

Synthetic Bedding and Wheeze in Childhood

Anne-Louise Ponsonby,^{1,2} Terence Dwyer,² Andrew Kemp,³ Jennifer Cochrane,²
David Couper,⁴ and Allan Carmichael⁵

Background. The reasons for the increase in childhood asthma over time are unclear. The indoor environment is of particular concern. An adverse role for synthetic bedding on asthma development in childhood has been suggested by cross-sectional studies that have found an association between synthetic pillow use and childhood wheeze. Prospective data on infant bedding have not been available.

Methods. Bedding data at 1 month of age were available from an infant survey for children who were participating in a 1995 follow-up study (N = 863; 78% traced). The 1995 follow-up was embedded in a larger cross-sectional survey involving 6,378 seven year olds in Tasmania (N = 92% of eligible). Outcome measures included respiratory symptoms as defined in the International Study of Asthma and Allergies in Childhood protocol. Frequent wheeze was defined as more than 12 wheeze episodes over the past year compared with no wheeze.

Results. Synthetic pillow use at 1 month of age was associated with frequent wheeze at age 7 (adjusted relative risk [aRR] = 2.5; 95% confidence interval [CI] = 1.2–5.5) independent of childhood exposure. Current synthetic pillow and quilt use was strongly associated with frequent wheeze (aRR = 5.2; CI = 1.3–20.6). Substantial trends were evident for an association of increasing number of synthetic bedding items with frequent wheeze and with increasing wheeze frequency. Among children with asthma, the age of onset of asthma occurred earlier if synthetic bedding was used in infancy.

Conclusions. In this cohort, synthetic bedding was strongly and consistently associated with frequent childhood wheeze. The association did not appear to be attributable to bedding choice as part of an asthma management strategy. (EPIDEMIOLOGY 2003;14:37–44)

Key words: prospective, cohort, childhood asthma, house dust mite, bedding.

The reasons for the increasing incidence of childhood asthma are unclear. The indoor environment, in particular exposure to house dust mite, is an area of particular concern.¹ Bedding is a significant source of house dust-mite allergen,² partly because of

proximity to the human airway. For example, airborne *Dermatophagoides* house dust-mite allergen levels near the face during sleep were reduced more than 10-fold by replacing used bed quilts with new ones.³ Synthetic pillows contain much higher levels of house dust mite and other indoor allergens compared with feather pillows^{4,5,6} and so it is plausible that the previously reported associations between synthetic bedding and adverse respiratory outcomes^{7–14} do not simply reflect feather-bedding avoidance measures in the more severe asthmatics.^{15,16} Prospective studies are required to examine the link between synthetic bedding and childhood wheeze and to evaluate the role of upper bedding in asthma.^{15,16}

An association between synthetic bedding and wheeze^{7–12} or rhinitis^{13,14} has been reported from several cross-sectional studies. A population-based case-control study comparing children with severe or frequent wheeze with children with no wheeze reported that foam pillows were associated with severe wheeze (odds ratio [OR] = 2.8; 95% confidence interval [CI] = 1.9–4.2).⁷ This association held even among children whose parents denied making changes to the child's bedroom for reasons related to allergy.⁷ Similarly, the association between nonfeather pillow use and perennial rhinitis re-

From the ¹National Centre for Epidemiology and Population Health, Australian National University, Canberra; ²Menzies Centre for Population Health, University of Tasmania, Hobart, Australia; ³Department of Immunology, Royal Children's Hospital, University of Melbourne, Melbourne, Australia; ⁴Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, NC; and ⁵Department of Paediatrics and Child Health, University of Tasmania, Hobart, Australia.

Address correspondence to: Anne-Louise Ponsonby, National Centre for Epidemiology and Population Health, Innovations Building, Eggleston Road, Australian National University ACT 0200; anne-louise.ponsonby@anu.edu.au

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mained after excluding subjects who changed pillows because of allergy (OR = 2.4; CI = 1.3–5.0).¹³ If these observations were causal, one possible mechanism might be that synthetic pillows increase the risk of atopic disease by placing a higher allergen load near the face compared with nonsynthetic bedding. Alternatively, synthetic bedding may have an adverse effect by other means such as chemical emissions⁷ or reduced bacterial endotoxin exposure compared with natural materials such as feather.¹⁷ High house dust-mite allergen levels, exposure to chemical emission compounds, and reduced exposure to bacterial endotoxin levels have all been implicated as environmental factors that may contribute to the development of wheeze in childhood.^{18–20}

Progress on the role of environmental factors in the development of asthma has been hampered by disease misclassification and the lack of prospective data. Asthma is a clinical syndrome reflecting airway inflammation and obstruction.¹ The specific contribution of allergen-induced, irritant-induced and infection-induced wheeze within the broad spectrum of asthma has not yet been clearly identified. Although the overall proportion of population-based childhood asthma attributable to atopy is low (with only approximately 38% attributable),²¹ atopic individuals are overrepresented at the severe end of the asthma spectrum.^{22–24} Further, although house dust-mite sensitization is only weakly associated with asthma (relative risk [RR] = 1.7), it is strongly associated with frequent wheeze (more than 12 episodes compared with no wheeze over the past year; RR = 19.6).²⁵ Thus, a focus on severe symptoms such as frequent wheeze should reduce disease misclassification in population-based studies examining house dust-mite-induced airway disease.²⁵ We now report the first prospective study on the use of synthetic bedding in infancy and subsequent wheeze, taking into account the type and frequency of wheeze in childhood.

