

ORIGINAL ARTICLE

Experimental Models of Allergic Disease

Prevalence of allergic sensitization to storage mites in Northern Europe

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Abstract

Background: Allergic sensitization to storage mites has mostly been related to occupational exposures like farming, grain/cattle handling, whereas for non-occupational settings, storage mite sensitization has been attributed to cross-reactivity with house dust mite (HDM) allergens.

Objective: We aimed to describe the prevalence of allergic sensitization to storage mites, co-sensitization to HDM allergens and respiratory symptoms in Denmark, Iceland, Norway and Sweden.

Methods: The population comprised of 1180 participants born 1945-1972 of the third follow-up of the population-based cohort European Community Respiratory Health Survey (ECRHS) in Aarhus, Bergen, Reykjavik and Uppsala. A clinical examination included skin prick tests (SPT) to *Lepidoglyphus destructor*, *Tyrophagus putrescentiae*, *Acarus siro* and common inhalant allergens, as well as standardized interviews.

Results: 8% were sensitized to HDM and 10% to storage mite, with some variation by study centre: Reykjavik 13%, Bergen 8% and Aarhus 7%. In Uppsala, only *L destructor* (3%) was measured. Storage mite sensitization was higher among men (11%) than women (8%). Among storage mite sensitized, 44% were also sensitized to HDM.

Storaas and Jacobsen Bertelsen are contributed equally.

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Storage mite sensitization was associated with asthma and nasal allergies, but not with age, education, pet keeping or place of upbringing.

Conclusions and Clinical Relevance: In this Northern European population-based study, allergic sensitization to storage mite was as common as HDM sensitization. Storage mite sensitization was, independently of HDM sensitization, associated with respiratory symptoms and asthma. Our findings suggest that storage mite sensitization should be evaluated with regard to inclusion into the common inhalant allergen panel in Northern Europe.

KEYWORDS

asthma, epidemiology, European Community Respiratory Health Survey, rhinitis

1 | INTRODUCTION

Allergy and sensitization to house dust mites (HDM), such as *Dermatophagoides farinae* and *D. pteronyssinus*, are well known and described in numerous studies.¹ However, sensitization to mites other than HDM is not equally well described.

Lepidoglyphus destructor may be found where plant or animal foods are processed and stored at a humidity level that is not too high. *Acarus siro* is the most common species of mite in foods. It is a flour mite, which contaminates grain and flour with allergens and transfer of pathogenic microorganisms. *Tyrophagus putrescentiae* is a common pest of stored products, especially those with a high protein and fat content. It is referred to as mould mite, and feeds on the fungi that grow on food.²

Storage mite sensitization has mainly been related to occupational settings³⁻⁵; first described in 1979 for Scottish farmworkers exposed through hay and grain used to feed cattle wintered indoors.⁶ Later studies on farmers from Northern Europe and Germany also confirmed these findings.⁷⁻¹¹ Furthermore, it has recently been shown that the general tendency to lower sensitization rates in farmers does not apply for storage mites. In a group of 1100 Danish farmers, the sensitization to *L. destructor* increased from 6% to 13% over 12 years.¹²

In a study on bakers in Norway, storage mite sensitization was verified among 20% of the study participants.⁵ In Danish, bakers' apprentices sensitization to HDM and storage mites were 18% and 11%, respectively.¹³ In comparison, in a study by Armentia et al,¹⁴ 30% of 43 patients with sensitization to wheat flour experienced co-sensitization to *L. destructor*, and about one-fourth of the storage mite sensitized patients did not have any relationship with bakery or agricultural sites.

In addition to work-related exposure, storage mites have been found in non-occupational settings. Storage mites were found in 21% of 571 samples of cereal-based food products purchased at food retail outlets in the UK,¹⁵ and 38% of 421 samples contained storage mites after 6 weeks storage in volunteer's homes.

However, sensitization to storage mites in the general population^{16,17} is less studied. In a population based study in Iceland by

Gislason et al,¹⁸ 6.3% of the study participants had positive skin prick test (SPT) reactivity towards *L. destructor*. In France; 44% of young asthmatic adults were sensitized to *L. destructor*.¹⁹

Allergenic cross-reactivity between storage mites and HDMs has been described.²⁰ In Barcelona, 11% of children, who attended an allergy unit for the first time due to respiratory symptoms, were sensitized to storage mites, of whom 92% were also sensitized to HDM.²¹ It has been reported that storage mites may induce symptoms of asthma and rhinoconjunctivitis in sensitized individuals in both rural and urban settings.²²

In our study, we aimed to describe the prevalence of both HDM and storage mite sensitization in participants from four study centres in the European Community Respiratory Health Survey (ECRHS III): Aarhus (Denmark), Bergen (Norway), Uppsala (Sweden) and Reykjavik (Iceland). Also, the associations of HDM and storage mite sensitization with allergic and respiratory symptoms and disease.

