Association of indoor dampness and molds with rhinitis risk: A systematic review and meta-analysis

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Background: A substantial proportion of the world's population is exposed to indoor dampness-related exposures. Since the 1990s, studies have assessed the relation between indoor dampness and mold and rhinitis, but the evidence has been inconclusive. No previous meta-analysis has been reported on this topic.
Objective: We conducted a systematic review and meta-analysis of studies on the relations between indoor dampness and mold and the risk of different types of rhinitis and investigated whether these relations differ according to the type of exposure.
Methods: A systematic search of the Ovid MEDLINE and EMBASE databases was conducted (1950 through August 2012), and reference lists of relevant articles were reviewed. Cross-sectional, case-control, and cohort studies in children or adults were selected according to *a priori* criteria and evaluated by 3 authors independently.
Results: Thirty-one studies on rhinitis, allergic rhinitis (AR), or rhinoconjunctivitis were included. In meta-analyses the largest risk was observed in relation to mold odor (rhinitis: 2.18 [95% CI, 1.76-2.71]; AR: 1.87 [95% CI, 0.95-3.68]). The risk related to visible mold was also consistently increased (rhinitis: 1.82 [95% CI, 1.56-2.12]; AR: 1.51 [95% CI, 1.39-1.64]; rhinoconjunctivitis: 1.66 [95% CI, 1.27-2.18]). In addition, exposure to dampness was related to increased risk of all types of rhinitis.
Conclusion: This meta-analysis provides new evidence that dampness and molds at home are determinants of rhinitis and its subcategories. The associations were strongest with mold odor, suggesting the importance of microbial causal agents. Our results provide evidence that justifies prevention and remediation of indoor dampness and mold problems, and such actions are likely to reduce rhinitis. (J Allergy Clin Immunol 2013;132:1099-110.)

Key words: *Rhinitis, mold, dampness, case-control, longitudinal, cross-sectional, meta-analysis*

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Abbreviations used
AR: Allergic rhinitis
EE: Effect estimate

A substantial proportion of the world's population is exposed to indoor dampness-related exposures, which constitute an important indoor problem globally. In a cold climate the prevalence of water damage and dampness exposures has been estimated to be 5% to 30%, whereas in moderate and warm climates it has been estimated to be 10% to 60%.[1-3] The prevalence of indoor mold exposure has been estimated as 5% to 10% in a cold climate and 10% to 30% in moderate and warm climates.[2]

Allergic rhinitis (AR) is a common disease among both children and adults, with the estimated prevalence being 10% to 40% and even greater than 50% in some general population-based studies.[4] Studies examining changes in prevalence have suggested that the occurrence of rhinitis is increasing even faster than that of asthma.[4,5] Rhinitis in general can reduce quality of life through symptoms and even insomnia, can impair workability, and can be related to comorbidities, such as development or exacerbations of asthma, thus having a major effect on public health and causing important health care and other costs.[4-6]

Since the 1990s, studies have addressed the relation between indoor dampness and molds and rhinitis in Europe, the United States, China, and Taiwan, with the majority being reported since the mid-2000s. The results of individual studies have been inconclusive and sometimes even contradictory, but no previous meta-analysis on indoor dampness, mold exposures, or both and rhinitis has been reported. To fill in this knowledge gap, we conducted a systematic review and meta-analysis through August 2012 to investigate the relation between indoor dampness and mold exposures and the risk of rhinitis. In addition, we investigated whether such relations differ according to the type of exposure by carrying out separate meta-analyses for different exposure indicators, including water damage, dampness, visible mold, and mold odor. Differences according to the type of exposure could provide insight into the specific causal agents and pathways and be of importance for preventive actions. Because the outcomes of studies varied, we also conducted separate meta-analyses for different outcomes, including rhinitis, AR, and rhinoconjunctivitis.

METHODS

Data sources

We performed a systematic literature search of the Ovid MEDLINE and EMBASE databases from 1950 through August 2012 using the terms

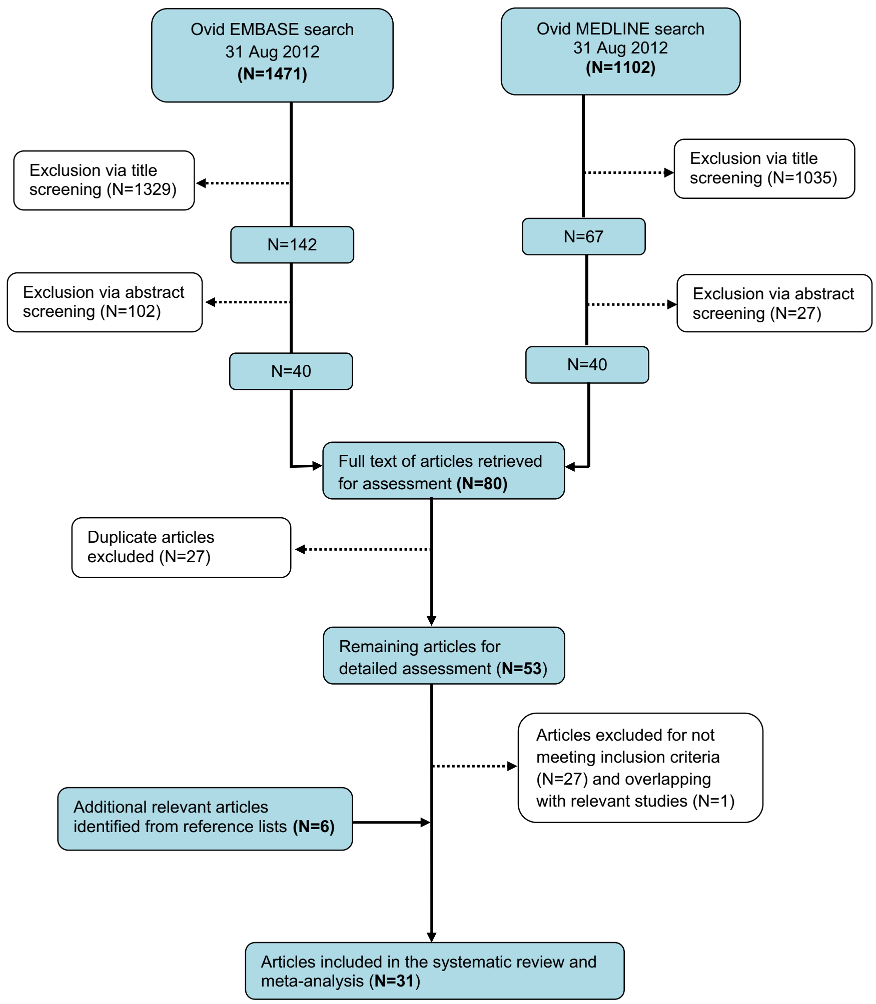

FIG 1. Flow diagram showing searches and study selection.

"mold/mould/fungus/damp/humidity" AND "allergic rhinitis/rhinitis/perennial rhinitis/hay fever/respiratory tract disease/respiratory symptoms." Fig 1 shows the flow chart of assessing the articles.

Study selection

In this systematic search and meta-analysis we followed the Meta-analysis of Observational Studies in Epidemiology[7] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses[8] guidelines. Three authors (S.A.M.H., T.T.H., and R.Q.) independently evaluated the articles. Studies that met the following *a priori* eligibility criteria were included: the study (1) was an original study; (2) was a cross-sectional, case-control or cohort study; (3) included rhinitis, AR or hay fever, or rhinoconjunctivitis as the outcome; (4) included a study population of infants or children or adults; (5) reported on the relations between dampness, mold exposure, or both and rhinitis outcomes; and (6) reported dampness, exposure, or both in the home environment. If more than 1 report was published from the same study, the most recent study or the study with the longest follow-up or providing the best assessment of exposure, outcome, or both was included. Table E1 in this article's Online Repository at www.jacionline.org displays the main characteristics of the eligible studies. The outcome of interest was occurrence of rhinitis or different subcategories (ie, AR and rhinoconjunctivitis). The definitions of rhinitis included different types of rhinitis self- or parent-reported in a questionnaire or interview. Some studies required a doctor's diagnosis, whereas others based the definition on occurrence of rhinitis-related symptoms with or without evidence of allergies. The definition of rhinoconjunctivitis included also eye symptoms. The definitions of exposure that were eligible included water damage, damp stains or other dampness indicators, visible mold, and mold odor. The description of the exposures in each study is given in Table E2 in this article's Online Repository at www.jacionline.org.

Data extraction and quality assessment

Eligible studies were examined, and the relevant characteristics were recorded in a standard data extraction form[9] independently by the 3 reviewers. Any disagreements were discussed among the whole team until a consensus was achieved. The study quality was assessed by using the Newcastle-Ottawa Scale.[10] For cross-sectional studies, the first 6 items of the Newcastle-Ottawa Scale were applied, and for case-control/cohort studies, all 9 items were used to assess quality. In the main analysis studies scoring 5 or more were categorized as high quality.

Data analysis

In the meta-analysis we calculated summary effect estimates (EEs) from the study-specific odds ratios or incidence rate ratios by using fixed- and random-effects models.[11] When available, we preferred the adjusted EEs. Following the tradition of meta-analyses of epidemiologic studies, we did not make any transformations of the odds ratios or incidence rate ratios because this would have been difficult with adjusted EEs. The summary EE from the fixed-effects model is presented when the study-specific EEs were homogeneous, whereas that from the random-effects model is presented when

