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Meta-Analyses of the Associations of Respiratory Health Effects with Dampness and Mold in Homes

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ABSTRACT

The Institute of Medicine (IOM) of the National Academy of Sciences recently completed a critical review of the scientific literature pertaining to the association of indoor dampness and mold contamination with adverse health effects. In this paper, we report the results of quantitative meta-analysis of the studies reviewed in the IOM report. We developed point estimates and confidence intervals (CIs) to summarize the association of several respiratory and asthma-related health outcomes with the presence of dampness and mold in homes. The odds ratios and confidence intervals from the original studies were transformed to the log scale and random effect models were applied to the log odds ratios and their variance. Models were constructed both accounting for the correlation between multiple results *within* the studies analyzed and ignoring such potential correlation. Central estimates of ORs for the health outcomes ranged from 1.32 to 2.10, with most central estimates between 1.3 and 1.8. Confidence intervals (95%) excluded unity except in two of 28 instances, and in most cases the lower bound of the CI exceeded 1.2. In general, the two meta-analysis methods produced similar estimates for ORs and CIs. Based on the results of the meta-analyses, building dampness and mold are associated with approximately 30% to 80% increases in a variety of respiratory and asthma-related health outcomes. The results of these meta-analyses reinforce the IOM's recommendation that actions be taken to prevent and reduce building dampness problems.

INTRODUCTION

The association of adverse health effects with dampness and mold in buildings has been the subject of much research. Most studies on this topic have found an increased risk of one or more adverse health effects in buildings with signs of dampness or visible mold. The Institute of Medicine (IOM) of the National Academy of Sciences recently completed a critical review (IOM 2004) of this scientific literature. The IOM concluded that *excessive indoor dampness is a public health problem,* noted that dampness problems are common, and recommended corrective measures. While the IOM report summarized the main features and results of the reviewed studies, which included a broad range of health outcomes, it provided no quantitative summaries of these studies.

In this paper, we report the results of quantitative meta-analyses of the studies reviewed in the IOM report. A meta-analysis uses statistical methods to combine data from different but comparable research studies, in order to provide a quantitative summary on the size and variability of an association. Studies are generally selected for relevance, quality, and similarity. The contribution of larger, more precise studies to the summary estimate is generally more heavily weighted. Results of meta-analyses presented here are central point estimates and confidence intervals (CIs) of odds ratios (ORs) that summarize the magnitude of increased risk of several health outcomes in buildings with dampness and mold. The central estimates and CIs of ORs, if assumed to reflect causality, can be used to communicate the importance of dampness and mold as health risks, to estimate the economic significance of dampness- and mold-related health effects to society, and to estimate the magnitude of health and economic benefits from programs that reduce dampness and mold.

METHODS

We began with the full list of studies included in Tables 5-1, 5-2, 5-3, 5-6, 5-7, 5-8 of the recent IOM review (IOM 2004). Details on the studies included in the meta-analyses are provided in Appendix 1.

Ideally, meta-analyses would combine estimates only from studies with the same precisely defined health outcome, risk factor, and population/subjects. Because the original studies included many differently defined respiratory health outcomes, risk factors, and populations, this was not possible, and we analyzed groups of studies that were as similar as practicable with respect to these. Table 1 shows the health outcome categories and specific outcomes from the studies included in each category.

Subject types

We grouped studies by subject type. The reviewed studies included diverse populations: adults, male adults, female adults, children (age < 18), and children (infants). We performed, where possible, separate analyses for: adults (including studies of mixed or single gender), children (including studies of age < 18 or infants), and all ages combined. However, for ever-diagnosed with asthma and asthma development, too few studies were available to support separate meta-analyses for children and adults.