2 | MATERIAL AND METHODS

The population comprised of 1180 participants (born 1945-1972) from the population-based European Community Respiratory Health Survey (ECRHS), where skin prick tests towards storage mites were performed: Aarhus (n = 195), Bergen (n = 358), Uppsala (n = 273) and Reykjavik (n = 354).

The ECRHS III study is the third follow-up. In 1988-1992, ECRHS included a random population-based sample of 1500 men and 1500 women aged 20-44 years in each of the participating study centres across Europe. A randomized subsample of these participants was invited to partake in clinical investigations and interviews.²³

2.1 | Ethics approval

The following local ethics committees for research approved the study for each study centre: De Videnskabetiske Komiteer for region Midtjylland, approval M-20110106 for Aarhus, Regional Ethics Committee West Norway, approval 2010/759 for Bergen, National

Bioethics committee of Iceland, approval VSN-11-121-S3 for Reykjavik and Regional Ethical Review Board in Uppsala, approval 2010/432 for Uppsala.

Written informed consent was obtained from all the study subjects.

2.2 | Allergic sensitisation and diseases

Allergic sensitization was determined by skin prick tests (SPT) to 12 allergens (ALK-Abello): Timothy grass, ragweed, *Dermatophagoides pteronyssinus*, *D farinae*, cat, dog, birch, *Blattella germanica*, olive, *Alternaria* spp., *Cladosporium* spp. and *Parietaria* spp., 0.9% saline and 10 mg/mL histamine solution were used for negative and positive controls, respectively. For Aarhus, Bergen and Reykjavik, the extended SPT protocol included the storage mite allergen *L destructor*, *T putrescentiae* and *A siro* (Allergopharma), whereas participants from Uppsala were tested for *L destructor* only. Reactions to the allergens were read after 15 minutes. Reactivity was considered positive if the mean wheal size was 3 mm greater than the negative control. "Any positive HDM SPT" was defined as positive SPT reactivity towards *D pteronyssinus* and/or *D farinae*. "Any positive storage mite SPT" was defined as positive SPT reactivity towards any of the following storage mites: *L destructor* and/or *T putrescentiae* and/or *A siro*.

SPTs were carried out by trained nurses following a standardized protocol, similar in all study centres.

Allergic diseases were assessed through standardised interviews, including questions on doctor's diagnosed asthma, symptoms of wheezing and nasal allergies.

See www.echrh.org for wording of the questionnaire and for the study protocols.

Doctor diagnosed asthma was defined as answering positively to both of the following questions:

Have you ever had asthma?

Was this confirmed by a doctor?

Nasal allergies were defined as answering positively to the following question:

Do you have any nasal allergies, including hay fever?

Asthma symptoms in the last 12 months were assessed using the following questions, each positive answer adding to the asthma score:

Have you had wheezing or whistling in your chest at any time in the last 12 months?

Have you woken up with a feeling of tightness in your chest at any time in the last 12 months?

Have you had an attack of shortness of breath that came on during the day when you were at rest at any time in the last 12 months?

Have you had an attack of shortness of breath that came on following strenuous activity at any time in the last 12 months?

Have you been woken by an attack of shortness of breath at any time in the last 12 months?

Have you been woken by an attack of coughing at any time in the last 12 months?

Have you had an attack of asthma in the last 12 months?

Have you used any inhaled medicines to help your breathing at any time in the last 12 months?

2.3 | Covariates

Data relating to age, sex, education level, occupation, pet keeping and smoking status were retrieved from questionnaires. Smoking was categorized into never smokers, previous smokers and current smokers. The study subject's level of education was categorized as primary school, secondary/technical education and college/university. Place of upbringing was defined by the answer to "What term best described the place you lived most of the time when you were under the age of 5 years?" with response categories (1) farm with livestock, (2) farm without livestock, (3) village in rural area, (4) small town, (5) suburb of city and (6) inner city. The responses were collapsed into three categories: "Livestock farm" for response 1, response 2-4 as "village," and response 5 and 6 as "city." Occupational data were coded according to International Standard Classification of Occupations (ISCO-88). Occupations related to exposure to storage mites (bakers, animal and grain handlers) were grouped together for analyses, because very few reported these occupations.