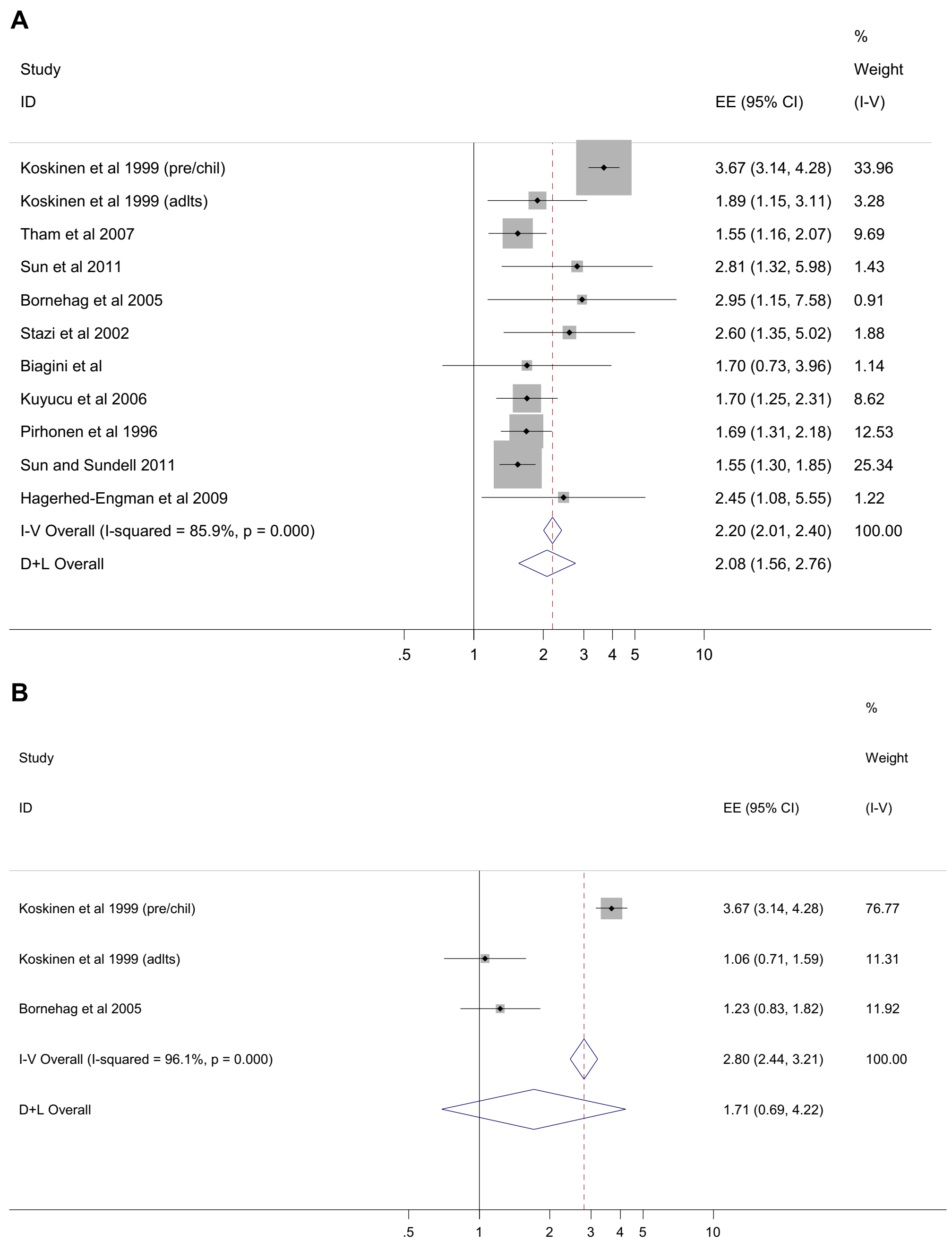

FIG 2. Forest plot for the relation between any exposure and rhinitis **(A)**, between water damage and rhinitis **(B)**, between dampness and rhinitis **(C)**, between visible mold and rhinitis **(D)**, and between mold odor and rhinitis **(E)**. *D+L*, Random-effects summary EE from the DerSimonian-Laird method; *I-V*, fixed-effects model summary EE from the generic inverse variable method.

moderate or substantial heterogeneity was observed. Heterogeneity was evaluated by using the Q and I^2 statistics (I^2 statistic >50% indicates high, 25% to 50% indicates moderate, and <25% indicates low heterogeneity). Stratified and meta-regression analyses were performed to elaborate heterogeneity.

The possibility of publication bias was explored with a funnel plot. The trim-and-fill method was used to assess the potential effect of missing studies in the funnel plot (eg, because of publication bias) on the summary EE.[12] We used the "metan" command to run the fixed- and random-effects models and "metatrim" command for the trim-and-fill method in STATA 11 software (StataCorp, College Station, Tex).[13]

RESULTS

Literature search

A step-by-step approach of the literature search is shown in Fig 1. Thirty-one studies[14-44] met the *a priori* inclusion criteria and were included in the systematic review and meta-analysis.

The MEDLINE search produced 1102 references, 1062 of which were excluded based on the title and abstract screening. The EMBASE search produced 1471 references, 1431 of which were excluded based on the title and abstract screening. The

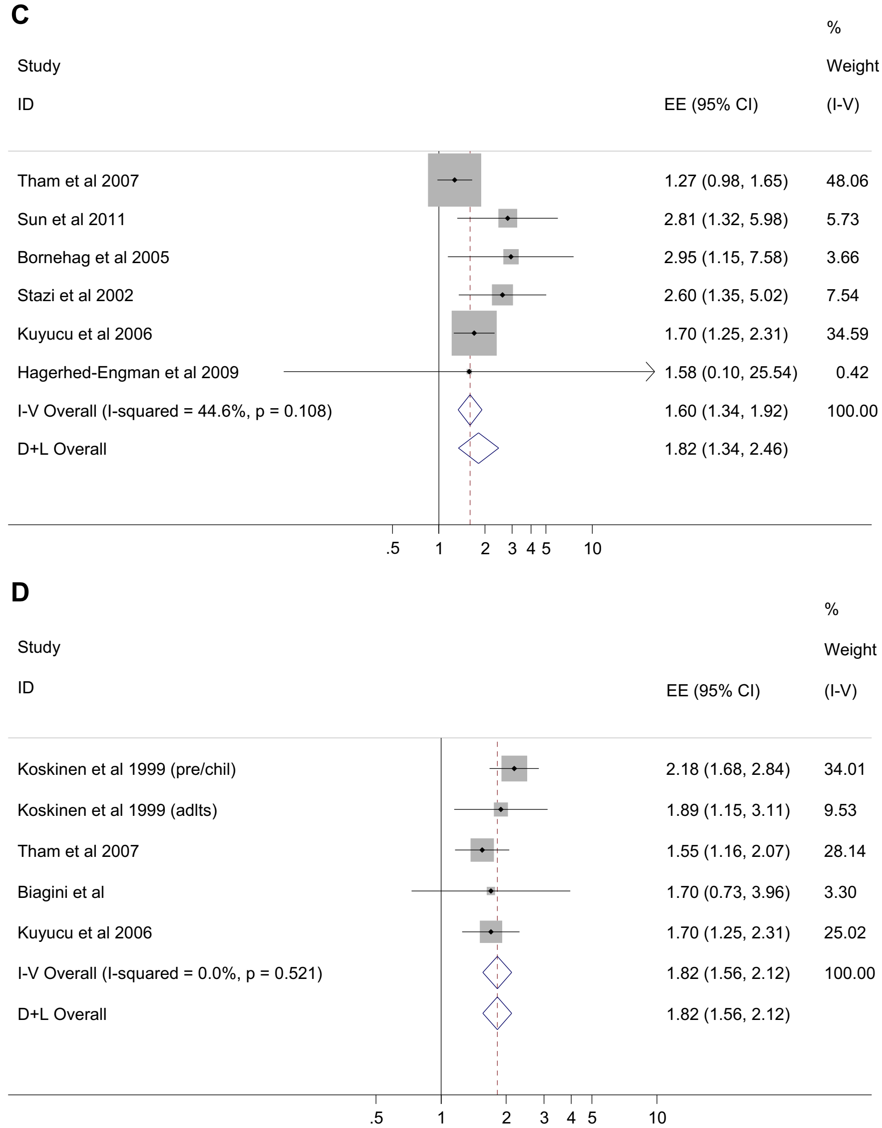

FIG 2. *(Continued)*

remaining 80 articles from both searches were retrieved, and after excluding 27 duplicates, the full text of 53 articles was assessed. Among these, 27 were excluded[45-70] for not meeting the *a priori* inclusion criteria, and 1 article[71] was excluded because of overlapping with the relevant studies. The reasons for excluding these 27 articles are given in Table E3 in this article's Online Repository at www.jacionline.org. An additional 6 articles were identified based on the reference lists of the relevant articles, and therefore altogether, 31 articles were included.

Characteristics of included studies

Characteristics of the 31 eligible studies are shown in Table E1. Three of them were cohort studies, 2 were case-control studies, and the remaining 26 were cross-sectional studies. One study investigated infants, 15 preschool children, 18 school-aged children, and 6 adults or adolescents. All studies based their outcomes on self-reports or parental reports, and 11 studies specified that a doctor's diagnosis was required. Information on exposure was reported by questionnaire in 26 studies and by a trained/professional inspector in 5 studies. The studies defined exposures in variable ways (Table E2), and we systematically categorized them into any exposure, water damage, dampness, visible mold, and mold odor. Eleven of the 31 studies provided EEs for relation with any exposure. For the rest, the EE for "any exposure" was chosen or calculated based on the highest EEs reported for the specific exposure indicators (Tables E4-E6 in this article's Online Repository at www.jacionline.org). The EEs based on the lowest study-specific estimates were calculated similarly.

Studies on rhinitis

Fig 2 and Table E4 show the study-specific findings, as well as the summary EEs, based on the 11 studies addressing the relations between different dampness or mold exposures and rhinitis.

The summary EE from the random-effects model for any exposure and rhinitis was 2.08 (95% CI, 1.56-2.76; Fig 2, *A*). Substantial heterogeneity was observed in the study-specific EEs. We elaborated sources of heterogeneity by conducting stratified analyses (see Table E7 in this article's Online Repository at www.

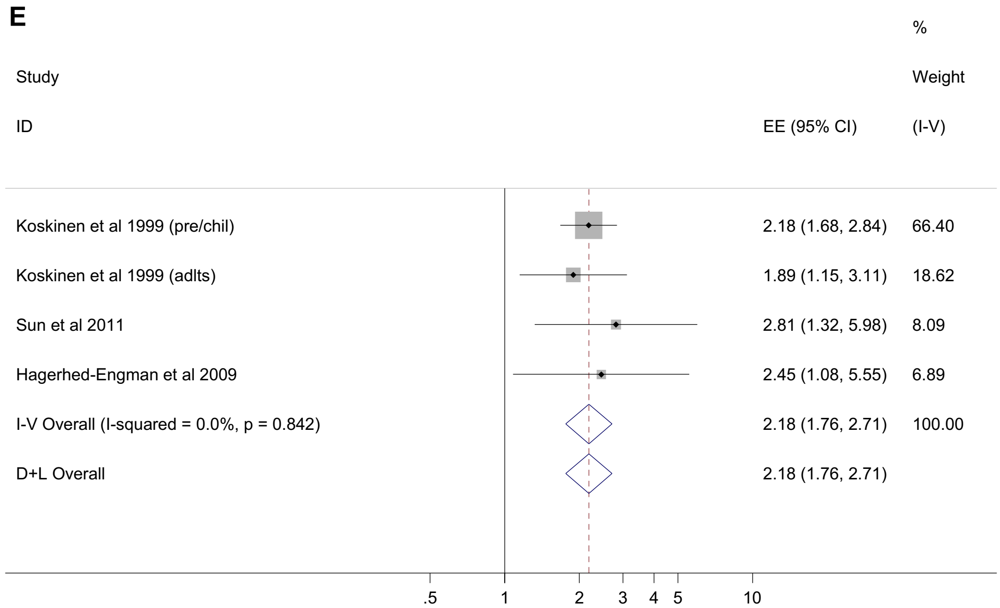

FIG 2. *(Continued)*

jacionline.org). These showed that the EE based on studies using home inspection for exposure assessment was substantially higher (2.60; 95% CI, 1.79-3.78) compared with that based on self-reported exposure (1.64; 95% CI, 1.46-1.85). Some differences in the EE were detected according to study design (case-control studies = 2.64 [95% CI, 1.52-4.59] vs cross-sectional studies = 2.01 [95% CI, 1.47-2.75]). The EE based on studies conducted in Europe was somewhat higher (2.29; 95% CI, 1.60-3.30) than among studies from Asia (1.88; 95% CI, 1.09-3.24) or the United States (1.51; 95% CI, 1.29-1.78), and the estimate based on more recent studies (since 2000) showed a higher EE (2.31; 95% CI, 1.28-4.17) than the older studies (1.67; 95% CI, 1.47-1.90). The EE based on studies with higher quality scores was somewhat stronger (2.31; 95% CI, 1.45-3.68) than in those with lower scores (2.03; 95% CI, 1.46-2.83), but both were statistically significant. The EEs were highest in continental cool summer and subarctic climatic zones. In meta-regression analysis the exposure assessment method was a significant determinant of heterogeneity ($P = .074$), but none of the other covariates explained heterogeneity. The funnel plot suggested a slight influence of small positive studies (see Fig E1 in this article's Online Repository at www.jacionline.org), and therefore we imputed the "missing" studies by using the "metatrim" procedure, and the adjusted EE increased marginally (2.16; 95% CI, 1.64-2.86). The summary EE based on the lowest study-specific estimates was 1.63 (95% CI, 1.39-1.90).