Risk factors

In general, the risk factors in the reviewed studies included were visible signs of dampness, visible mold, dampness or mold, dampness and mold, and measured concentrations of airborne mold spores or related agents of microbial origin. We included in meta-analyses only the studies with reports of dampness and/or mold as risk factors[1]. A large majority of all studies used these risk factors. We did not distinguish among dampness, mold, dampness or mold, and dampness and mold as risk factors. Our rationale – visible mold is always considered the result of excess dampness, whether or not the dampness is reported, and excess dampness is very often

Table 1. Health outcomes from reviewed studies, grouped into outcome categories used in meta-analysis

Outcome Category for the Meta-Analysis	Outcomes from Individual Studies Used in Each Category
Upper respiratory tract (URT) symptoms	irritated, stuffy, or runny nose; nasal symptom; nasal congestion; nasal congestion or runny nose; nasal excretion; nose irritation; rhinitis; sinusitis; allergic rhinitis; allergy; hay fever
Cough	cough; cough with phlegm; cough without phlegm; day or night cough; dry cough; morning cough; long-term cough; night cough with wheeze; persistent cough
Wheeze	wheeze; persistent wheeze; wheeze apart from cold; wheeze including shortness of breath and asthma; wheeze/breathlessness
Ever diagnosed with asthma	• positive response to -- has a doctor ever diagnosed mother (father) to have attacks of shortness of breath (asthma)[2]; • positive response to-- did a doctor ever diagnose your having attacks of shortness of breath or asthma?; • physician-diagnosed asthma; • physician-diagnosed asthma, ever (atopic and non-atopic); • physician diagnosis of asthma since age > 16; • self-reported physician-diagnosed or nurse-diagnosed asthma
Current asthma	• current physician-diagnosed asthma, defined as diagnosis plus symptoms in last 12 months; • ever doctor-diagnosed asthma plus asthma symptoms or medication in past 12 months; • current asthma defined as combination of bronchial hyper-responsiveness and at least one of wheeze or breathlessness in last 12 months; • subjective symptoms of asthma plus one or more of the following: doctor diagnosed asthma attack and the disappearance of wheezing; doctor diagnosed asthma attack and > 15% decrease in PEF or FEV1; > 15% decrease in PEF or FEV1 in exercise test; > 20% daily variation in PEF at least 2 days per week in 4 weeks of tracking; > 15% rise in PEF or FEV1 in a bronchodilating test; • asthma - current and diagnosed by physician; • current asthma diagnosed by a doctor -- text implies that current refers to the last 12 months; • asthma currently present and reported to be confirmed by a physician; • occurrence of doctor diagnosed asthma in past year; • positive response to following two questions -- has your doctor ever said your child has asthma? does he or she still have asthma?
Asthma development	• newly doctor-diagnosed cases of asthma in past 2.5 years; • physician diagnosis of asthma since age > 16; • first time diagnosis of asthma

accompanied by mold, although the mold may not be visible. Thus, it is not possible to make a clean distinction among these risk factors. We excluded from the meta-analyses ORs from

[2] The question's wording reflects the fact that the study assessed the risk of asthma in mothers and fathers of school children as a function of dampness in the home as part of a broader study focusing on children's asthma symptoms

studies with measured concentrations of microbial agents or measured or reported high air humidity (Appendix 2).

Presence of dampness and/or mold were made in each study by either the occupants or the researchers. We did not distinguish between occupant-reported dampness and/or mold and researcher-reported dampness and/or mold. Most studies that have compared occupant reports and researcher reports of dampness and/or mold have found the two types of reports to be fairly well correlated. Also, whether or not researcher-based reports are more accurate is still a subject of debate.

The large majority of studies have assessed the risks of dampness and/or mold in homes. ORs associated with dampness and/or mold in other types of buildings, such as schools or work places, were excluded from our analyses (Appendix 2).

Health outcome categories

For the non-asthma outcomes of upper respiratory tract (URT) symptoms, cough, and wheeze (Table 1), we categorized the health outcomes as in the IOM report (IOM 2004). The URT symptom category included the broadest set of health outcomes, but nasal symptoms predominated.

For asthma outcomes, however, based on review of the original papers, we developed different outcome categories than were used in the IOM report (IOM 2004). Our asthma development category included ORs from studies that attempted to assess whether the *development* of asthma, as opposed to *presence* of asthma symptoms, was associated with dampness and mold; however, the associated time period for the asthma diagnosis or development ranged widely and there were few studies in this category.