2.4 | Statistical analyses

Descriptive statistics for the study population was reported as mean and standard deviation for continuous variables and numbers and percentages for categorical variables. STATA (StataCorp) version IC 15.0 was used in all analyses. Logistic regression was applied to assess associations between SPT reactivity to storage mites, HDMs and allergic and respiratory symptoms. All models were adjusted for both storage mite and HDM SPT positivity and clustered by centre.

3 | RESULTS

Men and women were equally represented in the overall study population. The prevalence of positive skin prick test results towards storage mite allergens (any) was 10% and higher in men than in women (11% and 8%, respectively, $P = .09$). SPT positivity towards *L destructor* was almost twice as high in men (7%) as in women (4%) for all centres combined ($P = .02$) (Table 1). HDM SPT positivity was 8% in the total population.

Overall 34% of the study population was sensitized to at least one allergen (*L destructor*, *T putrescentiae* and *A siro*, as well as Timothy grass, ragweed, *Dermatophagoides pteronyssinus*, *D farinae*, cat, dog, birch, *Blattella germanica*, olive, *Alternaria* spp., *Cladosporium* spp.

TABLE 1 Characteristics of study population. Percent of total, men and women (unless otherwise specified)

	All (n = 1180)	Men (n = 585)	Women (n = 595)	Gender difference P-value
Age (mean, range)	54 (39-67)	54 (40-67)	53 (39-67)	
Age groups				
<50 y	34	31	36	.2
50-60 y	43	45	41	
>60 y	23	24	23	
Geography (centre)				
Aarhus	17	49	51	.1
Bergen	30	55	45	
Reykjavik	30	47	53	
Uppsala	23	46	54	
Education				
Primary school	11	10	12	.1
Secondary/Technical education	44	43	37	
College/University	49	47	51	
Place of upbringing				
Livestock farm	13	13	14	.6
Village	39	38	39	
City/suburb of city	48	49	47	
Pet keeping				
Cat	19	20	18	.4
Dog	20	20	20	1
No pets	64	64	65	.6
Smoking status				
Never	45	44	47	.3
Previous	38	38	38	
Current	17	18	15	
Disease characteristics				
Asthma, ever	15	9	20	<.001
Doctor diagnosed asthma	14	8	19	<.001
Asthma symptoms ^b	24	20	27	<.01
Nasal allergies, ever	29	25	33	<.01
Eczema or skin allergy, ever	47	42	52	<.01
Sensitization				
Any positive SPT	35	34	35	.7
Any positive HDM SPT	8	8	7	.5
^a Any positive storage mite SPT	10	11	8	.1
Positive <i>Lepidoglyphus Destructor</i> SPT	5	7	4	.02
Positive <i>Acarus siro</i> SPT	6	6	5	.6
Positive <i>Tyrophagus putrescentiae</i> SPT	6	7	4	.05

Note: Missing information by number of participants: education (n = 56), smoke (13), asthma (ever) (n = 11), nasal allergies (ever) (n = 8) and pet keeping (n = 11).

^aUppsala not included (only *L destructor* measured).

^bMore than two asthma symptoms (wheezing or whistling, breathlessness, tightness in chest, night-time cough or shortness of breath and asthma medication usage) in the last 12 months.

TABLE 2 SPT reactivity towards mites according to study centre. Percent of centre (unless otherwise specified)

	Aarhus (n = 195)	Bergen (n = 358)	Uppsala (n = 273)	Reykjavik (n = 354)	P-value of difference between centres
Gender					
Men	49	55	47	47	.1
Age (mean, range)	53 (40-65)	53 (40-64)	54 (40-67)	55 (42-67)	.9
Any positive HDM SPT	7	9	4	9	.1
^a Any positive storage mite SPT	7	8	-	13	.04
Positive <i>Lepidoglyphus</i> <i>Destructor</i> SPT	3	6	3	7	.02
Positive <i>Acarus siro</i> SPT	6	5	-	6	.9
Positive <i>Tyrophagus putrescentiae</i> SPT	5	4	-	7	.2

^aUppsala only 1 storage mite SPT (*L destructor*).

and *Parietaria* spp.). 14% were monosensitized and 20% polysensitized. Among the monosensitized, *T putrescentiae* was the fifth most commonly recognised allergen (Appendix S1).

The Reykjavik population had a higher prevalence (13%) of positive storage mite SPT than Bergen and Aarhus (8% and 7% respectively, $P = .04$, Table 2). However, in terms of HDM-positive SPT, participants within Bergen and Uppsala had the highest prevalence. Reykjavik and Bergen had higher prevalence of positive *L destructor* SPT (7% and 6%, respectively), than Uppsala and Aarhus (both 3%) (Table 2). Characteristics of the study population according to each study centre is available in Appendix S2.