The summary EE for water damage and rhinitis was 1.71 (95% CI, 0.69-4.22) from the random-effects model, and the study-specific estimates showed large heterogeneity (Fig 2, *B*). This estimate was based on 3 studies. Six studies provided study-specific estimates for dampness and rhinitis, resulting in a summary EE from the random-effects model of 1.82 (95% CI, 1.34-2.46; Fig 2, *C*). The study-specific estimates showed moderate heterogeneity. The funnel plot on dampness and rhinitis provided no indication of publication bias (see Fig E2 in this article's Online Repository at www.jacionline.org).

The summary EE for visible mold and rhinitis from the fixed-effects model was 1.82 (95% CI, 1.56-2.12; Fig 2, *D*) based on 5 studies providing rather homogeneous study-specific estimates. The I^2 statistic equaling zero indicates no heterogeneity. The funnel plot was symmetric without any evidence of publication bias (see Fig E3 in this article's Online Repository at www.jacionline.org). Four studies investigated the effect of mold odor on rhinitis, resulting in a summary EE from the fixed-effects model of 2.18 (95% CI, 1.76-2.71; Fig 2, *E*). No major heterogeneity was detected in study-specific estimates.

Studies on AR

Altogether, 18 studies (providing 19 EEs) investigated the relation between different dampness or mold exposures and AR, which included hay fever. The study-specific estimates, as well as the summary EEs, are shown in Fig 3 and Table E5.

The summary EE for any exposure from the random-effects model was 1.52 (95% CI, 1.29-1.80; Fig 3, *A*), and the study-specific estimates showed substantial heterogeneity, but stratified analyses did not identify any major source of heterogeneity (see Table E8 in this article's Online Repository at www.jacionline.org). The EE was strongly influenced by one large study, but the funnel plot did not indicate publication bias (see Fig E4 in this article's Online Repository at www.jacionline.org). Exclusion of this study resulted in an EE of 1.40 (95% CI, 1.32-1.94).

The relation between water damage and AR was assessed in 4 studies, resulting in a summary EE of 1.46 (95% CI, 0.98-2.19; Fig 3, *B*) in the random-effects model. The study-specific estimates showed considerable heterogeneity. The summary EE from the random-effects model for the effect of dampness on AR was 1.50 (95% CI, 1.38-1.62) based on 6 studies (Fig 3, *C*). There was slight heterogeneity between the study-specific estimates. The funnel plot showed no sign of publication bias (see Fig E5 in this article's Online Repository at www.jacionline.org).

The effect of visible mold on AR was assessed in 11 studies (providing 12 EEs), resulting in a summary EE of 1.51 (95% CI, 1.39-1.64) in the fixed-effects model (Fig 3, *D*). There was no heterogeneity in the study-specific estimates. The largest summary

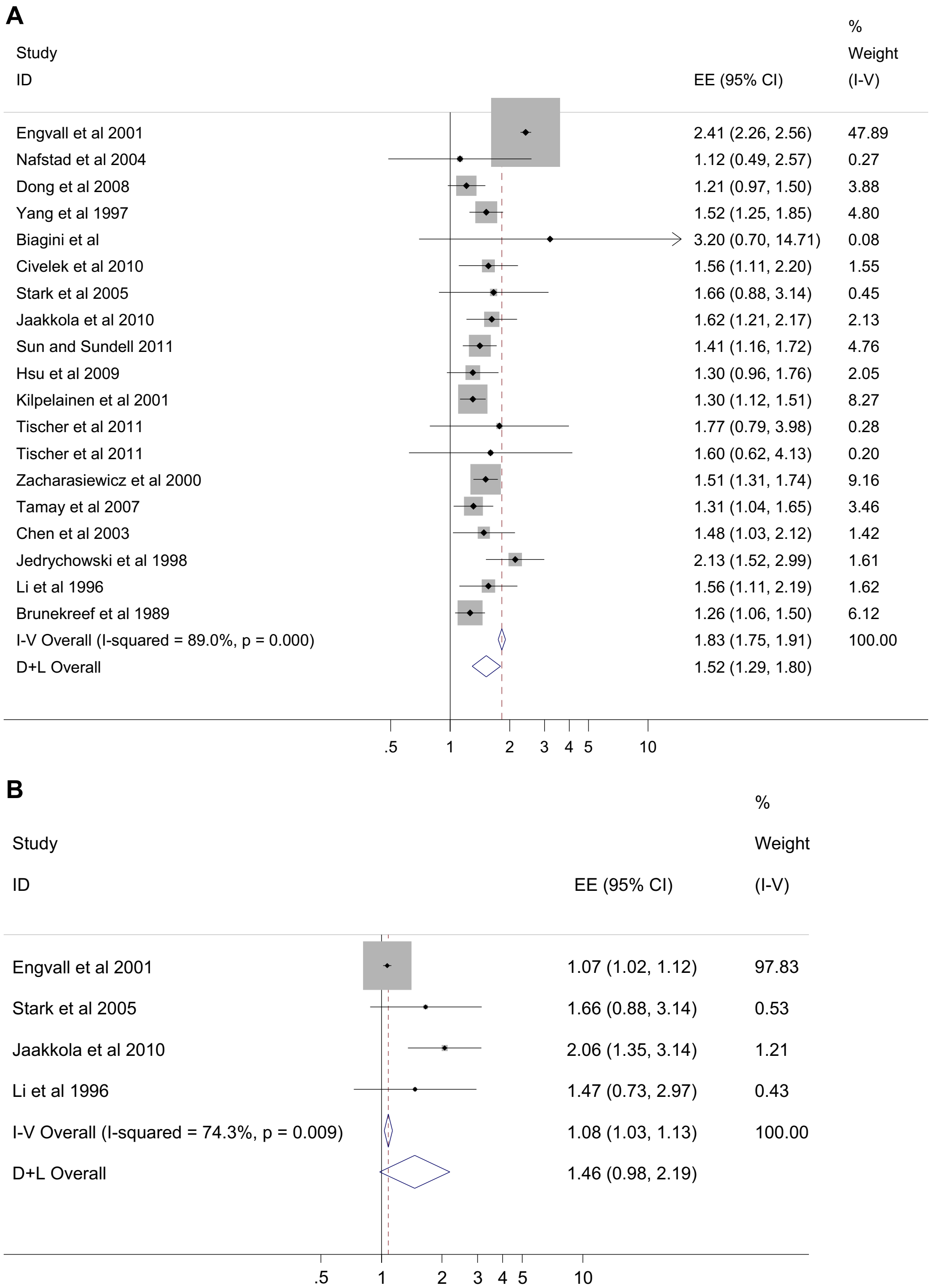

FIG 3. Forest plot for the relation between any exposure and AR **(A)**, between water damage and AR **(B)**, between dampness and AR **(C)**, between visible mold and AR **(D)**, and between mold odor and AR **(E)**. *D+L*, Random-effects summary EE from the DerSimonian-Laird method; *I-V*, fixed-effects model summary EE from the generic inverse variable method.

EE for AR was seen in relation to mold odor: 1.87 (95% CI, 0.95-3.68; Fig 3, *E*) from the random-effects model based on 3 studies that showed considerable heterogeneity.

Studies on rhinoconjunctivitis

Fig 4 and Table E6 show the study-specific and summary EEs for the 6 studies addressing the relations between different dampness and mold exposure indicators and rhinoconjunctivitis. No study provided estimates for water damage or mold odor.

The summary EE for any exposure from the random-effects model was 1.68 (95% CI, 1.41-2.00; Fig 4, *A*). The study-specific estimates showed slight heterogeneity. Stratified analyses were performed to address this, but there were insufficient data for meta-regression analysis. The only study characteristic that