Several studies were excluded from meta-analyses because of outcomes used (Appendix 2). For the asthma diagnosis and development categories, we excluded ORs from Wever-Hess et al. (2000) and Oie et al. (1999), with outcomes of asthma diagnosis or bronchial obstruction in children with an age less than 2, because it is not clear that asthma can be diagnosed before age 2. We excluded results from a single study performed in rural Kenya (Mohamad et al. 1995) because the living and health care conditions in this study population were distinctively different from those in other studies. The ORs from Pihronen et al (1996) were also excluded because they indicated the odds of having one or more of a diverse set of outcomes (asthma, hay fever, allergic rhinitis, or eczema).

Statistical methods

Some of the reviewed studies reported separate estimates for multiple outcomes within the same subjects in the same study. Because these findings within the same study may not be statistically ”independent,” ignoring this dependence within a meta-analysis might overestimate the number of truly independent inputs to the summary model, and thus overestimate the precision of the summary estimates produced. These meta-analyses use “random effect” models, which assume a single fixed mean effect (i.e., the association between the risk and the outcome in each model) across all studies, plus a random component that varies across studies or sub-studies. Random effect models can estimate any within-study correlations included in the meta-analysis, and

adjust the estimates produced as necessary. Such adjustment makes little difference in point estimates, but may increase the confidence interval for estimates. We used the SAS procedure PROC MIXED, which allows fixing the within-study variances (matrix *R* in SAS) while estimating between-study variance (matrix *G* in SAS) at a different level.

The odds ratios and 95% confidence intervals reported in each reviewed study were first transformed to the log scale. The transformed results were then combined using a random effect model (DerSimonian & Laird, 1986). Models were constructed both accounting for the correlation between multiple results *within* studies ("dependent sub-studies"), and ignoring such potential correlation ("independent sub-studies").

The model for independent sub-studies was

$$y_{ij} \sim N(\beta_0 + \beta_{0ij},\ \sigma_{ij}^2) \qquad (1)$$

The model for dependent sub-studies was

$$y_{ij} \sim N(\beta_0 + \beta_{0i},\ \sigma_{ij}^2) \qquad (2)$$

where:

y_{ij} is the *ln* OR in *j*th sub-study of *i*th study;
β_0 is the fixed effect across all studies;
β_{0ij} is the random effect in the *j*th sub-study of the *i*th study;
$\beta_{0ij} \sim N(0,\ \sigma^2)$; σ^2 is the between-sub-study variance;
β_{0i} :is the random effect in the *i*th study. $\beta_{0i} \sim N(0,\ \sigma^{*2})$;
σ^{*2} is the between-study variance; and
σ_{ij}^2 is the within-study variance, calculated from log confidence interval.

RESULTS

Major results of the meta-analyses are summarized in Table 2. (Appendix 3 shows, as an example, ORs and CIs for the association of wheeze with dampness and mold in the original studies, and also from the summary estimates produced in the meta-analysis.) Central estimates of ORs ranged from 1.32 to 2.10, with most central estimates between 1.3 and 1.8. Confidence intervals (95%) excluded unity for 26 of 28 analyses, and in most cases the lower bound of the CI exceeded 1.2. In general, the two meta-analysis methods produced similar estimates for ORs and CIs. ORs for health effects in children were not consistently larger or smaller than corresponding ORs for adults. CIs tended to be smaller for analyses including both adults and children, presumably because of the larger numbers of studies. CIs for asthma development were broad, with lower bounds near unity, presumably because the analyses included data from only three studies.

Table 2. Key results of the meta-analyses

Outcome	Subjects	# of Studies	Odds Ratio Random-Effect Model **Dependent** Sub-studies	Odds Ratio Random-Effect Model **Independent** Sub-studies
Upper respiratory tract symptoms	**All**	**10**	**1.53 (1.26-1.87)**	**1.54 (1.33-1.78)**
	Adults	6	1.39 (1.12-1.71)	1.37 (1.17-1.59)
	Children	4	1.92 (1.08-3.41)	2.04 (1.41-2.96)
Cough	**All**	**19**	**1.77 (1.47-2.12)**	**1.79 (1.57-2.03)**
	Adults	5	2.10 (1.27-3.47)	2.04 (1.55-2.68)
	Children	14	1.62 (1.35-1.94)	1.65 (1.44-1.88)
Wheeze	**All**	**16**	**1.81 (1.45-2.26)**	**1.65 (1.48-1.83)**
	Adults	3	1.68 (1.14-2.49)	1.66 (1.42-1.95)
	Children	13	1.91 (1.42-2.57)	1.65 (1.43-1.90)
Current asthma	**All**	**10**	**1.51 (1.40-1.62)**	**1.51 (1.41-1.61)**
	Adults	3	1.82 (1.28-2.59)	1.82 (1.52-2.19)
	Children	7	1.45 (1.33-1.58)	1.45 (1.34-1.57)
Ever diagnosed asthma	**All**	**8**	**1.59 (1.26-2.00)**	**1.70 (1.42-2.04)**
Asthma development	**All**	**3**	**1.39 (0.69-2.80)**	**1.32 (.98-1.77)**