Storage mite sensitization was not associated with place of upbringing. However, sensitization to (any) storage mite allergen was higher among dog keepers (13%) than among cat keepers (5%) (Table 3). Of 11 persons in occupations assumed more likely to be storage mite exposed (bakers, grain and animal handlers), none were sensitized to storage mite. No association was seen between storage mite sensitization and age, education or smoking (Table 3).

Among the storage mite sensitized participants, 44% were also sensitized to HDM (Figure 1A). Co-sensitization between HDM and storage mites was highest among *A siro* sensitized individuals (30%) and lowest among those sensitized to *T putrescentiae* (26%) (Figure 1B).

Asthma and nasal allergies were more frequent among participants sensitized to storage mites (Table 3). In a logistic regression model with mutual adjustment for storage mite and HDM SPT positivity, we found that storage mite SPT reactivity was associated with nasal allergies (adjusted odds ratio [aOR] 2.09; 95% CI: 1.31, 3.33) and asthma (aOR 1.46 [1.14, 1.86]) (Table 4). Furthermore, when analysing each storage mite species separately, SPT positivity to *L destructor* was associated with increased odds of having two or more asthma symptoms in the last 12 months (aOR 1.46 [1.20, 1.79]) and nasal allergies (aOR 1.98 [1.07, 3.68]). These findings were consistent across study centres (Figure 2).

When evaluating the risk of storage mite sensitization as a part of different combinations of allergic symptoms, sensitization to any storage mite was associated with increased odds of having nasal allergies without asthma (aOR 2.79; 95% CI: 2.32, 3.36), asthma

without nasal allergies (1.16; 1, 1.34) and asthma with nasal allergies (with nasal symptoms) (4.87; 3.72, 6.37) when compared with non-allergic participants without asthma.

Sensitization to *A siro* was associated with increased odds of having nasal allergies without asthma (2.93; 1.62, 5.39) and asthma with nasal allergies (with nasal symptoms) (3.51; 2.29, 5.39), but not asthma without nasal allergies (0.36; 0.09, 1.44) when compared with non-allergic participants without asthma, similar results were found for *T putrescentiae* and *L destructor* (Table 5).

The groups remained too small for stratified analyses according to centre or age group.

3.1 | Sensitivity analyses

The numbers monosensitized to mite species remained too small (*D pteronyssinus* $n = 18$; *L destructor* $n = 10$; *T putrescentiae* $n = 5$; *A siro* $n = 2$) to analyse differences between mono- and polysensitized. After excluding the monosensitized, the odds ratios for the associations of storage mite sensitization with nasal allergies were as follows: any storage mite (aOR 4.97; 95% CI: 3.61, 6.85), *A siro* (4.17; 2.10, 8.29) and *T putrescentiae* (4.09; 2.51, 6.68). When stratified by age group, there were not significant differences between the age groups.

4 | DISCUSSION

Tyrophagus, *Lepidoglyphus*, *Glycyphagus*, *Acarus* and *Blomia* are the most studied genera of storage mites.²⁰ In our study, we included the species *Tyrophagus putrescentiae*, *Lepidoglyphus destructor* and *Acarus siro*, as these have been associated with allergic symptoms in occupational and non-occupational settings.

Apart from studies from occupational settings, there are only few previous reports on storage mite sensitization in Northern European countries. A study of storage mite sensitization among outpatients examined for allergy in an urban area on the west coast of Norway

TABLE 3 Percentage of storage mite SPT positivity according to population characteristics

	Any storage mite (%)	<i>Acarus siro</i> (%)	<i>Tyrophagus putrescentiae</i> (%)	<i>Lepidoglyphus destructor</i> (%)	P-value for difference by any storage mite sensitivity
Age groups					
<50 y	11	5	6	4	.99
50-60 y	10	7	6	5	
>60 y	10	4	5	6	
Education					
Primary school	11	4	8	4	.4
Secondary/ Technical education	11	8	7	6	
College/University	10	4	4	5	
Place of upbringing					
Livestock farm	9	7	5	4	.5
Village	9	6	6	6	
City/suburb of city	11	5	5	5	
Cat keeping					
Yes	5	3	1	3	.03
No	11	6	7	6	
Dog keeping					
Yes	13	7	9	8	.08
No	9	6	5	5	
Any pet keeping					
Yes	10	6	6	5	.9
No	10	5	6	5	
Smoking status					
Never	8	4	5	4	.3
Previous	10	7	5	6	
Current	12	7	10	7	
Asthma, ever					
Yes	15	7	8	8	.03
No	9	6	5	5	
Asthma symptoms, last 12 months					
Yes	11	7	6	7	.6
No	10	5	6	5	
Nasal allergy, ever					
Yes	18	11	11	9	<.001
No	7	4	4	4	
Eczema, ever					
Yes	9	6	6	5	<.9
No	10	5	5	5	
HDM SPT positivity (n = 78)	44	32	28	29	<.01