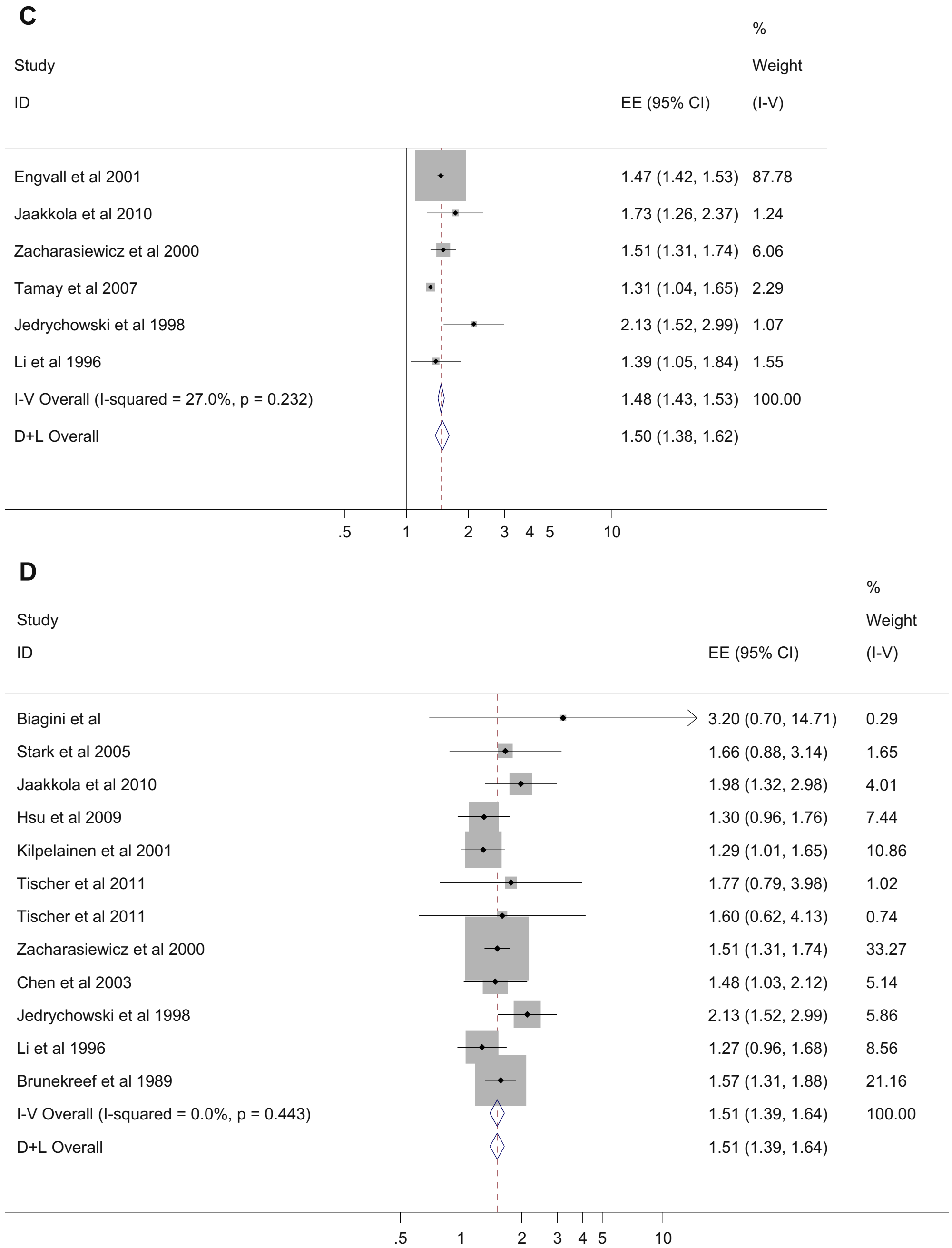

FIG 3. *(Continued)*

explained heterogeneity was the study design because cross-sectional studies showed a clear effect of 1.71 (95% CI, 1.51-1.94), whereas 2 cohort studies showed no effect (0.91; 95% CI, 0.40-2.10). The funnel plot showed 1 small negative study as an outlier, and this actually influenced the EE of the 2 cohort studies in the stratified analyses, but the shape of the funnel plot did not indicate typical publication bias (see Fig E6 in this article's Online Repository at www.jacionline.org). Exclusion of this negative cohort study resulted in a marginally increased summary EE of 1.70 (95% CI, 1.50-1.93).

The summary EE from the fixed-effects model for dampness was 1.67 (95% CI, 1.41-1.98) based on 3 studies on rhinoconjunctivitis (Fig 4, *B*) showing no heterogeneity. The summary EE for visible mold was 1.66 (95% CI, 1.27-2.18) from the random-effects model based on 5 studies (Fig 4, *C*). The study-specific estimates showed moderate heterogeneity.

DISCUSSION

Main findings

This systematic review and meta-analysis provides evidence that the risk of rhinitis is significantly increased in relation to home dampness and mold exposures. The largest risk was observed in relation to mold odor (rhinitis, 2.18; AR, 1.87), and the risk related to visible mold was also consistently increased

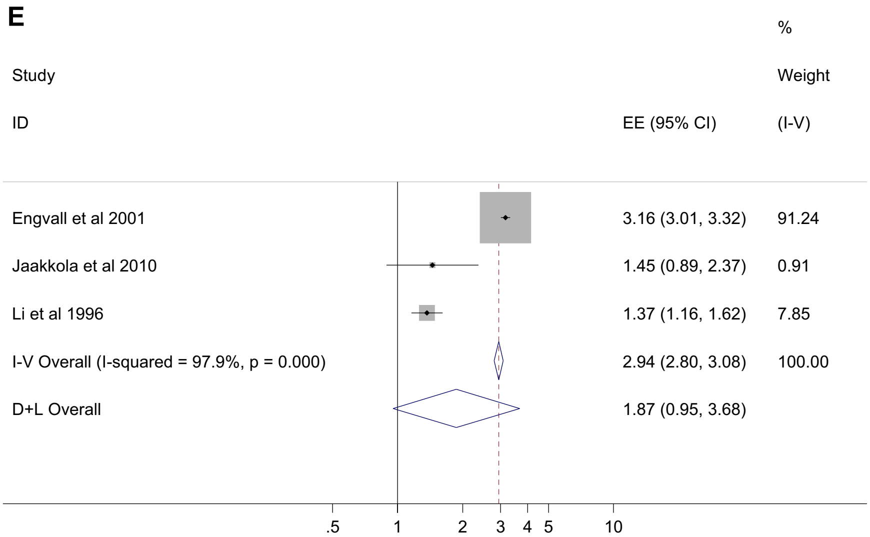

FIG 3. *(Continued)*

(rhinitis, 1.82; AR, 1.51; rhinoconjunctivitis, 1.66), with mainly homogeneous EEs.

The summary EEs for any exposure were consistently increased (rhinitis, 2.08; AR, 1.52; rhinoconjunctivitis, 1.68), but the study-specific estimates showed usually more heterogeneity. Stratified analyses were conducted to elaborate potential sources of heterogeneity. Interestingly, studies with exposure assessment based on home inspection showed a stronger effect on rhinitis than those with self-reported exposure.

The summary EEs for dampness were also consistently increased (rhinitis, 1.82; AR, 1.50; rhinoconjunctivitis, 1.67) and of similar magnitude as those related to visible mold. The study-specific EEs for dampness showed more heterogeneity between the studies than those for mold odor or visible mold. In contrast to the other exposure indicators, water damage was not significantly related to increased risk of rhinitis outcomes, and heterogeneity between study-specific estimates was large.

The finding that the strongest risk was usually related to mold odor suggests that microbial exposures play an important role for rhinitis outcomes. This finding is consistent with a hypothesis that mold odor is a sign of more relevant exposure, perhaps related to the fact that when exposure can be "smelled," there is a connection between the exposure source and the nasal mucosa. Because the risk of both rhinitis and AR were similarly increased, it seems that other mechanisms than allergic ones might also be of importance, as has been suggested for asthma.[9] Dampness *per se* was also consistently related to increased risk of rhinitis outcomes, but there was more heterogeneity between studies, which suggests that other dampness-related exposures than microbes are likely to be involved, causing variability in EEs.

Validity of results

The strengths of our study include selection of studies based on a clearly defined search strategy. In addition to the primary Ovid MEDLINE and EMBASE database searches, we also used references that were cited by the articles identified in the primary search. Three reviewers checked independently the eligibility of the studies according to *a priori* set of inclusion and exclusion criteria and decided on the most appropriate EE. We followed the approach of the Meta-analysis of Observational Studies in Epidemiology[7] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses[8] guidelines.

Our meta-analysis was limited by the characteristics of the studies that were available in the literature. Among the 31 studies fulfilling our inclusion criteria, 26 were cross-sectional in design, 2 were prevalent case-control studies, and only 3 were cohort studies. Thus the majority of the data comes from cross-sectional studies in which it is not possible to judge the temporal relation between exposure and the outcome of interest. The 3 cohort studies addressed AR as the outcome, and therefore the conclusions are strongest for AR. The consistency in the findings between cross-sectional and longitudinal studies supports the validity of the findings. The results covered a wide age range.

Most of the studies on the health effects of indoor dampness and mold problems have based their exposure assessment on questionnaire reports by the occupants studied. Sometimes a building inspection has been used. Several studies have compared the occupant-reported presence of indoor dampness, mold problems, or both with findings in building inspections or measurements of fungi in indoor dust, as reviewed by Jaakkola and Jaakkola.[72] Most of these have shown relatively good agreement between these methods of exposure assessment. In general, it has been found that subjects tend to underestimate dampness/mold problems at home compared with inspection or dust mold measurements, but this trend is observed among both those with disease and healthy control subjects, and therefore there is no indication of bias. Such unbiased misclassification of exposure is likely to lead to an underestimation of the true health effect related to indoor mold problems. Consistent with this, in our analyses on any exposure and rhinitis stratified by the exposure assessment method, the EE was higher in relation to inspection (EE, 2.60) compared with the EE related to self-reported exposure (EE, 1.64). Vesper et al compared inspection and the occupant's report of mold odor and moisture with dust measurements of 36

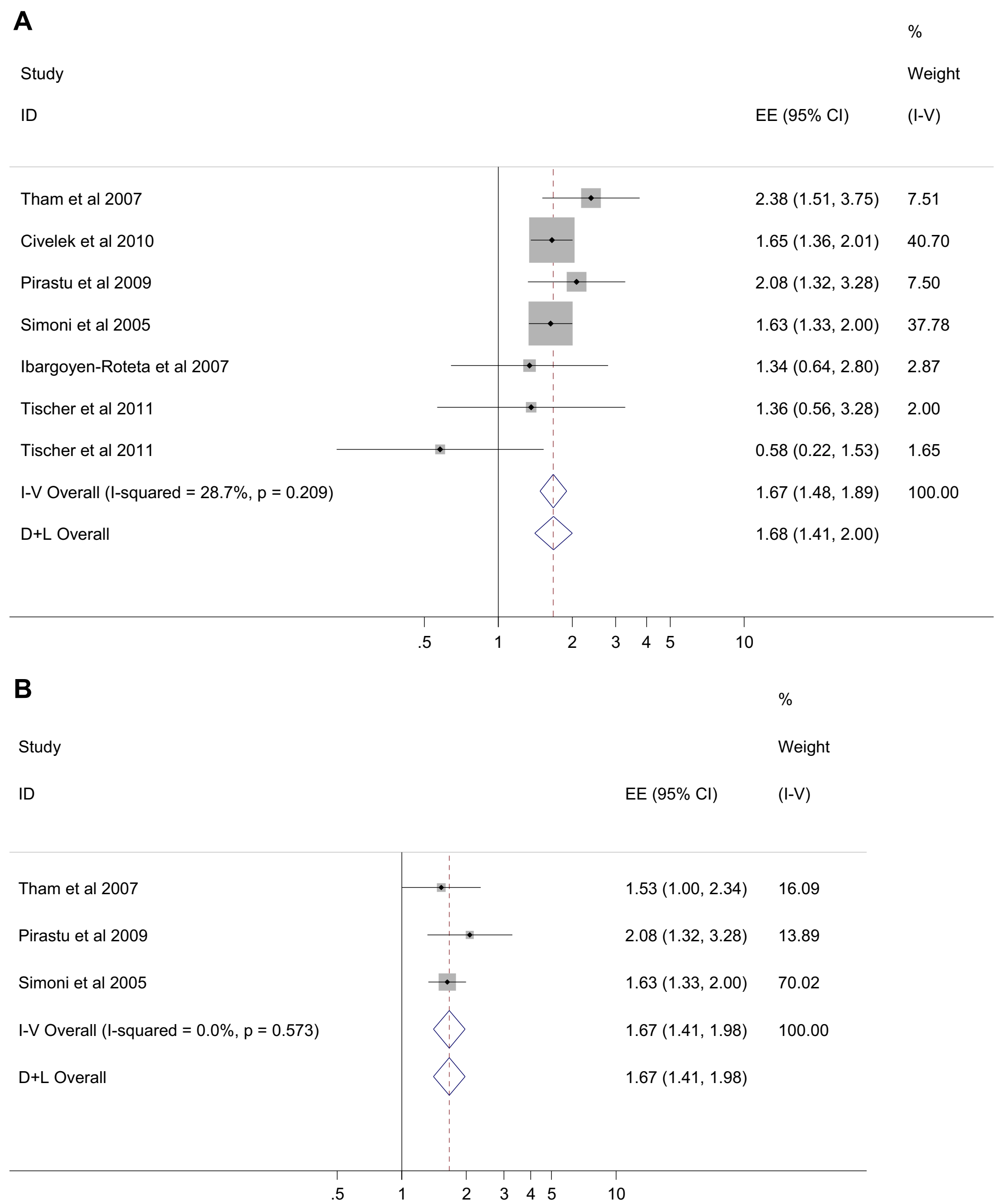

FIG 4. Forest plot for the relation between any exposure and rhinoconjunctivitis **(A)**, between dampness and rhinoconjunctivitis **(B)**, and between visible mold and rhinoconjunctivitis **(C)**. *D+L*, Random-effects summary EE from the DerSimonian-Laird method; *I-V*, fixed-effects model summary EE from the generic inverse variable method.

mold species and found that dust analysis might be useful to find hidden mold problems not detected by the occupant himself or herself or by an inspector. On the other hand, dust measurements and inspection usually reflect just one point in time, whereas occupant report might reflect better long-term exposures that are more relevant for health effects. Reponen et al reported that air concentrations of endotoxin and β-D-glucan were consistently higher in homes with mold odor but were not consistently associated with visible mold damage.