DISCUSSION

Importance of building dampness

Based on the meta-analyses described in this report, building dampness and mold are associated with 30% to 80% increases[3] in a variety of health outcomes in a variety of populations. These associations are statistically significant – with 95% CIs excluding unity -- in almost all cases. The similar results obtained from two analysis methods suggest little problem with correlation of health outcomes within studies. Statistical associations do not prove that dampness and mold are causally related to the health outcomes. Building dampness itself is very unlikely to directly cause adverse health effects. However, the consistent and relatively strong associations of dampness with adverse health effects strongly suggest causation by dampness-related exposures. Building dampness may cause the building to become contaminated with microorganisms such

[3] The 30% to 80% increase in symptoms is an approximate estimate based on the central estimates of the ORs for the various health outcomes in Table 2. When the health outcome prevalence is below approximately 15%, which is typically the case for wheeze and asthma-related outcomes, the percentage increase in the outcome among the population experiencing the risk factor (e.g., dampness) is well estimated by 100%(1-OR). The central estimates of ORs for these health outcomes ranges from 1.32 to 1.91, implying a 33% to 91% increase in health outcome prevalence. However, when the prevalence of the outcome is substantially higher than 15%, as is often the case for URT symptoms and cough, this simple calculation overestimates the percentage increase in the outcome in the population with the risk factor. For example, assuming an outcome prevalence of 0.3 for URT symptoms and cough in the population with dampness, the OR in Table 2 of 1.79 for cough indicates a 53% increase in cough among the exposed population and the OR of 1.54 in Table 2 for URT symptoms indicates a 38% increase in URT symptoms among the exposed population.

as mold or bacteria, which might in-turn cause adverse health effects (IOM 2004). Building dampness could also cause increased emissions of some chemical pollutants from materials and surfaces (IOM 2004). Research has not yet determined the causal agent(s) (IOM 2004).

Implication of building dampness as a public health problem requires that the presence of building dampness increase health risks, and also that a substantial proportion of the population is exposed to dampness. Most available data indicate that at least 20% of homes have dampness problems or visible mold (IOM 2004). In addition, the adverse consequences of building dampness go beyond health effects and the related personal and economic costs. Dampness causes structural damage to buildings that is expensive to repair. Also, mold contamination resulting from building dampness often precipitates very expensive remediation efforts (Levin 2005).

Despite the current lack of proof that dampness or mold actually causes these health effects, available knowledge suggests that it is prudent to prevent building dampness and mold and to take corrective actions where such conditions occur (IOM 2004). Many of the preventive and corrective actions are straightforward. Examples include better training of those in the construction industry about the means of reducing dampness risks and instituting ongoing preventive maintenance programs to identify and quickly remedy roof and plumbing leaks or other causes of moisture accumulation or mold growth.

Limitations in this analysis

These meta-analyses used data only from studies referenced in the IOM's recent critical review (IOM 2004), and, thus, omitted more recently published studies. However, as research on dampness and mold has occurred for over two decades, it is unlikely that studies published in the last few years (i.e., since 2003) would substantially affect the outcomes of our meta-analyses.

Because our meta-analyses used only studies cited in the IOM's review, we have effectively relied on the IOM to select studies of suitable quality. All original studies were published in refereed archival journals, which is one indicator of study quality. The IOM did not precisely describe other study selection criteria, but in general their reviews consider only studies without significant evident methodological flows, with control for major known confounding factors via the study design or method of data analysis, and with a statistical analysis of study data. Remaining errors from any confounding and bias in the reviewed studies may be reflected in results of the meta-analyses, although some of these, due to the combination of different studies, may cancel out and have a modest impact on results of the meta-analyses.