^aUppsala only 1 storage mite SPT (*L destructor*)

showed 12% sensitization²⁴ close to the 10% found in this study. An earlier follow-up of the ECRHS Reykjavik cohort reported 6.3% allergic sensitization to *L destructor* and showed that participants feeding horses were more likely to be sensitized to *L destructor*.¹⁸

Unfortunately, for the current study, information about close contact with horses was not available. Similar to the present study, the study participants from Reykjavik were often sensitized to several inhalant allergens and were more likely to suffer from nasal allergies.¹⁸

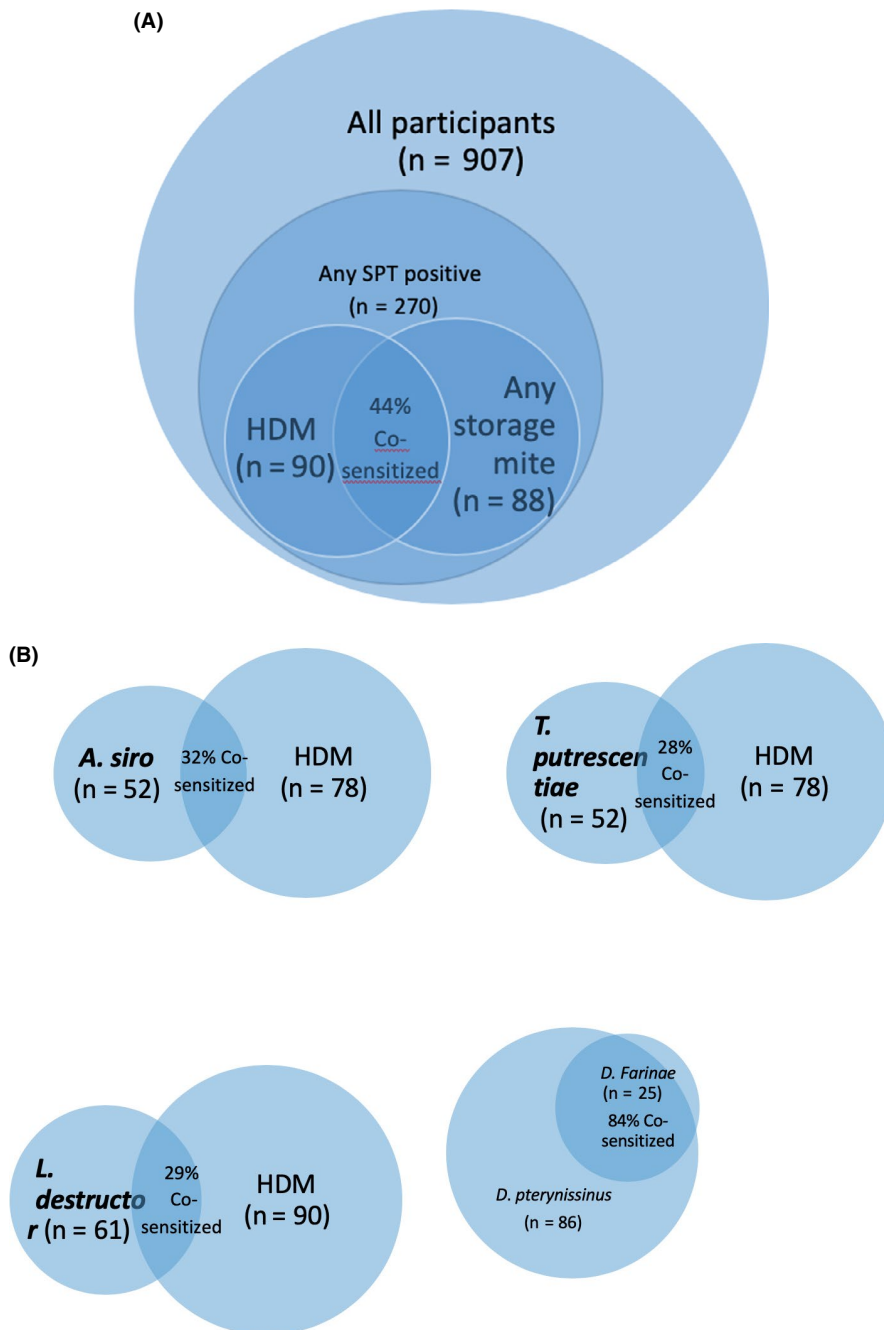


FIGURE 1 A, Storage mite and house dust SPT positivity in total population, excluding Uppsala centre. B, Storage mite and HDM species SPT co-sensitization