When studying rhinitis as the outcome, the EE for self-reported outcome was slightly higher (2.10; 95% CI, 1.50-2.94) than the EE for doctor-diagnosed outcome (1.81; 95% CI, 1.26-2.61), but both indicated a substantial effect and were statistically significantly increased. When studying AR as the outcome, the EE was practically the same for these 2 types of outcome assessments. Thus there did not seem to be any bias related to the outcome assessment method.

Publication bias was addressed by using funnel plots. The funnel plot for any exposure and rhinitis suggested a slight influence of small positive studies, and therefore we imputed the "missing" studies by using the "metatrim" procedure, which actually increased the summary EE marginally. The other plots showed no indication of publication bias.

Synthesis with previous knowledge

There are no previous meta-analyses on indoor dampness and mold problems and rhinitis. The original studies (presented

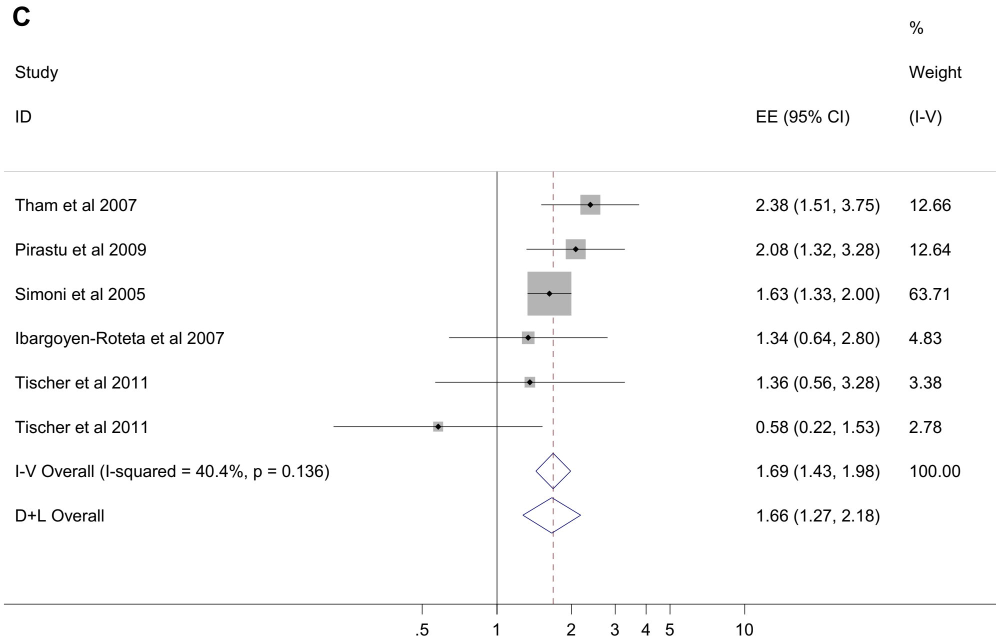

FIG 4. *(Continued)*

in Figs 2-4 and Tables E4-E6) showed inconclusive and sometimes even contradictory results. In 2007, Fisk et al[73] investigated the risk of upper respiratory tract symptoms related to any exposure based on 13 studies and reported increased risk. However, they did not study specifically rhinitis or any subtype of rhinitis, nor did they address different types of exposures separately. A qualitative review up to 2009 by Mendell et al[74] in 2011 reported that there were new studies published on this topic, but they did not conduct any quantitative analysis of the studies.

In our previous meta-analysis on the effect of dampness and mold exposure on the development of asthma, we detected a gradient in the effect that increased from water damage to dampness exposure to visible mold and mold odor, and a simplified causal pathway was suggested.[9] In the meta-analyses presented here we found somewhat larger summary EEs for rhinitis than for asthma. We did not observe such a clear gradient across different types of exposure, but mold odor was usually the strongest determinant of rhinitis, as was seen for asthma. This suggests that microbes play an important role also for rhinitis. However, other exposures suggested to be important for asthma might have some role also for rhinitis, including house dust mites and chemicals emitted from damp materials because dampness *per se* was also related to increased risk of rhinitis outcomes.

This meta-analysis provides new evidence that dampness and molds in the home are determinants of rhinitis and its subcategories of AR and rhinoconjunctivitis. The associations were especially strong in relation to mold odor, suggesting the importance of microbial causal agents. Associations observed with dampness might be related also to other indoor exposures. Our results provide evidence that justifies prevention and remediation of indoor dampness and mold problems, and such actions are likely to reduce rhinitis, leading to savings in health care costs and improvements in public health.

Key messages

- **This meta-analysis provides new evidence that dampness and mold exposures at home are determinants of rhinitis and its subcategories of AR and rhinoconjunctivitis.**
- **The associations were strongest with mold odor, suggesting the importance of microbial causal agents.**
- **Our results provide evidence that justifies prevention and remediation of indoor dampness and mold problems, and such actions are likely to reduce rhinitis.**

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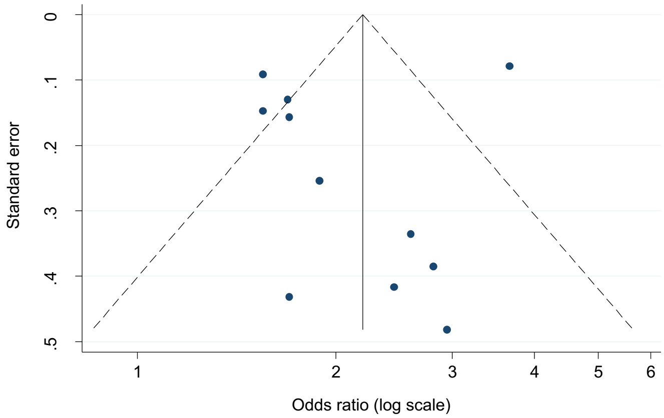

FIG E1. Funnel plot with pseudo–95% confidence limits for any exposure and rhinitis.

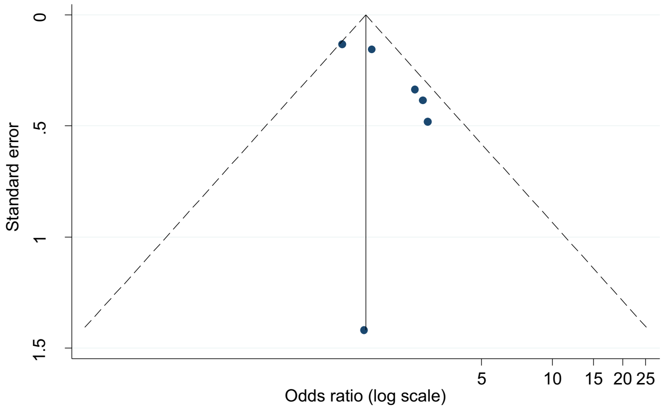

FIG E2. Funnel plot with pseudo–95% confidence limits for dampness and rhinitis.

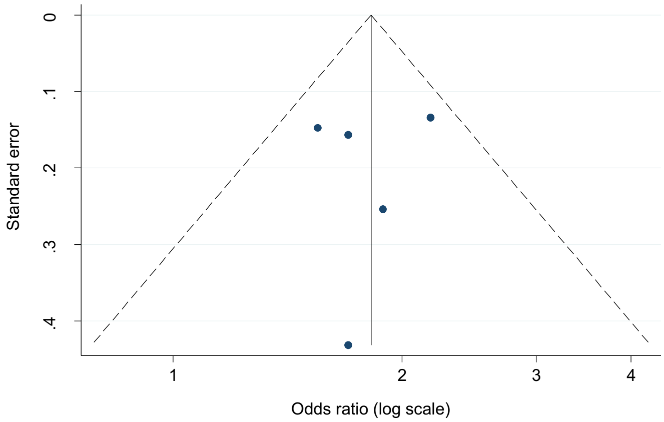

FIG E3. Funnel plot with pseudo–95% confidence limits for visible mold and rhinitis.

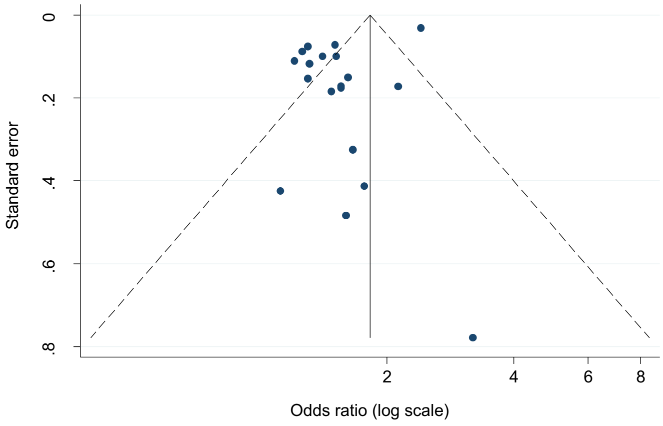

FIG E4. Funnel plot with pseudo–95% confidence limits for any exposure and AR.

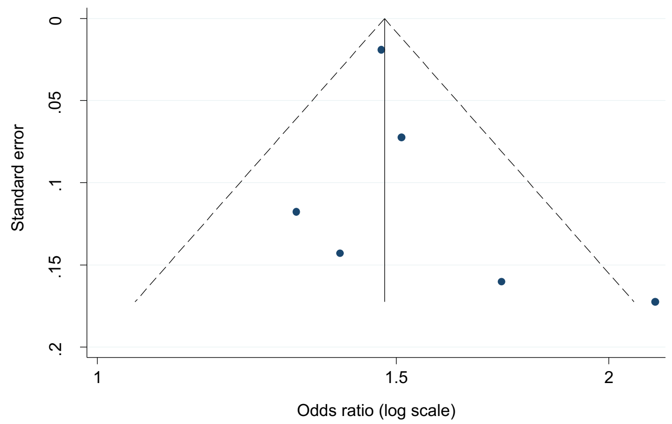

FIG E5. Funnel plot with pseudo–95% confidence limits for dampness and AR.

