

The use of domestic steam cleaning for the control of house dust mites

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Summary

Background Control of dust mites using extremes of temperature is an alternative to the use of acaricides. In the past we have attempted control by freezing with liquid nitrogen. The present paper deals with the opposite extreme, the use of steam.

Objective To assess the feasibility and effectiveness of a domestic steam cleaner for the control of dust mites, its effect on mite populations and concentrations of the allergen Der p 1.

Methods A domestic steam cleaner was used to treat carpet squares that had been seeded in the laboratory with known numbers of dust mites (*Dermatophagoides pteronyssinus*). The number of live mites was monitored for a period of 4 months in eight treated carpet squares and eight controls. Dust samples were taken from 12 standardized areas of carpet in a tenement flat in Glasgow, UK, before and after steam cleaning treatment, and the concentration of allergen Der p 1 was compared with 12 adjacent, control areas.

Results No live mites were found at any time in the treated carpet squares, whereas in the control squares geometric mean mite population density rose from 11 after 3 days to 39 after 1 month, 66 after 2, 122 after 3 and 185 after 4 months. There was a mean reduction of 86.7% in Der p 1 concentration (3.3–0.44 µg/g) compared with a reduction of 4.7% (2.22–2.116 µg/g) in control areas, a difference that was statistically significant at the 5% level.

Conclusion These data indicate that steam cleaning has considerable potential as an highly effective and efficient method of killing dust mites and reducing concentrations of Der p 1 in domestic premises.

Keywords: house dust mites, control, steam cleaning, allergens, Der p 1

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Introduction

Many methods are available for the control of house dust mites, both chemical and physical [reviewed in 1]. Physical methods include the exploitation of extremes of temperature and humidity, such as freezing, both with liquid nitrogen [2,3] and using domestic freezers for small items such as pillows and childrens' soft toys; dry heating

with electric blankets [4,5], hot-cycle washing in domestic washing machines [6,7], drying with silica gel [8], dehumidifiers [9,10], mechanical ventilation systems [9, 11–13] or by passively airing rooms and bedding [14,15]. Although steam cleaning of bedding and other fabrics is performed commercially and in hospital laundries, there has been no attempt until now to examine the feasibility and efficacy of steam cleaning for the eradication of house dust mites in a format that could be used within domestic premises.

In Europe, the use of portable, domestic, steam-

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cleaning apparatus is becoming increasingly widespread. Such devices are favoured, in part, because of the reduced need for chemical cleaning agents in the home but also because they are capable of cleaning a wide variety of surfaces and fabrics.

We investigated a domestic steam cleaner to discover whether it was effective at killing dust mites and their eggs, what temperatures it could achieve, and whether the steam had any effect on concentrations of a major dust mite allergen, Der p 1.

Materials and methods

Laboratory investigations

Carpet squares (Kosset High Esteem[®]; Coloroll Carpets Ltd, UK) made of 100% nylon (Stainmaster[®]; Dupont Ltd, UK), of dimensions 45 × 45 cm (2025 cm²) and pile depth 1.5 cm were used for this study. A total of 16 carpet squares were frozen overnight at -30°C, thawed, and vacuum cleaned thoroughly. The vacuum samples were examined to ensure that no live mites were present. Each square was then seeded with dust mites as follows: cultures of *Dermatophagoides pteronyssinus* were reared in the laboratory in a culture medium consisting of a 1:1:1 mix of bakers' yeast granules, wheatgerm and dried *Daphnia* at 27°C, 85% relative humidity (RH). Cultures were pooled, sieved through a nest of test sieves (Endecott Ltd, UK) of mesh-square breadth range 1000–37 µm, and the fraction of size range < 300, > 75 µm, which consisted almost entirely of live mites, was divided into three samples of 100 mg each. The mites were killed by immersion in liquid nitrogen and counted under a stereobinocular microscope to determine numbers of mites per unit weight. Each square was seeded with 500 mg of live mites, equivalent to an arithmetic mean of 9209 mites/square (range 8610–9745; or 4.3–4.8 mites/cm²), and 3 g of fresh, mite-free culture medium. The mites and culture medium were distributed evenly over the surface of the carpet squares and gently brushed in. The squares were then incubated at 23°C, 75% RH for 72 h to allow the mites to settle and disperse within the carpet. Humidity was controlled with saturated sodium chloride solution according to standard methods.