The prevalence of storage mite sensitization in the present study as well as in the studies from Reykjavik and on allergic outpatients referred to above is lower compared to storage mite sensitization reported for bakers in Bergen (14% with SPT positivity) as well as among farmers in Denmark (14%, *L. destructor*).^{5,25} This suggests that occupational exposure may be an important factor for storage mite sensitization. However, in this study, we did not identify a single person with storage mite sensitization in occupations related to higher exposure to storage mites. We only had data about current occupation and cannot exclude the possibility that people could have been exposed to storage mite at their previous occupations.

In addition to the differences in prevalence of storage mite sensitization between the four study centres, the sites also differed

by other population characteristics. Reykjavik has the highest prevalence of positive SPT for storage mites. The educational level is slightly lower in Reykjavik (19% primary school) compared to Aarhus and Bergen (7% both) and Uppsala (9%). Furthermore, the level of university/college degree was highest in Uppsala, which also had the lowest level of storage mite sensitivity among the three study centres. Thus, it is possible that fewer of the study participants in Uppsala had a history of occupational exposure to storage mites.

In addition to having the lowest prevalence of HDM sensitization, the study population in Uppsala had also a low prevalence of *L. destructor* sensitization (3%) similar to Aarhus (3%) and lower than Reykjavik and Bergen (7% and 6%, respectively).

TABLE 4 Adjusted odds ratio (aOR) and 95% CI for storage mite species and house dust mite (HDM) skin prick test positivity as associated with respiratory and allergic symptoms, in a mutually adjusted model

	Storage mite SPT positivity		House dust mite SPT positivity		
	Any storage mite (n = 88) ^c	<i>Acarus siro</i> (n = 52)	<i>Tyrophagus putrescentiae</i> (n = 52)	<i>Lepidoglyphus destructor</i> (n = 61)	<i>Dermatophagoides farinae</i> and <i>D pteronyssinus</i> combined (n = 90)
aOR ^a (95% CI):					
Combined asthma symptoms ^b	1.06 (0.63, 1.78)	1.22 (0.53, 2.73)	0.98 (0.78, 1.24)	1.46 (1.20, 1.79)	1.37 (0.74, 2.56)
Asthma, ever (n = 898)	1.46 (1.14, 1.86)	0.74 (0.54, 1.02)	1.26 (0.69, 2.29)	1.32 (0.91, 1.91)	2.24 (1.50, 3.34)
Nasal allergies, ever (n = 901)	2.09 (1.31, 3.33)	1.84 (1.36, 2.50)	1.93 (1.63, 2.29)	1.98 (1.07, 3.68)	3.73 (0.80, 17.3)
Eczema, ever (n = 895)	0.97 (0.73, 1.31)	1.32 (0.84, 2.05)	1.44 (0.91, 2.29)	1.11 (0.79, 1.55)	1.04 (0.43, 2.54)

Note: ^aAdjusted for: gender, storage mite and HDM SPT positivity, clustered by study centre.

^bMore than two asthma symptoms (wheezing or whistling, breathlessness, tightness in chest, night-time cough or shortness of breath and asthma medication usage) in the last 12 months.

^cUppsala only 1 storage mite SPT (*L destructor*)

The prevalence of HDM and storage mite sensitization is quite similar in our population, which makes the above-mentioned characteristics interesting. HDM thrive in higher humidity, whereas storage mites prefer lower humidity. Possibly, the climatic characteristics for the geographic areas covered by this study give the possibility for both genera of mites to thrive. This has also been shown in a study with limited number of participants from Northern Norway, where 7 mite species were described in mattress samples, of which 2 were HDM and 5 storage mite species.²⁶ HDM allergens have previously been measured in dust samples from some of these regions and compared to other European countries, Iceland and Sweden showed the least concentration of allergens in the bedrooms.²⁷ Although bedroom and indoor locations are believed to be the main sites of exposure, other places such as cars, public transport etc have been shown to be of importance.²⁸ The concentration and composition of storage mite allergens, however, have not been measured in non-occupational settings. Our study suggests that storage mite sensitization might be more important beyond occupational settings than previously anticipated, identifying a need to study this in other parts of Europe and the world. It would be interesting to compare our findings with areas with more humid or dry climates to explore the impact of environmental conditions on prevalence and sensitization of mites. Furthermore, other factors may affect the prevalence of mites. As reported by studies from Ireland²⁹ and Sweden,³⁰ both storage mites and HDMs are found in home environments. Mattresses, stuffed furniture, household pets and pet beds are sources of both mite types, suggesting that the mites thrive in these environments. Human hair and pet fur, skin scales and possibly traces of food³¹ create a viable environment for the mites in mattresses and furniture. Although we did not measure storage mite allergens per se in our study, we observed an association between storage mite sensitization and dog keeping. Cat keepers were, however, less likely to be sensitized to storage mites.