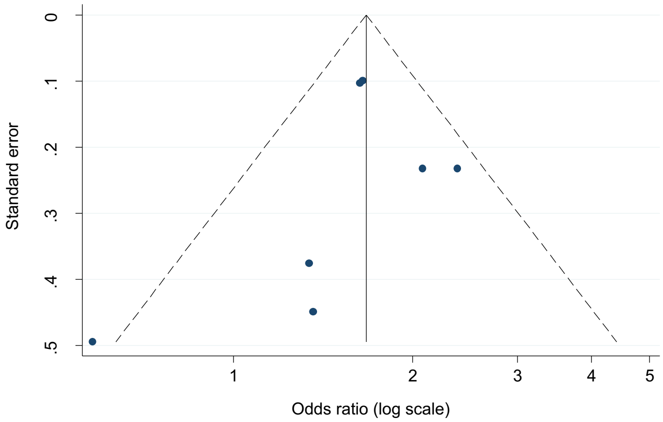

FIG E6. Funnel plot with pseudo–95% confidence limits for any exposure and rhinoconjunctivitis.

TABLE E1. Characteristics of eligible studies included in the systematic review and meta-analysis (n = 31)

Reference, study year/ country	Study population	Study design	Study size	Follow-up (y)	Definition of outcome	Method of data collection for exposure	Total score on NOS
Sun and Sundell,[14] 2011/ United States	Preschool and schoolchildren (1-8 y)	Cross-sectional	2,819	NA	Self-reported doctor-diagnosed hay fever on questionnaire by parents and self-reported rhinitis based on questionnaire to parents	Self-reported based on questionnaire to parents	4/6
Sun et al,[15] 2011/China	Adults	Case-control	Cases: 143 Control subject: 205	NA	Self-reported rhinitis based on questionnaire (problem with sneezing or runny or blocked nose with no cold or flu)	Inspection by trained inspectors	7/9
Tischer et al,[16] 2011/ Germany and The Netherlands	Preschool children (6 y)	Cohort	346 (Germany) 332 (The Netherlands)	6 y	Self-reported doctor-diagnosed AR based on questionnaire to parents (Germany) and self-reported hay fever based on questionnaire to parents (The Netherlands) and self-reported rhinoconjunctivitis based on questionnaire to parents in Germany and The Netherlands	Self-reported based on questionnaire to parents	6/9
Civelek et al,[17] 2010/Turkey	Schoolchildren (9-11 y)	Cross-sectional	6,817	NA	Self-reported current rhinoconjunctivitis and physician-diagnosed AR based on questionnaire to parents	Self-reported based on questionnaire to parents	3/6
Jaakkola et al,[18] 2010/Finland	Schoolchildren (7-13 y)	Cohort	1,863	6 y	Doctor-diagnosed AR reported on questionnaire	Self-reported based on questionnaire to parents	7/9
Hsu et al,[19] 2009/Taiwan	Preschool and schoolchildren (6-13 y)	Cross-sectional	1,368	NA	Self-reported AR based on questionnaire to parents (presence of typical nasal/ symptoms, including watery rhinorrhea, sneezing, and nasal obstruction of >12 mo duration, positive history of known allergen or triggering factors and pale nasal mucosa)	Self-reported based on questionnaire to parents	4/6
Hägerhed-Engman et al,[20] 2009/Sweden	Preschool and schoolchildren (3-8 y)	Case-control	Cases: 198 Control subjects: 202	NA	Doctor-diagnosed rhinitis	Inspection by inspectors	8/9

(Continued)

TABLE E1. *(Continued)*

Reference, study year/ country	Study population	Study design	Study size	Follow-up (y)	Definition of outcome	Method of data collection for exposure	Total score on NOS
Pirastu et al,[21] 2009/Italy	Preschool and schoolchildren (5-10 y)	Cross-sectional	3,455	NA	Self-reported current rhinoconjunctivitis based on questionnaire to parents (frequent sneeze or runny/ stuffy nose apart from common flu/cold with itching/watery eyes in past 12 mo	Self-reported based on questionnaire to parents	4/6
Dong et al,[22] 2008/China	Preschool and schoolchildren (6-13 y)	Cross-sectional	10,784	NA	Doctor-diagnosed AR reported on questionnaire	Self-administered questionnaire to parent	4/6
Ibargoyen-Roteta et al,[23] 2007/Spain	Preschool and schoolchildren (5-8 y)	Cross-sectional	3,360	NA	Self-reported allergic rhinoconjunctivitis based on questionnaire to parents (child had problem with sneezing or running or blocked nose when child did not have cold or flu and accompanied by itchy, watery eyes)	Self-reported based on questionnaire to parents	3/6
Tham et al,[24] 2007/Singapore	Preschool children (1.5-6 y)	Cross-sectional	4,759	NA	Self-reported rhinitis and rhinoconjunctivitis based on questionnaire to parents	Self-reported based on questionnaire to parents	4/6
Tamay et al,[25] 2007/Turkey	Preschool and schoolchildren (6-12 y)	Cross-sectional	2,387	NA	Self-reported AR based on questionnaire to parents (problem with sneezing or running or blocked nose in absence of cold or flu in last 12 mo)	Self-reported based on questionnaire to parents	3/6
Biagini et al,[26] 2006/United States	Infants	Cross-sectional	495	NA	Self-reported rhinitis and AR based on interview-administered questionnaire to parents (rhinitis: sneezing or running or blocked nose not associated with cold or chest infection in past 30 d; AR: having rhinitis at least once on any diary and positive SPT response to ≥1 aeroallergens at 12-mo clinical examination	Inspection by a trained assessor	Rhinitis: 4/6* AR: 5/6†

Kuyucu et al,[27] 2006/Turkey	School children (8-11 y)	Cross-sectional	2,774	NA	Self-reported current rhinitis based on questionnaire to parents (problem with sneezing or runny or blocked nose when child did not have cold or flu in last 12 mo)	Self-reported based on questionnaire to parents	4/6
Bornehag et al,[28] 2005/Sweden	Preschool children (1-6 y)	Cross-sectional	10,851	NA	Doctor-diagnosed rhinitis reported on questionnaire	Self-administered questionnaire to parents	4/6
Simoni et al,[29] 2005/Italy	Children and adolescent	Cross-sectional	20,016 children 13,266 adolescents	NA	Self-reported current rhinoconjunctivitis (frequent sneezes or runny/stuffy nose apart from common cold or flu and itching/watery eyes in previous 12 mo) based on questionnaire by parents and adolescents	Self-reported based on questionnaire to parents and adolescents	4/6
Stark et al,[30] 2005/United States	Preschool children (0-5 y)	Cohort	405	5 y	Doctor-diagnosed AR or hay fever reported on questionnaire by primary caretaker	Self-reported based on questionnaire and telephone interview to primary caretaker	5/9
Nafstad et al,[31] 2004/Norway	Preschool children (3-5 y)	Cross-sectional	942	NA	Doctor-diagnosed hay fever reported on questionnaire	Self-reported based on questionnaire to parents	4/6
Spengler et al,[32] 2004/Russia	Schoolchildren (8-12 y)	Cross-sectional	5,951	NA	Self-reported any allergy (doctor-diagnosed allergy, reported hay fever, or pollinosis) based on questionnaire to parents	Self-reported based on questionnaire to parents	4/6
Chen et al,[33] 2003/Taiwan	Schoolchildren (7-12 y)	Cross-sectional	1,452	NA	Self-reported doctor-diagnosed AR based on questionnaire to parents	Self-reported based on questionnaire to parents	3/6
Stazi et al,[34] 2002/Italy	Preschool children (3 mo-5 y)	Cross-sectional	201	NA	Rhinitis based on interview-administered questionnaire to parents (ever had frequent sneezy, stuffy, or runny nose apart from cold?)	Self-reported based on questionnaire to parents	3/6
Engvall et al,[35] 2001/Sweden	Adults (≥18 y)	Cross-sectional	3,174	NA	Self-reported hay fever based on questionnaire	Self-reported based on questionnaire and telephone interview	3/6

(Continued)

TABLE E1. *(Continued)*

Reference, study year/ country	Study population	Study design	Study size	Follow-up (y)	Definition of outcome	Method of data collection for exposure	Total score on NOS
Kilpelainen et al,[36] 2001/ Finland	Adults (18-25 y)	Cross-sectional	10,667	NA	Self-reported doctor-diagnosed current AR (ever had hay fever or other allergic nasal symptoms; sneezing, itchy, running nose) from pollen or animals	Self-reported based on questionnaire	3/6
Zacharasiewicz et al,[37] 2000/ Austria	Children (6-9 y)	Cross- sectional	18,606	NA	Self-reported atopic rhinitis based on questionnaire to parents (child ever sneezed or had running, obstructed, or itchy nose apart from cold in last 12 mo)	Self-reported based on questionnaire to parents	4/6
Koskinen et al,[38] 1999/ Finland	Preschool children (<7 y) Schoolchildren (7-15 y)	Cross-sectional	204	NA	Self-reported rhinitis based on questionnaire to parents	Observation by trained building engineers and interview of parents	4/6
Koskinen et al,[39] 1999/ Finland	Adults (≥16 y)	Cross-sectional	699	NA	Self-reported rhinitis based on questionnaire	Observation by trained building engineers and interview of occupants	4/6
Jedrychowski et al,[40] 1998/ Poland	Children (9 y)	Cross-sectional	1,129	NA	Self-reported hay fever based on interview to parents	Self-reported based on interview to parents	4/6
Yang et al,[41] 1997/Taiwan	Schoolchildren (6-12 y)	Cross-sectional	4,164	NA	Self-reported AR based on questionnaire to parents (sneezing, nasal congestion, and/or itching nose with absence of cold)	Self-reported based on questionnaire to parents	4/6
Li et al,[42] 1996/Taiwan	Children (8-12 y)	Cross-sectional	1,340	NA	Self-reported AR based on questionnaire to parents (sneezing, nasal congestion, and/or itchy nose, absence of cold)	Self-reported based on questionnaire to parents	4/6
Pirhonen et al,[43] 1996/ Finland	Adult (24-65 y)	Cross-sectional	1,460	NA	Self-reported rhinitis based on questionnaire	Self-reported based on questionnaire	4/6
Brunekreef et al,[44] 1989/ United States	Children (7/8-11/12? y)	Cross-sectional	4,625	NA	Self-reported hay fever based on questionnaire to parents	Self-reported based on questionnaire to parents	4/6

NA, Not applicable; *NOS*, Newcastle-Ottawa Scale; *SPT*, skin prick test.
*Total score for rhinitis on the Newcastle-Ottawa Scale.
†Total score for AR on the Newcastle-Ottawa Scale.