After this period, eight carpet squares were kept as untreated controls and eight squares were steam cleaned, each for 30 s, using a 'MediVap' domestic steam cleaner (Medivac PLC, Wilmslow, UK). This device consists of a 4.3 L capacity boiler, heated by a 220–240 V electrical element. The maximum tank temperature is 150°C. Steam was delivered from the boiler via a hose outlet with a brush attachment covered in a cleaning rag. The

boiler was operated at full power and pressure (2000 W, approximately 320 kPa) according to the manufacturer's instructions. Temperature and humidity were monitored at the base of the carpet pile before, during and after steam cleaning using an electronic thermohygrometer, coupled through a digital analogue converter to a pen recorder [16]. Following treatment, each square was left to cool and dry (approximately 30 min–1 h). The treated and control squares were then vacuum-sampled for 30 s per square using a Medivac medical dust sampler (flow rate 2.2 m³/min; Medivac PLC, Wilmslow, UK), fitted with a 25 µm nylon mesh filter contained within a cylindrical sampling tube which was attached to the sampler hose. After this procedure they were returned to the incubators. Sampling was repeated at 28-day intervals on four occasions.

To count the numbers of live mites, the material adhering to the filter was recovered and weighed and the mites extracted according to the method of Arlian *et al.* [17]. In brief, the whole sample was suspended in 50 mL saturated sodium chloride solution and 1–2 drops of domestic detergent were added as a wetting agent. The suspension was stirred, filtered through a 37 µm mesh test sieve (Endecott Ltd, UK), rinsed with tap water and stained on the sieve using 1% aqueous crystal violet (C.I. 42555). Excess stain was rinsed out and the mites and culture medium transferred to a 9 cm diameter glass Petri dish. Active, live mites were then counted under a stereobinocular microscope at × 20 magnification.

Following the final vacuum sampling, each of the treated carpet squares was further assessed for the presence of live mites using the heat escape method of Bischoff and Fischer [18]. The underside of the carpet squares was heated on a hot plate at 80°C for 15–30 min. Live mites, if present, move away from the heat source and are captured on strips of transparent adhesive tape laid over the top surface of the carpet square. We used 3 × 100 cm² strips of tape per square, which were removed after heating and examined under a stereobinocular microscope for the presence of live mites.

Field investigations

Two adjacent areas, each of 0.25 m², were delineated with a quadrant and masking tape on bedroom, living room, kitchen and hall carpets in a groundfloor tenement flat in Glasgow, UK. There were three sets of adjacent areas per room, making a total of 12 sets. The flat was approximately 100 years old, with central heating, of sandstone block construction, with no signs of damp or mould growth. The residents were non-atopics, and the carpets were 10–15 years old and made of synthetic fibres. Dust samples were taken from each area, as

described in the laboratory investigations section above. One area was then steam cleaned and the other left untreated. After the treated carpet had dried, another dust sample was taken from each area.

Dust samples were weighed and diluted to 1:20 (w/v) in PBS, vortexed, mixed by rotation for 2 h, centrifuged at 1000 g for 15 min; the supernatant was removed, sterile filtered and stored at -30°C until use. Der p 1 was assayed using a two-site monoclonal antibody ELISA, as described elsewhere [19].

Statistics

Values of Der p 1 were log transformed and one-way analysis of variance used to compare means of values from treatment squares vs control squares on both sampling occasions and before-treatment values vs after-treatment values of the treatment group and the controls.

Results

Laboratory investigations

Temperature and relative humidity of carpet squares were at ambient prior to treatment (24.7°C , 49.6% RH). The temperature in the eight carpet squares during treatment rose to an arithmetic mean maximum of 103.4°C (range 97.9 – 121.3°C) and declined to ambient within 20 min. Humidity increased to saturation within 10 s of applying steam, remained at saturation for 25 min and fell to ambient after 140 min.

No live mites were found in any of the vacuum samples, nor the heat escape samples, taken from the eight steam-treated carpet squares. By way of contrast, the numbers of live mites extracted from the eight control squares rose from a geometric mean of 11 on day 3 post-seeding, to 39 after one month, 66 after 2, 122 after 3 and 185 after 4 months (Fig. 1).

Field investigations

There was a derived-mean reduction in Der p 1 concentration from 3.3 (95% C.I. range: 1.14–7.64) to $0.44\text{ }\mu\text{g/g}$ (95% C.I. range: 0.19–0.74) in areas of carpet that were treated with steam cleaning. This represents a percentage derived-mean reduction in Der p 1 concentration of 86.7%. By way of contrast, there was a derived-mean reduction from 2.22 (95% C.I. range: 0.64–5.35) to $2.12\text{ }\mu\text{g/g}$ (95% C.I. range: 0.63–4.94), equivalent to 4.7% in the adjacent, control areas that were not steam-cleaned but were sampled before and after the steam-cleaned areas were treated (Fig. 2). By

analysis of variance we found the change in Der p 1 values of the steam-treated areas was statistically significantly different from the change in the control group (variance ratio 4.34 with 2 and 44 d.f.; $P < 0.05$). There was no difference between treatment group values (pooled: both sampling occasions) and pooled control values (variance ratio 0.35 with 1 and 44 d.f.), indicating the differences in Der p 1 values was due to steam cleaning and not differences between the two carpet groups.