One potential source of bias pertains to the methods used to determine whether a building had dampness or mold. Most studies have relied on the occupants to report whether dampness or mold is present in their home. It is possible that homeowners with respiratory health problems would be more aware of, and thus, more likely to report dampness and mold than homeowners without such health problems. If true, this reporting bias would lead to overestimated ORs in the original studies and corresponding overestimated ORs from our meta-analyses. On the other hand, as homeowners within each study would report dampness or mold in a relatively unstandardized way, the resulting random error in assessment could result in what is called "nondifferential exposure misclassification," leading to underestimated ORs in those studies.

Alternately, some studies have relied on trained surveyors who inspected buildings for signs of dampness and mold. Surveyors would have used standardized methods of assessment for dampness or mold within each study, thus reducing that source of inaccuracy. Surveyors, however, are likely to have missed indicators of dampness and mold that were not present or evident during their brief survey, leading to random errors in exposure assessment and consequent underestimates of any true risk. In general, both types of studies have found increased risks of respiratory health effects among occupants of homes with dampness and molds. Unfortunately, we do not have a sufficient number of studies with surveyor-assessed dampness and mold to enable separate meta-analyses.

Reviews and meta-analyses are also subject to publication bias – the overestimation of summary estimates of association that can occur because studies with positive findings are published more often (IOM 2004, pg 20) and more quickly than studies that failed to find significant associations. Publication bias would bias the results of our meta-analyses upward; i.e., estimated ORs based on all published studies would exceed true central estimates based on all performed studies. While there are statistical tools available that enable one to check for evidence of publication bias, it remains difficult to quantify the extent of publication bias or to make corrections in the resulting central estimates of ORs.

It is important to note that the confidence intervals associated with our central estimates of ORs reflect only the probabilistic or chance uncertainties. The full uncertainties in the magnitudes of increased health risks are likely to be larger because they would also include the potential uncontrolled confounding and bias noted above.

Asthma development -- comparison to findings of IOM

The IOM Committee found limited or suggestive evidence of an association between building dampness and asthma development, and inadequate or insufficient evidence to determine whether an association exists between mold and asthma development. These statements are consistent with the results of our meta-analysis. We calculated ORs of 1.32 and 1.39 for asthma development if the home had dampness or mold; however, neither CI excluded unity. Also, our meta analysis for asthma development was based on only three studies and the definitions for asthma development used in these three studies were variable.

CONCLUSIONS

Based on our meta-analyses, building dampness and mold are associated with 30% to 80% increases in a variety of respiratory and asthma-related health outcomes and the associations are statistically significant in nearly all cases. Given what is known today, it would be prudent to avoid building dampness and mold problems and to take corrective actions where such problems occur.

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Appendix 1. Description of studies included in the meta-analyses.

Table A1.1 Studies with upper respiratory tract symptoms

Subjects	Author	Year	Risk Factor	Symptomx
adults	Engvall	2002	moldy odor & water leakage in preceding 5 years	nasal
	Koskinen	1999	surveyor assessed moisture	rhinitis
				sinusitis
			mold	rhinitis
				sinusitis
	Wan	1999	flood	nasal congestion or runny nose
			mold	
	Wieslander	1999	damp concrete floor	irritated, stuffy, or runny nose
men	Brunekreef	1992	damp stains or mold growth in last 2 years	allergy
women				
children	Brunekreef	1989	damp ever	hay fever
			mold ever	
	Jaakkola	1993	mold odor in past year	nasal congestion
				nasal excretion
			water damage >1 year ago	nasal congestion
				nasal excretion
	Koskinen	1999	surveyor assessed moisture	rhinitis
				sinusitis
	Zacharasiewicz	2000	damp	nasal
	Kilpeläinen	2001	visible mold	allergic rhinitis
students	Kilpeläinen	2001	visible mold or damp stains or water damage	allergic rhinitis