In previous studies from Norway and Iceland, storage mites or HDM are rarely found in mattress dust samples, despite the relatively high prevalence of HDM sensitization in the general population,³¹⁻³³ suggesting that sensitization occurs during travelling or due to cross-reactivity with other allergens.^{34,35} One of the cross-reactive allergens, tropomyosin, is also an allergenic compound of invertebrates, including shrimp, mites, mosquitoes and helminths.³⁶ Furthermore, tropomyosin is a somatic antigen of the helminth *Ascaris lumbricoides*, which has been reported to be a primary cause of sensitization to storage mite (*Blomia* spp.) in endemic regions.³⁷ Although data about *Ascaris* prevalence in the Nordic countries are limited, the exposure to *Ascaris* can be quite high in these regions, with 29% in the Bergen ECRHS III cohort.³⁸ In the light of extremely low findings of HDM and HDM mite allergens in bedroom mattress samples, identifying cross-reactive proteins of other causes is relevant for future research into the cause of allergies and sensitization to mites.

Co-sensitization between storage mites and HDMs is well known, but we know little about how storage mite sensitivity might affect allergic and asthmatic symptoms in the general population. Asthma and nasal symptoms may be symptoms of an underlying allergy to storage mites. The prevalence of co-sensitization between storage mites and HDMs in this study (44%) was lower than the prevalence reported in other studies³⁹ with 70% of those sensitized to storage mites also being sensitized to HDM.

There are several limitations in our study that should be considered. First, sensitization was defined by SPTs since storage mite-specific IgEs were not available, and our results and interpretation are limited to this method. However, SPT is a validated method of measuring sensitization. Secondly, in Uppsala, only sensitization towards *L destructor* was measured. This limits our understanding of storage mite sensitization in general in Uppsala, but does not introduce an error in specific analyses of the associations between sensitization to *L destructor* and allergic symptoms. Thirdly, the ECRHS questionnaire is extensively studied and