TABLE E2. Definitions of exposure in studies included in the meta-analysis (n = 31)

Reference, study year/country	Exposures as defined in the studies
Sun and Sundell,[14] 2011/United States	Dampness defined as mold/damp spots, floor moisture, water leakage, suspected moisture problems, and condensation on window pane in winter
Sun et al,[15] 2011/China	Stuffy and moldy odor; signs of moisture, such as moldy/damp stains on walls or ceilings and peeling of wall covering, assessed by inspector
Tischer et al,[16] 2011/Germany and The Netherlands	Visible mold in the child's home
Civelek et al,[17] 2010/Turkey	Dampness/mold at 1 y of age
Jaakkola et al,[18] 2010/Finland	Mold odor defined as mold odor in the dwelling during past 12 mo; visible mold defined as ever had visible mold in the dwelling; moisture defined as ever had wet spots on the ceilings, floors, or walls of the occupied rooms in the dwelling; water damage defined as ever had water damage in the dwelling; any exposure defined as the presence of any exposure indicator above
Hsu et al,[19] 2009/Taiwan	Mold (not defined)
Hägerhed-Engman et al,[20] 2009/Sweden	Mold odor defined as moldy odor skirting along the board; dampness defined as floor dampness
Pirastu et al,[21] 2009/Italy	Mold or dampness exposure defined as mold/dampness/fungi on walls or ceiling of your child's bedroom
Dong et al,[22] 2008/China	Mold defined as signs of flooding, water damage, or mold growth (on any surface other than food)
Ibargoyen-Roteta et al,[23] 2007/Spain	Mold on walls (no definition); moisture on walls (no definition)
Tham et al,[24] 2007/Singapore	Dampness defined as visible damp stains on floors, walls, or ceilings in room in which child sleeps; mold defined as visible mold on floors, walls, or ceilings in room in which child sleep
Tamay et al,[25] 2007/Turkey	Dampness (not defined)
Biagini et al,[26] 2006/United States	Mold defined as visible mold and water damage
Kuyucu et al,[27] 2006/Turkey	Dampness/mold at 1 y of age
Bornehag et al,[28] 2005/Sweden	Water leakage (flooding and/or water leakage during previous year or earlier during child's lifetime in child's or parent's bedroom or in kitchen or bathroom) defined as water damage; visible dampness (visible mold or damp spots in child's or parent's bedroom) defined as dampness
Simoni et al,[29] 2005/Italy	Mold/dampness exposure defined as mold/dampness/fungi on walls or on ceiling of your child's bedroom in first year of your child's life (early exposure) and recently (current exposure)
Stark et al,[30] 2005/United States	Water damage or mold/mildew in 1 y was defined from composite variable representing presence of either water damage or visible mold or mildew in home in the child's first year of life generated from visible water damage; mold or mildew inside home and report of water damage in basement, presence of concrete floors in the baby's room, use of humidifier, and use of air conditioner
Nafstad et al,[31] 2004/Norway	Dampness indicator defined as signs of molds, water leakage, damage to floor or wall
Spengler et al,[32] 2004/Russia	Water damage: not clearly stated; presence of mold: not clearly stated
Chen et al,[33] 2003/Taiwan	Visible mold patches at home
Stazi et al,[34] 2002/Italy	Dampness defined as either living in humid zone or having dampness in the bedroom
Engvall et al,[35] 2001/Sweden	History of water leakage (any episode of major water leakage during last 5 y) defined as water damage; ≥1 sign of dampness (combination of ≥1 odor and episodes of a major water leakage during last 5 y) defined as dampness; mold odor; reports of ≥1 odor combined with structural building dampness (combination of ≥1 odor and episodes of a major water leakage during last 5 y) defined as any exposure
Kilpeläinen et al,[36] 2001/Finland	Visible mold: mold growth on surfaces of any of your dwellings during last year; visible mold or damp stains or water damage: damp stains on walls or ceiling of any dwellings during last year or leak or water damage in any of your dwellings during last year or mold growth on surfaces of any of your dwellings during last year
Zacharasiewicz et al,[37] 2000/Austria	Dampness at home defined as dampness or mold at home
Koskinen et al,[38] 1999/Finland	Visible signs of moisture observed by trained engineers defined as signs of leakage, moist spot, detachment of paint, or other surface material and deformation or coloration of wood or other such material; mold at home in table described as mold growth and mold odor in text was defined as moisture or mold and house's history with respect to major repairs, accidental leaks, and other such stuff
Koskinen et al,[39] 1999/Finland	Visible signs of moisture observed by trained engineers defined as signs of leakage, moist spot, detachment of paint or other surface material, and deformation or coloration of wood or other such material; mold at home in table described as mold growth and mold odor in text was defined as moisture or mold and house's history with respect to major repairs, accidental leaks, and other such stuff
Jedrychowski et al,[40] 1998/Poland	Mold/dampness defined as moisture stains and/or visible mold growth noticed on the walls within household
Yang et al,[41] 1997/Taiwan	Home dampness (exposure to any 1 of the following: visible mold or mildew growth on surfaces inside home, appearance of standing water within home, water damage, or leaks of water into building) defined as any exposure

(Continued)

TABLE E2. *(Continued)*

Reference, study year/country	Exposures as defined in the studies
Li et al,[42] 1996/Taiwan	Mold: visible mold or mildew growing on surface inside the home; self-dampness: home considered damp by residents; stuffy odor: appearance of stable odor; water damage: water damage or leaks to the building; flooding: appearance of flooding; dampness: presence of mold, water damage, or flooding
Pirhonen,[43] et al 1996/Finland	Have you previously had or are you presently able to see visible mold growth on walls or structure of your home; have you previously or are currently aware of an odor of mold or cellular-like fusty air in your home; have you previously or do you currently notice moisture stains in the structures of your home; or have you previously or are you currently suffering from water/moisture damage in your home?
Brunekreef et al,[44] 1989/United States	Mold: has there ever been mold or mildew on any surface inside home; dampness: does water ever collect on basement floor, or has there ever been mold or mildew on any surface inside the home?

TABLE E3. Studies identified in the search but excluded from the meta-analysis (n = 27)

Excluded studies	Reasons for exclusion
Keall et al,[45] 2012	Exposure definition not compatible with ours
Celtik et al,[46] 2011	Exposure definition not compatible with ours
Adhikari et al,[47] 2011	Exposure definition not compatible with ours
Civelek et al,[48] 2011	Outcome definition not compatible with ours
Pegas et al,[49] 2011	Exposure definition not compatible with ours
Simoni et al,[50] 2011	Exposure definition not compatible with ours
Bunyavanich et al,[51] 2010	Outcome definition not compatible with ours
Randriamanantany et al,[52] 2010	Exposure definition not compatible with ours
Effat and Madany,[53] 2009	Definition of exposure and outcome of interest not compatible with ours
Karvala et al,[54] 2008	Reported on exposure occurring at workplace only
Sun et al,[55] 2009	Overlaps with Sun et al, 2011
Antova et al,[56] 2008	Was a pooled analysis
Larsson et al,[57] 2008	Exposure definition not compatible with ours
Vesper et al,[58] 2007	Exposure and outcome definitions not compatible with ours
Osborne et al,[59] 2006	Exposure definition not compatible with ours
Galante et al,[60] 2006	Exposure and outcome definitions not compatible with ours
Meyer et al,[61] 2005	Exposure definition not compatible with ours
Zhang et al,[62] 2005	Exposure definition not compatible with ours
Dangman et al,[63] 2005	Exposure definition not compatible with ours
Gelincik et al,[64] 2005	Exposure definition not compatible with ours
Meyer et al,[65] 2004	Exposure definition not compatible with ours
Immonen et al,[66] 2002	Exposure definition not compatible with ours
Austin et al,[67] 1997	Insufficient data to compute EE
Åberg et al,[68] 1996	Insufficient data to compute EE
Brunekreef et al,[69] 1992	Outcome definition not compatible with ours
Waegemaekers et al,[70] 1989	Outcome definition not compatible with ours
Patovirta et al,[71] 2004	Overlaps with Pirhonen et al, 1996

TABLE E4. EEs of studies for the relations between dampness/mold indicators and rhinitis (the highest EEs reported for any exposure)

	Exposure measures and EEs				
Reference, year/country	Any exposure, EE (95% CI)	Water damage, EE (95% CI)	Dampness, EE (95% CI)	Visible mold, EE (95% CI)	Mold odor, EE (95% CI)
Sun et al,[15] 2011/China	2.81 (1.32-5.97)		2.81 (1.32-5.97)		2.81 (1.32-5.97)
Sun and Sundell,[14] 2011/United States	1.55 (1.30-1.86)				
Hägerhed-Engman et al,[20] 2009/Sweden	2.45 (1.08-5.54)		1.58 (0.10-26.14)		2.45 (1.08-5.54)
Tham et al,[24] 2007/Singapore	1.55 (1.16-2.07)		1.27 (0.98-1.65)	1.55 (1.16-2.07)	
Biagini et al,[26] 2006/United States	1.70 (0.70-3.80)			1.70 (0.70-3.80)	
Kuyucu et al,[27] 2006/Turkey	1.70 (1.25-2.31)		1.70 (1.25-2.31)	1.70 (1.25-2.31)	
Bornehag et al,[28] 2005/Sweden	2.95 (1.15-7.59)	1.23 (0.83-1.82)	2.95 (1.15-7.59)		
Stazi et al,[34] 2002/Italy	2.60 (1.10-4.10)		2.60 (1.10-4.10)		
Koskinen et al,[38] 1999/Finland	3.67 (3.53-4.81)	3.67 (3.53-4.81)		2.18 (1.99-3.37)	2.18 (1.99-3.37)
Koskinen et al,[39] 1999/Finland	1.89 (1.15-3.11)	1.06 (0.71-1.59)		1.89 (1.15-3.11)	1.89 (1.15-3.11)
Pirhonen et al,[43] 1996/Finland	1.69 (1.31-2.18)				
Q statistic, *P* value	70.97, .000	50.92, .000	9.02, .108	3.22, .521	0.83, .842
I^2 index (%)	85.9	96.1	44.0	0.0	0.0
Summary EEs					
Fixed-effects model	2.20 (2.01-2.40)	2.80 (2.45-3.21)	1.60 (1.34-1.92)	1.82 (1.56-2.12)	2.18 (1.76-2.71)
Random-effects model	2.08 (1.56-2.76)	1.71 (0.69-4.22)	1.82 (1.34-2.46)	1.82 (1.56-2.12)	2.18 (1.76-2.71)

TABLE E5. EEs of studies for the relations between dampness/mold indicators and AR (highest EEs reported for any exposure)