Table A1.2 Studies with cough as an outcome

Subjects	Author	Year	Risk	Health outcome
adults	Engvall	2001	moldy odor & major water leakage	cough
	Engvall	2001	moldy odor & signs of hi humidity	cough
	Gunnbjörnsdottir	2003	water damage or mold	long-term cough
	Koskinen	1999	moisture	cough w/ phlegm
	Koskinen	1999	moisture	cough w/o phlegm
	Koskinen	1999	moisture	night cough
	Koskinen	1999	mold	cough w/ phlegm
	Koskinen	1999	mold	cough w/o phlegm
	Koskinen	1999	mold	night cough
	Pirhonen	1996	mold or damp	cough
men	Brunekreef	1992	damp stains or mold growth last 2 yrs	cough
men	Waegemaekers	1989	damp	cough
women	Brunekreef	1992	damp stains or mold growth last 2 yrs	cough
women	Waegemaekers	1989	damp	cough
children	Andriessen	1998	moisture stains	cough
	Andriessen	1998	mold	cough
	Austin	1997	damp	cough
	Austin	1997	mold	cough
	Brunekreef	1989	damp ever	cough
	Brunekreef	1989	mold ever	cough
	Dales	1991	flood	cough
	Dales	1991	moisture	cough
	Dales	1991	Mold site	cough
	Dales	1991	Mold sites	cough
	Dales	1991	mold or damp	cough
	Dales	1999	mold or mildew	night cough or wheeze
	Dijkstra	1990	mold & damp	cough
	Dijkstra	1990	mold or damp	cough
	Jaakkola	1993	mold odor past yr	persistent cough
	Jaakkola	1993	water damage >1 yr ago	persistent cough
	Jedrychowski	1998	mold or damp	cough
	Koskinen	1999	moisture	cough w/ phlegm
	Koskinen	1999	moisture	cough w/o phlegm
	Koskinen	1999b	moisture	night cough
	Verhoeff	1995	damp	cough
	Verhoeff	1995	mold	cough
	Waegemaekers	1989	damp	day or night cough
	Waegemaekers	1989	damp	morning cough
infants w/ asthmatic sibling	Gent	2002	water leaks	cough
infants w/ asthmatic sibling + asthmatic mother	Belanger	2003	persistent mold or mildew previous year	persistent cough
infants w/ asthmatic sibling + non-asthmatic mother				
adolescents	Nicolai	1998	past or present damp	cough

Table A1.3 Studies with wheeze as an outcome.

Subjects	Author	Year	Risk	Outcome
adults	Gunnbjörnsdottir	2003	water damage or mold	wheeze
	Norbäck	1999	>1 signs of dampness	wheeze
			damp floor	
			visible mold on indoor surfaces	
			moldy odor	
			water damage or flood	
men	Brunekreef	1992	damp stains or mold growth in last 2 yrs	wheeze
	Waegemaekers	1989	damp	wheeze
women	Brunekreef	1992	damp stains or mold growth in last 2 yrs	wheeze
	Waegemaekers	1989	damp	wheeze
children	Brunekreef	1989	damp ever	wheeze
		1989	molds ever	wheeze
	Dales	1991	flood	wheeze
			moisture	
			mold site	
			mold sites	
			mold or damp	
	Dijkstra	1990	mold & damp	wheeze
			mold or damp	
	Jaakkola	1993	mold odor in past year	persistent wheeze
			water damage >1 yr ago	
	Jedrychowski	1998	mold or damp	wheeze
	Maier	1997	basement water	wheeze
			mold	
			mold, water damage, basement water, or water condensation	
			water condensation	
			water damage	
	Slezak	1998	mold or damp	wheeze
	Strachan	1990	mold	wheeze
	Taskinen	1999	damp	wheeze
	Waegemaekers	1989	damp	wheeze
infants w/ asthmatic sibling	Gent	2002	Water leaks	wheeze
infants w/ asthmatic sibling + asthmatic mother	Belanger	2003	persistent mold or mildew in previous year	wheeze
infants w/ asthmatic sibling, + *nonasthmatic* mother				
adolescent	Nicolai	1998	damp	wheeze
			damp, adjusted for mite allergen concentration	

