a glue residue on the mattress, and the time the traps were laid (which occasionally deviated from 7 days for logistical reasons).

Potential confounding variables examined were: the use

of electric blankets and hot water bottles; the number of people using the bed; whether the mattress had been vacuumed, and how recently; whether the underblanket had been washed, and how recently; whether the pillows had been washed, and how recently; whether participants had snacked in the bed; how long they had stayed in bed during weekdays and weekends; whether pets had slept in the bed; whether pesticides or acaricides had been used (with mattress and carpet cases); whether any other antimite activity had been undertaken; whether the carpet had been vacuumed and how recently; whether the carpet under the bed had been vacuumed, and how recently (this is where the traps were laid); whether the carpet had been shampooed, how recently; whether the carpet was shampooed under the bed; change of underblanket or pillows during the study period.

There was evidence to suggest that, in the DG in particular, cases where underblankets and pillows were changed during the study period tended also to be those cases showing a decline in HDM/m². However, change of underblanket or pillow(s) per se during the study period was not significantly associated with round four HDM/m². In addition, these changes cannot explain the effects on carpet counts. The precise details of the extent of vacuuming prior to carpet trap laying by group were not available (although this was likely to have been minimal). One other artefactual explanation for the results might be that the traps become less efficient with lower humidities. However, despite significant differences in RH between intervention groups in data collection rounds two, three and four, and significant differences in AH at round four, no significant differences were found in HDM/m². This indicates that the traps are not less efficient at lower humidities.

Discussion

The relatively low participation rate in this study was not surprising, given the degree of commitment required. However, the sample cannot be viewed as generalisable. One obvious bias was a tendency for householders to have some connection with asthma, with 22 (28.9%) households containing an individual with asthma-like symptoms. Other households often reported other allergies such as hayfever, or a general interest in asthma. This bias could be considered unproblematic, since interventions to reduce HDMs would be aimed at households with resident asthma sufferers.

It has been argued [10] that in the UK, where humidities are high and homes are 'leaky', it is unlikely that dehumidifiers will have a sufficient effect to reduce HDM numbers. In the main analyses, the dehumidifier was not associated with a large enough decline in HDM numbers and allergen, relative to that observed in the other study groups, for the difference to be statistically significant. Consequently, it is

unlikely that the dehumidifier intervention, as organized here, has had a major impact on HDM and HDM allergen. These main analyses were not helped by the large number of households with no HDM, especially by round four.

Korsgaard's theory [16] implies that running the machine during the winter months, when the mite population is at its weakest, is the most important time. One serious limitation of this study was the timing of the intervention. For logistical reasons it was not possible to get the dehumidifiers into participating homes at the start of the winter. It is possible that had the intervention started 2 or 3 months earlier, the lower humidities seen in round two could have been achieved for a longer period of time, with a possibly greater effect on HDM. Another problem related to the fact that dehumidifiers could only be run during the day due to their noise. It is therefore probable that humidities fluctuated during the 24 h cycle. It has been suggested that to obtain useful control of HDM populations, it is likely that lower RHs must be maintained continuously [17].

Despite the lack of significant results for the main data analyses, the DG showed a significantly greater shift towards having no HDM than the other two groups combined for some trap measures in the secondary analysis. These analyses were necessary because of the large proportion of households for which no HDM were retrieved, in particular in round four. There are reasons to believe that these results are not spurious. First, the study design was a randomized controlled trial, and a large number of potential confounding variables were considered. Second, the analyses of other measures, although yielding statistically nonsignificant results, were changing in a consistent direction.

There is a debate over the relative importance of AH and RH in HDM survival. One study by Korsgaard [18] found very few HDM in homes where the AH was below 7 g/kg. However, the importance of AH is disputed [17,19]. In a discussion of the complexities of humidity and HDM control, Cunningham's review [17] cites a range of literature data on mite viability showing quantitatively that RH is the appropriate controlling quantity rather than AH. Based on the data reviewed he argues that the figure of 7 g/kg as a guideline for humidity control should be viewed with caution, as it only holds in the temperature range of 20–22 °C (when RH is around 45%). In the case of the study reported here, it is clear that the dehumidifier had a more significant impact on RH than AH. If RH is considered more important than AH in HDM control, this supports the view that the reduced RHs seen here are associated with the small effect on HDM, seen in the secondary data analysis.

One problem relating to studies of HDM avoidance generally is that of power, with many studies being very small. This study was relatively large in comparison with other studies of dehumidifiers (and HDM interventions in general). By round four, six (27.3%) of the DG households

and three (14.3%) of the CG households had Der p 1 levels below 2 µg/g, the level at which sensitization is thought to occur [20]. It was calculated that the sample size required to detect these differences as significant at 2-tailed $P < 0.05$ level with 80% power, would have to be 150 households per group. Owing to economic constraints, a larger study was not possible here.

If it is accepted that the decline in the proportion of households with trap-based HDM resulted from the intervention described in this paper, it is important to note that the precise pattern of reduction is unclear. It could be argued that HDMs have merely withdrawn from the mattress and carpet surfaces rather than there being an overall reduction in the population of HDMs. The increase in the proportion of homes with 'no HDM' in the DG was not accompanied by a significantly greater decline in Der p 1 levels in this group compared to the other two groups, although it is possible that this may be a function of study size.

It was considered important in this study to evaluate how well participants got on with the interventions. Feedback from participants in the DG indicated that the two most important problems encountered were those of noise and heat. Whilst the problem of noise needs to be addressed, the problem of heat may be less relevant if dehumidifiers need only to be run during the winter months, as Korsgaard implies [16]. In this study, there were two reasons why participants were encouraged to use dehumidifiers during the summer. First, to make the environment as uncomfortable as possible for the mites, for as long as possible. Second the interventions were started fairly late on in the winter.

This study involved a general population sample, although there was evidence of bias towards those with some link to asthma and allergies. It is obviously important to assess the safety of humidity reduction for asthma sufferers. There is literature relating to low humidity and the viability of respiratory micro-organisms [21–24], and also low humidity and exercise-induced asthma [25,26], which should be considered. Dehumidifiers also produce a slight draught that could theoretically influence airborne allergen levels. Studies have shown that domestic activity can raise the airborne allergen load [27]. Only one study has examined the effect of dehumidifiers on asthma patients specifically [11] and this reported that the dehumidifiers used were well-tolerated by the clinically stable patients in the study.

Conclusions

Neither the dehumidifier nor the behavioural intervention had a major effect on HDM counts or allergen levels. However, the study did have a number of limitations. First, the dehumidifier was not in operation for the whole

winter period; nor did it operate during the night. It is not possible to determine whether starting the intervention earlier, and running the dehumidifiers constantly would have produced more obvious effects. Second, although the study was much larger than other previous work, the sample size was still relatively small. The interesting results from the secondary data analysis do possibly point to some effect of dehumidification, but clearly, in this study, these effects were small.

On a more general note, it would be useful to have more information on the effect of reducing ambient humidity on the humidity of the HDM microclimate, and HDM reactions to reduced ambient humidity in terms of their distribution within mattresses and carpets.

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