Discussion

The fact that no live mites were found in any of the eight steam-treated carpet squares at any time during the laboratory study indicates that steam-cleaning is a highly efficient method of killing house dust mites in carpets. In order to check that the absence of live mites was not an artefact of the low efficiency of vacuum sampling as a means of recovering live mites [18], we used the heat escape method on the carpet squares after we had finished the vacuum sampling regime. It has a far

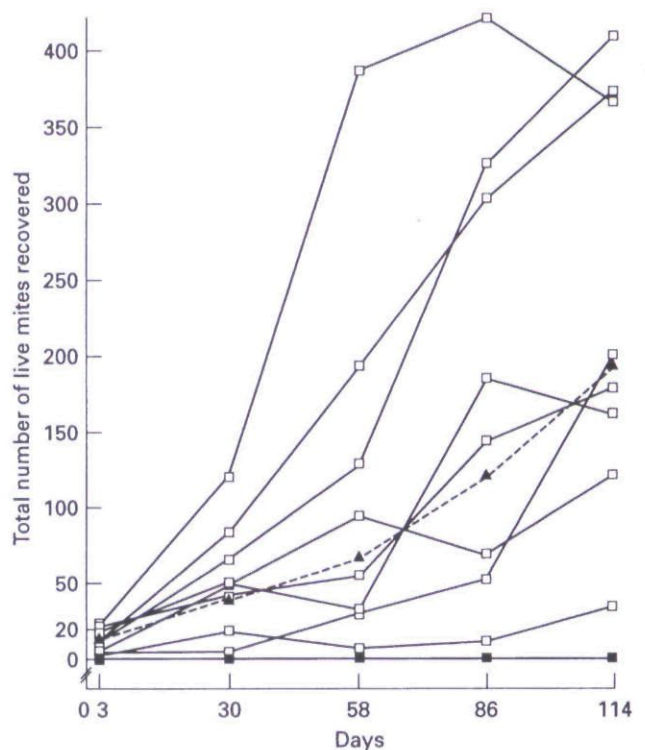


Fig. 1 Numbers of live mites extracted from eight steam-treated carpet squares (—■—) and eight untreated control squares (—□—) at 3 days after seeding the squares with live mites, then at monthly intervals for 4 months; with geometric mean of total mites in untreated carpet squares (---Δ---).