Table A1.4 Studies with asthma diagnosis as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Hu	1997	indoor damp	Dr. dx asthma
			visible mold	
			water leaks	
	Norbäck	1999	>1 damp	current asthma defined as combination of bronchial hyper-responsiveness and at least one asthma sx in last year
			damp floor	
			moldy odor	
			visible mold	
			water damage or flood	
men	Brunekreef	1992	damp or mold	Dr. dx. asthma
men	Waegemaekers	1989	damp	Dr. dx.asthma or dyspnea
women	Brunekreef	1992	damp or mold	Dr. dx. asthma
women	Waegemaekers	1989	damp	Dr. dx asthma or dyspnea
children	Jedrychowski	1998	mold or damp	Dr. dx. asthma
	Rönmark	1999	damp home	Dr. dx atopic asthma
				Dr. dx atopic or non-atopic asthma
				Dr. dx non-atopic asthma
	Slezak	1998	damp or mold	Dr. or nurse dx asthma
	Waegemaekers	1989	damp	Dr. dx asthma or dyspnea
children & adults	Williamson	1997	damp	Dr. dx asthma
			damp or condensation current home	
			damp previous home	
			mold	
			severe damp	
			significant mold	

Abbreviations: sx = symptom; dx = diagnosis

Table A1.5 Studies with current asthma as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Hu	1997	indoor damp	Dr. dx asthma + sx or medication in past year
			visible mold	
			water leaks	
	Norbäck	1999	>1 damp	current asthma defined as combination of bronchial hyper-responsiveness and at least one asthma sx in last year
			damp floor	
			moldy odor	
			visible mold	
			water damage or flood	
children	Brunekreef	1989	damp ever	Dr. dx asthma in past year
			mold	
	Dales	1991	flood	Current asthma confirmed by Dr.
			moisture	
			mold	
			mold 2	
			mold or damp	
	Dekker	1991	damp or visible mold	Dr. dx asthma + current sx
	Jaakkola	1993	any damp indicator ever	current Dr. dx asthma
			moisture > 1yr ago	
			moisture past yr	
			mold odor past yr	
			visible mold past yr	
			water damage >1 yr ago	
	Taskinen	1999	damp home	Dr. dx asthma + sx
	Yang	1997	damp home	current Dr. diagnosed asthma
students	Kilpeläinen	2001	visible mold	current Dr. dx asthma
			visible mold, damp stains or water damage	
adolescent	Nicolai	1998	past or present damp	>5 asthma attacks previous yr

Abbreviations: sx = symptom; dx = diagnosis

Table A1.6 , Studies with asthma development as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Jaakkola	2002	damp stains or paint peeling	newly Dr. dx asthma in past year
			visible mold or odor	
			water damage	
	Thorn	2001	damp	Dr. dx asthma since age > 16
			damp or visible mold	
			visible mold	
	Yang	1998	damp or mold or water damage	first-time Dr. dx asthma

Abbreviations: dx = diagnosis

Appendix 2. Excluded Studies

Author	Year	Excluded from	Reason for exclusion*
Belanger	2003	cough, wheeze	excluded measured conc of microbial agent
Dales	1999	upper respiratory sx	some sx not upper respiratory sx
Dijkstra	1990	asthma sx	no clear diagnosis of asthma
Engvall	2002	upper respiratory sx	excluded throat sx
Gent	2002	cough, wheeze	excluded measured conc. of microbial agent; or excluded humidifier as risk factor
Infante-Rivard	1993	newly diagnosed	excluded humidifier as risk factor
Jaakkola	2002	newly diagnosed asthma	Excluded studies of risks at workplaces
Kilpeläinen	2001	common cold>4/yr	excluded cold sx
Koskinen	1999	sore throat	excluded throat sx
Mohamed	1995	asthma sx	socio-economic status and housing conditions of the Kenyan subjects was atypical of that in other studies
Nafstad	1998	bronchial obstr	age < 2 too early for asthma diagnosis
Park	2001	wheeze	excluded measured conc. of microbial agent
Pirhonen	1996	asthma sx	ORs are for atopy and should not be used for asthma sx
		dry or sore throat	excluded throat sx
Rylander	1998	cough, wheeze	excluded risk factors at school
Rylander	2000	cold, sore throat	excluded cold sx
			humidity is not used in our study as an indicator of a dampness or mold
			excluded throat sx
Taskinen	1999	asthma sx, cough, wheeze	excluded studies of risks of dampness at school
Thorn	1998	cough, UR	excluded measured conc. of microbial agent
Waegemaekers	1989	wheeze includes shortness of breath, asthma	excluded measured conc. of microbial agent
Wever-Hess	2000	asthma	age < 2 too early for asthma diagnosis
Wieslander	1999	UR	excluded eye sx
Yazicioglu	1998	asthma sx	excluded self-reported high humidity as risk factor
Zock	2002	wheeze	meta-analysis itself
Øie	1999	bronchial obstruction	age < 2 too early for asthma diagnosis