	Exposure measures and EEs				
Reference, year/country	**Any exposure, EE (95% CI)**	**Water damage, EE (95% CI)**	**Dampness, EE (95% CI)**	**Visible mold, EE (95% CI)**	**Mold odor, EE (95% CI)**
Tischer et al,[16] 2011/Germany and The Netherlands	Germany: 1.77 (0.79-3.99) The Netherlands: 1.60 (0.62-4.14)			Germany: 1.77 (0.79-3.99) The Netherlands: 1.60 (0.62-4.14)	
Sun and Sundell,[14] 2011/United States	1.41 (1.16-1.72)				
Civelek et al,[17] 2010/Turkey	1.56 (1.24-2.47)				
Jaakkola et al,[18] 2010/Finland	1.62 (1.21-2.18)	2.06 (1.35-3.13)	1.73 (1.27-2.38)	1.98 (1.32-2.99)	1.45 (0.89-2.37)
Hsu et al,[19] 2009/Taiwan	1.30 (0.96-1.75)			1.30 (0.96-1.75)	
Dong et al,[22] 2008/China	1.21 (0.97-1.50)				
Tamay et al,[25] 2007/Turkey	1.31 (1.04-1.65)		1.31 (1.04-1.65)		
Stark et al,[30] 2005/United States	1.66 (0.88-3.15)	1.66 (0.88-3.15)		1.66 (0.88-3.15)	
Biagini et al,[26] 2006/United States	3.20 (0.70-14.8)			3.20 (0.70-14.8)	
Nafstad et al,[31] 2004/Norway	1.12 (0.49-2.59)				
Chen et al,[33] 2003/Taiwan	1.48 (1.03-2.12)			1.48 (1.03-2.12)	
Engvall et al,[35] 2001/Sweden	2.41 (2.27-2.57)	1.07 (1.02-1.12)	1.47 (1.42-1.53)		3.16 (3.01-3.32)
Kilpeläinen et al,[36] 2001/Finland	1.30 (1.12-1.51)			1.29 (1.01-1.66)	
Zacharasiewicz et al,[37] 2000/Austria	1.51 (1.31-1.74)		1.51 (1.31-1.74)	1.51 (1.31-1.74)	
Jedrychowski et al,[40] 1998/Poland	2.13 (1.52-2.99)		2.13 (1.52-2.99)	2.13 (1.52-2.99)	
Yang et al,[41] 1997/Taiwan	1.52 (1.25-1.85)				
Li et al,[42] 1996/Taiwan	1.56 (1.11-2.18)	1.47 (0.73-2.97)	1.39 (1.05-1.84)	1.27 (0.96-1.68)	1.37 (1.31-1.83)
Brunekreef et al,[44] 1989/United States	1.26 (1.06-1.50)			1.57 (1.31-1.87)	
Q statistics, *P* value	150.66, .000	11.69, .009	6.85, .232	11.00, .443	96.51, .000
I^2 index (%)	89.0	74.3	27.0	0.0	97.9
Summary EEs					
Fixed-effects model	1.83 (1.75-1.91)	1.08 (1.03-1.13)	1.48 (1.43-1.53)	1.51 (1.39-1.64)	2.94 (2.80-3.08)
Random-effects model	1.52 (1.29-1.80)	1.46 (0.98-2.19)	1.50 (1.38-1.62)	1.51 (1.39-1.64)	1.87 (0.95-3.68)

TABLE E6. EEs of studies for the relations between dampness/mold indicators and rhinoconjunctivitis (highest EEs reported for any exposure)

Reference, year/country	Any exposure, EE (95% CI)	Water damage, EE (95% CI)	Dampness, EE (95% CI)	Visible mold, EE (95% CI)	Mold odor, EE (95% CI)
	Exposure measures and EEs				
Tischer et al,[16] 2011/Germany and The Netherlands	Germany: 1.36 (0.56-3.26) The Netherlands: 0.58 (0.22-1.53)			Germany: 1.36 (0.56-3.26) The Netherlands: 0.58 (0.22-1.53)	
Civelek et al,[17] 2010/Turkey	1.65 (1.36-2.01)				
Pirastu et al,[21] 2009/Italy	2.08 (1.32-3.28)		2.08 (1.32-3.28)	2.08 (1.32-3.28)	
Tham et al,[24] 2007/Singapore	2.38 (1.51-3.75)		1.53 (1.00-2.33)	2.38 (1.51-3.75)	
Ibargoyen-Roteta et al,[23] 2007/Spain	1.34 (0.64-2.79)			1.34 (0.64-2.79)	
Simoni et al,[29] 2005/Italy	1.63 (1.30-1.95)		1.63 (1.30-1.95)	1.63 (1.30-1.95)	
Q statistics, P value	8.42, .209		1.11, .573	8.39, .136	
I^2 index	28.7		0.0	40.4	
Summary EEs					
Fixed-effects model	1.67 (1.48-1.89)		1.67 (1.41-1.98)	1.69 (1.42-1.98)	
Random-effects model	1.68 (1.41-2.00)		1.67 (1.41-1.98)	1.66 (1.27-2.18)	

TABLE E7. Summary EEs for the relation between any exposure (highest EEs in the studies) and rhinitis (n = 11) and stratified analysis according to study characteristics

	Model				Heterogeneity statistics		
	Fixed-effects model		Random-effects model				
Stratification	**EE**	**95% CI**	**EE**	**95% CI**	***Q* (n)**	**I^2 statistics (%)**	***P* value**
Main analysis	2.20	2.01-2.40	2.08	1.56-2.47	70.97 (11)	85.9	.000
Stratified analysis							
Study population							
Preschool children (1-7 y)	1.83	1.45-2.31	1.89	1.45-2.46	5.38 (6)	7.0	.371
Children (up to 16 y)	1.64	1.41-1.91	1.80	1.30-2.48	5.13 (3)	61.0	.077
Adults	1.80	1.45-2.24	1.80	1.45-2.24	1.61 (2)	0.0	.447
Study design							
Cross-sectional	2.19	2.00-2.40	2.01	1.47-2.75	70.49 (9)	88.7	.00
Case-control	2.64	1.52-4.59	2.64	1.52-4.59	0.06 (2)	0.0	.809
Cohort							
Study size*							
Large	1.80	1.41-2.31	1.99	1.40-2.82	3.96 (4)	24.3	.266
Small	2.26	2.06-2.49	2.03	1.41-2.92	64.17 (7)	90.7	.000
Geographic location							
United States	1.56	1.31-1.85	1.51	1.29-1.78	38.89 (7)	84.60	.000
Europe	2.67	2.38-2.99	2.29	1.60-3.30	2.08 (2)	0.00	.149
Asia	1.67	1.28-2.19	1.88	1.09-3.24	0.04 (2)	52.0	.834
Year of publication							
2000-2012	2.89	2.54-3.28	2.31	1.28-4.17	29.02 (4)	93.1	.000
1980-1999	1.67	1.47-1.90	1.67	1.47-1.90	70.97 (7)	0.0	.456
Exposure assessment method							
Home inspection	3.34	2.90-3.84	2.60	1.79-3.78	9.66 (5)	58.6	.047
Self-report	1.64	1.46-1.85	1.64	1.46-1.85	4.00 (6)	0.0	.549
Definition of rhinitis							
Doctor diagnosed	1.62	1.36-1.92	1.81	1.26-2.61	2.77 (3)	27.7	.251
Self-report	2.47	2.22-2.74	2.10	1.50-2.94	51.33 (8)	86.4	.000
Quality							
High (scores ≥5)	2.31	1.45-3.68	2.31	1.45-3.68	0.78 (3)	0.0	.676
Low (scores <5)	2.19	2.00-2.40	2.03	1.46-2.83	70.4 (8)	90.0	.000
Climatic zone							
Continental cool summer	2.65	1.43-4.92	2.65	1.43-4.92	0.09 (4)	0.0	.771
Humid subtropical	1.60	1.34-1.91	1.86	1.09-3.17	2.26 (2)	55.8	.133
Subarctic	2.89	2.54-3.28	2.31	1.28-4.17	29.02 (2)	93.1	.000
Other	1.62	1.32-1.99	1.62	1.32-1.99	0.20 (2)	0.0	.907

*A large study was defined as a cohort study with a sample size of greater than 700, and a case-control study had a sample size of greater than 181.

TABLE E8. Summary EEs for the relation between any exposure (highest EEs in the studies) and AR (n = 19 EEs) and stratified analysis according to study characteristics

	Model				Heterogeneity statistics		
	Fixed-effects model		Random-effects model				
Stratification	EE	95% CI	EE	95% CI	*Q* (n)	I^2 statistics (%)	*P* value
Main analysis	1.83	1.75-1.91	1.52	1.29-1.80	150.66 (19)	89.0	.000
Stratified analysis							
Study population							
Preschool children (1-7 y)	1.55	0.96-2.51	1.55	0.96-2.51	1.50 (3)	0.0	.475
Children (up to 16 y)	1.43	1.34-1.53	1.43	1.34-1.53	13.07 (14)	0.5	.443
Adults	2.20	2.08-2.33	1.78	0.97-3.25	55.93 (2)	98.0	.000
Study design							
Cross-sectional	1.83	1.75-1.91	1.50	1.25-1.81	163.22 (15)	91.4	.000
Case-control							
Cohort	1.64	1.28-2.09	1.64	1.28-2.09	0.04 (4)	0.0	.998
Study size*							
Large	1.40	1.30-1.50	1.40	1.30-1.50	7.84 (10)	0.0	.550
Small	2.13	2.02-2.25	1.61	1.25-2.09	69.24 (9)	88.4	.000
Geographic location							
United States	1.34	1.18-1.53	1.34	1.18-1.53	2.42 (4)	0.0	.490
Europe	2.01	1.91-2.11	1.62	1.28-2.06	3.11 (10)	0.0	.540
Asia	1.39	1.24-1.56	1.39	1.24-1.56	100.83 (5)	91.1	.000
Year of publication							
2000-2012	1.89	1.81-1.98	1.52	1.29-1.80	139.15 (15)	89.9	.000
1980-1999	1.46	1.30-1.64	1.53	1.26-1.87	7.87 (4)	61.9	.049
Exposure assessment method							
Home inspection							
Self-report	1.82	1.75-1.91	1.51	1.28-1.78	163.52 (18)	89.6	.000
Definition of AR							
Doctor diagnosed	1.83	1.75-1.91	1.50	1.27-1.81	163.15 (12)	90.8	.000
Self-report	1.59	1.18-2.15	1.59	1.18-2.15	0.08 (7)	0.0	.961
Quality							
High (scores ≥5)	1.66	1.31-2.12	1.66	1.31-2.12	0.77 (5)	0.0	.578
Low (scores <5)	1.83	1.75-1.91	1.49	1.24-1.79	162.71 (14)	92.0	.000
Climate zone							
Continental cool summer	2.20	2.08-2.32	1.79	1.37-2.35	0.56 (4)	0.00	.765
Humid subtropical	1.45	1.30-1.62	1.45	1.30-1.62	1.0 (3)	5.8	.910
Subarctic	1.42	1.33-1.59	1.41	1.31-1.62	2.61 (4)	0.0	.843
Other	1.30	1.15-1.47	1.30	1.15-1.47	56.70 (7)	87.9	.000

*A large study was defined as a cohort study with a sample size of greater than 700, and a case-control study had a sample size of greater than 181.