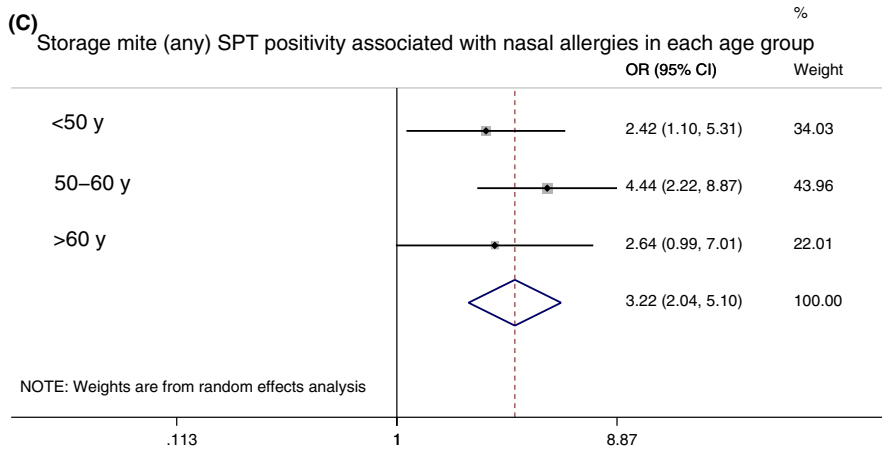
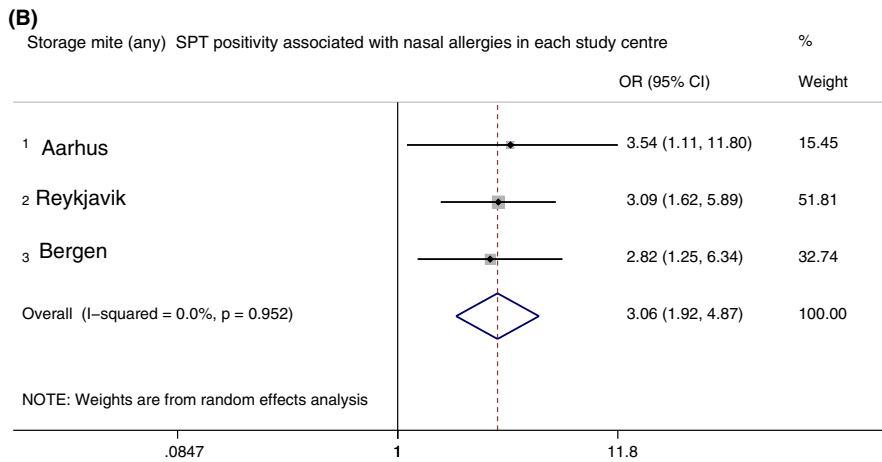
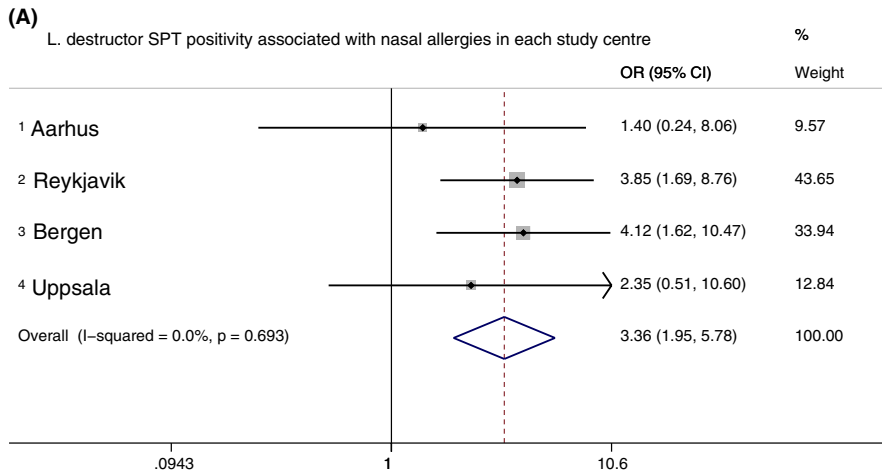


FIGURE 2 A, *Lepidoglyphus destructor* SPT positivity associated with nasal allergies in each study centre. B, Any storage mite SPT positivity associated with nasal allergies in each study centre (excluding Uppsala). C, Any storage mite SPT positivity associated with nasal allergies stratified by age group (excluding Uppsala)

widely used in epidemiological studies for defining asthma,⁴⁰ but we acknowledge that this definition differs from that of clinical diagnostics.

5 | CONCLUSION

The prevalence of sensitization to storage mites in these general populations from North Europe was 10%, which was as high as HDM

sensitization. Storage mite sensitization was found to be most prevalent in Reykjavik, followed by Bergen and Aarhus. We observed a higher percentage of storage mite sensitization among men than women. Forty-four percent co-sensitization between HDM and storage mites were observed for our study population, but storage mite SPT positivity was significantly and independently associated with asthma and nasal allergies also when adjusting for HDM sensitization. This suggests that storage mite sensitization occurs in a general population independently of HDM sensitization and might

TABLE 5 Adjusted odds ratio (aOR) and 95% CI for storage mite skin prick test positivity as associated with allergic diseases compared to non-allergic patients without asthma

Storage mite	Allergic profile			
	Non-allergic No asthma (n = 755)	Nasal allergies without asthma (n = 243)	Asthma without nasal allergies (n = 78)	Asthma with nasal allergies (n = 92)
aOR (95% CI):				
Any storage mite (n = 88) ^a	Ref.	2.79 (2.32, 3.36)	1.15 (1.00, 5.65)	4.87 (3.72, 6.37)
<i>Acarus siro</i> (n = 52)	Ref.	2.93 (1.62, 5.29)	0.36 (0.09, 1.44)	3.55 (2.29, 5.39)
<i>Tyrophagus putrescentiae</i> (n = 52)	Ref.	2.64 (1.91, 3.68)	0.77 (0.19, 3.19)	4.71 (2.81, 7.89)
<i>Lepidoglyphus destructor</i> (n = 61)	Ref.	2.73 (1.95, 3.85)	1.26 (0.28, 6.68)	4.39 (2.63, 7.32)

Note: Adjusted for: gender, storage mite and HDM SPT positivity, clustered by study centre.

^aUppsala only 1 storage mite SPT (*L. destructor*)

potentially contribute to allergic disease. In the light of our findings, we suggest that storage mites should be considered for the common inhalant allergen SPT panel in Northern Europe.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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