Abbreviations: sx= symptom

Appendix 3. Example of original data and results of a meta- analysis.

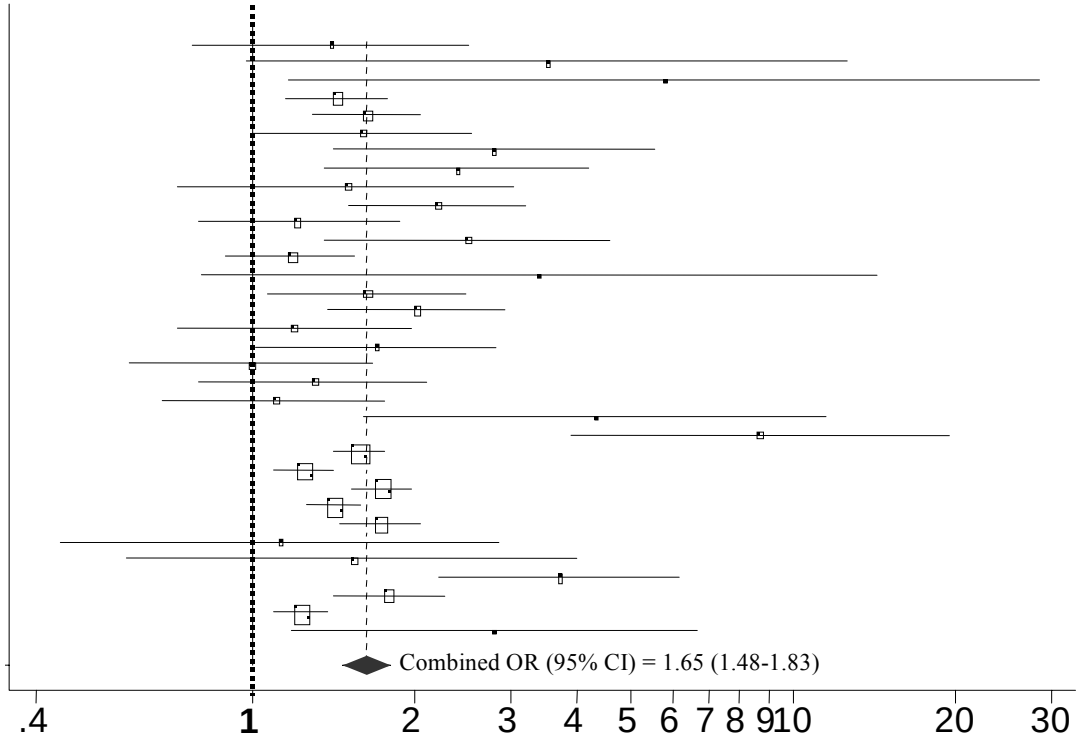

Figure A3-1. Odds ratios and confidence intervals for wheeze from original studies and from a meta-analysis performed using the random effects model and assuming independent sub-studies. The width of the boxes (some so small they appear as points) is proportional to the precision (inverse of variance) of the study and the ends of the horizontal lines represent lower and upper 95% confidence limits. The dark vertical line is located at an odds ratio of unity which corresponds to no increased risk of wheeze, while nearly all the reported odds ratios are greater than unity indicating an increase in risk with dampness and mold. The central estimate from the meta-analysis is indicated by the light dashed vertical line and the left- and right-side points of the diamond at the bottom (labeled combined) of the figure indicate the lower and upper 95% confidence limits from the meta-analysis.