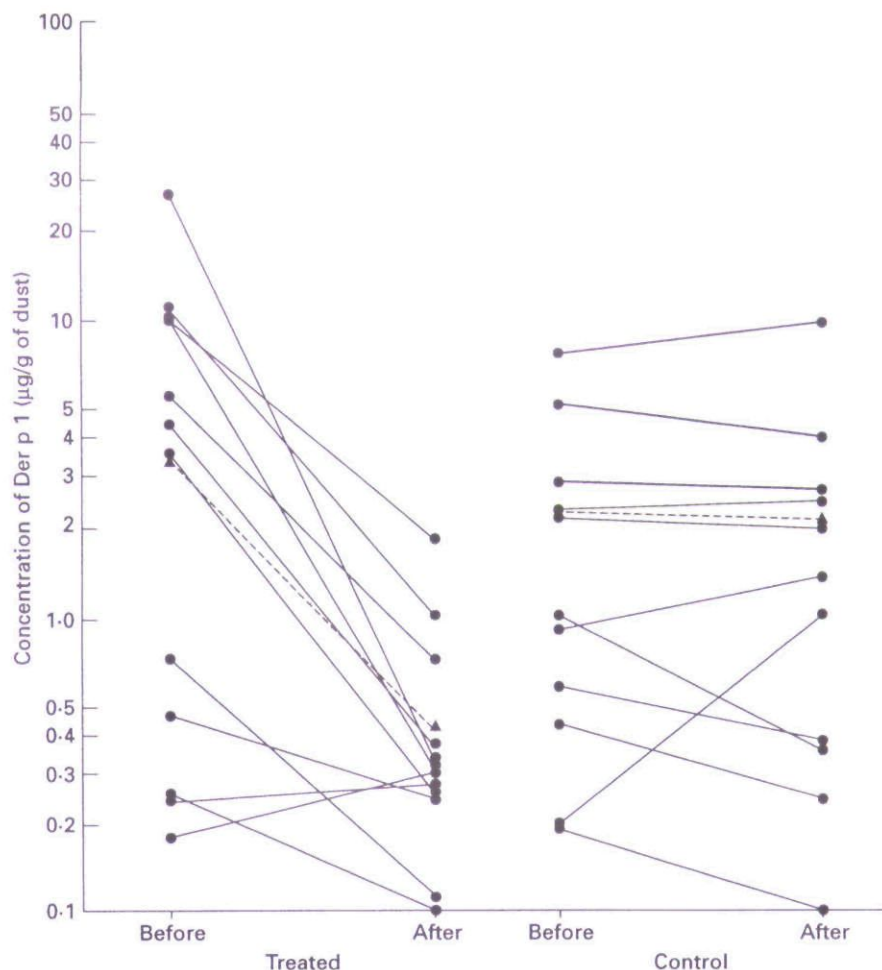


Fig. 2 Concentrations of allergen *Der p 1* ($\mu\text{g/g}$) in dust samples removed from $12 \times 0.25 \text{ m}^2$ areas of carpet in a tenement flat in Glasgow, UK, before and after steam cleaning, compared with those from samples from 12 untreated, adjacent, control areas taken before and after the treated areas were steam cleaned. $\blacktriangle$ — $\blacktriangle$, Derived means.

higher extraction efficiency than vacuuming, in the order of 30–60% recovery [18], but again, no live mites were found. In only one control carpet square was there insignificant population increase of mites, with only 35 recovered on day 114. Some dust mite colonies are markedly slower to increase in size than others for no apparent reason, and it may be that this colony would have thrived were the experiment continued beyond day 114.

The results of the field study demonstrate clearly the considerable reduction in *Der p 1* concentrations achieved by steam-cleaning, with only minor deviations from this trend. In one control sample *Der p 1* concentration fell from 0.19 to below the assay detection limit of $0.1 \mu\text{g/g}$, and in two treated areas the concentrations rose from 0.24–0.27 and from 0.18–0.295 $\mu\text{g/g}$. These values are all in the lower end of the range of *Der p 1*

concentrations and are probably due to combined dust sampling and *Der p 1* assay error.

This study does not demonstrate, nor does it seek to demonstrate, an unequivocal effect of heat on the chemical denaturation of *Der p 1*. Such denaturation has been demonstrated by Lombardero *et al.* [20] who found that heating *Der p 1* at 100°C for 10 min reduced the binding of IgE antibodies by > 100-fold in competitive inhibition radioimmunoassays. But they also found that the major allergen *Der p 2* was heat-stable. By way of contrast, Ford *et al.* [21] found no effect of heating on *Der p 1* (100°C for 5 min) on binding of IgE to immunoblots. The heat stability of *Der p 2* was confirmed by Stewart *et al.* [22], who also investigated the effects of heat on three serine proteases of *Dermatophagoides* spp.: trypsin (group 2 allergen); chymotrypsin (group 6) and an allergenic elastase-like enzyme. They

found that all protease activity was lost after treating spent mite growth medium at 65°C for 200 s, although it is not clear whether there was a concomitant effect on allergenicity. Nevertheless, these data serve to indicate the possibility that the IgE binding activity of major dust mite allergens in addition to Der p 1 may be adversely affected by heat.

In the present study it was not possible to discriminate between whether allergen was being denatured or selectively retained in the carpet in some way as a result of the steam-cleaning process. However, a comparison of the weights of dust samples removed from treated areas before (geometric mean 232 mg) and after treatment (289 mg) indicated there was no significant difference compared with the control areas (before 207; after 259 mg). This strengthens our contention that the reduction in Der p 1 concentrations was due to the denaturing effects of heat and not to retention of allergen in the carpet.

In the domestic cleaner used in this study, water is heated electrically within an insulated boiler, under pressure, to produce steam which is capable of reaching temperatures well in excess of the boiling point of water at atmospheric pressure. The maximum temperatures achieved in the eight carpet squares during steam-treatment in the laboratory study exceeded 100°C in all but two cases, reaching an absolute maximum of nearly 122°C. Following treatment, temperatures in excess of 90°C were maintained at the base of the carpet pile for up to 3 min. These temperatures and durations are likely to achieve a similar degree of denaturation of Der p 1 to that recorded by Lombardero *et al.* [20].

Steam cleaning requires nothing more than water and heat and therefore is non-polluting compared with mite eradication methods that require the use of detergents and other chemical agents. Furthermore, the design of the steam cleaner renders it safe for domestic use as long as the manufacturer's instructions are followed; the risk of scalds could be considered no greater than that from an electric kettle. We observed no damage or shrinkage of the fabric of any of the treated carpet squares, nor discolouration, and the carpet dried out within half an hour of treatment. There is no indication of prolonged retention of residual moisture, as may be the case with wet-vacuum cleaning and which may promote population growth of mites that colonize subsequent to treatment.

Finally, steam-cleaning as reported herein is the only method of house dust mite control that combines effective killing of mites and substantial reduction in allergen concentrations within a single system. These factors, taken together, render domestic steam cleaning apparatus especially suitable for the management of dust

mites and their allergens in the homes of people with mite-mediated allergies.

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