Methods

The Tasmanian Infant Health Survey

Eligible infants for this birth cohort study represented approximately one-fifth of live births in the state of Tasmania who were scored at birth to be at higher risk of sudden in-

fant death syndrome (SIDS) (Figure 1). From 1988 to 1995, 9,826 (89%) of the eligible infants participated in hospital and home interviews. The eligibility criteria and methods are outlined elsewhere.²⁶ We defined an at-birth family history of asthma as asthma among the infant's siblings, parents or grandparents reported by interview of the mother during the first postnatal week. We conducted a second interview in the infant's home during the fifth postnatal week. Measurements were carried out on the baby, features of the home were observed, and a structured verbal parental questionnaire was administered. We recorded features of the infant's sleeping environment, including type of pillow, mattress liner, mattress and bed, plus the number and types of upper bedding items that would be used in cold weather.

The 1995 Tasmanian Asthma Survey

We conducted a cross-sectional survey on all children who turned 7 years of age in Tasmania, identified through primary schools and home-learning and distance-education organizations (Figure 1).²⁷ Data included sleeping environment and asthma symptoms, using questions from the International Study of Asthma and Allergy in Childhood.²⁸ Previous validation work has shown that the report of wheeze over the past 12 months has a sensitivity of 0.81 and a specificity of 0.85 for the physician diagnosis of asthma in childhood.²⁹ In addition, the child's age at onset (in completed years) of wheezy breathing or asthma was obtained. Of the 1,111 who participated in the 1988 TIHS home interview, 863 (78%) also participated in this asthma survey (Figure 1).

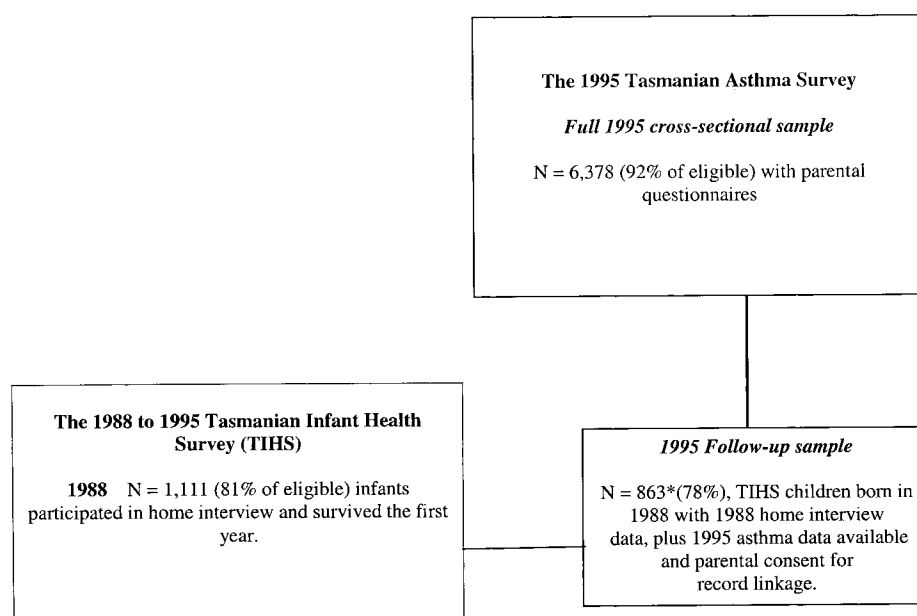


FIGURE 1. The Tasmanian infant cohort and related child asthma studies.

TABLE 1. Study Sample Characteristics

	1995 Follow-Up Sample (N = 863)*		Full 1995 Cross-Sectional Sample (N = 6,364)*	
	%	N	%	N
Mean age (years)	6.9 (SD = 0.3)		6.9 (SD = 0.3)	
Synthetic pillow used in childhood	90	770	90	5,709
Synthetic quilt used in childhood	41	354	42	2,648
Synthetic pillow used at 1 month of age	15	127	NA	NA
Asthma ever	32	280	27	1,710
Night wheeze over past year	19	160	14	889
Wheeze frequency over past year				
None (0 episodes)	73	601	77	4,707
Moderate (1–12 episodes)	23	192	21	1,264
Frequent (12 episodes or more)	4	30	2	136

NA = not applicable.

* Smaller N for some characteristics. Smallest N for wheeze frequency (N = 823 for follow-up sample; N = 6,107 for cross-sectional sample).

These studies were approved by the Ethics Committee (Human Experimentation) of the University of Tasmania and parents provided informed written consent, including consent for data linkage between the TIHS and the 1995 Tasmanian Asthma Survey.

Classification of Synthetic Bedding

Pillows reported as foam/sponge/tontine/polyester/Dacron were classified as synthetic. A small number of children in infancy or childhood (1995 cross-sectional study only, N = 23) were excluded because the pillow was described as “antiallergy” but information on composition was not available. A synthetic quilt in infancy was defined as the use of a synthetic quilt over the infant during cold weather. A synthetic quilt in childhood was defined as a polyester or Dacron quilt/doona/duvet over the child. The parental report of infant synthetic-pillow use showed high agreement with nurse observation of infant pillow used in the last night in a 1995 substudy (data not shown). For the present report, synthetic bedding refers to the use of either a synthetic pillow or synthetic overlying quilt. Synthetic-bedding use in childhood was very common (Table 1). The “consistent” use of a bedding item refers to use in both infancy and childhood.

Statistical Methods

To control simultaneously for multiple confounders and to obtain confidence intervals for relative risk estimates, a generalized linear model with a log-link function and binomial error structure was used for the cross-sectional and prospective analyses.^{30,31} We assessed the relation between infant synthetic bedding and age of onset of asthma symptoms using discrete proportional hazard modelling.³² A log-rank test for the equality of survivor functions was used for analysis of age at onset of asthma or wheezy breathing.

We examined frequent and moderate wheeze over the past year rather than the presence of any wheeze over the past year. Moderate wheeze was defined as 12 or

fewer wheeze episodes and frequent wheeze was defined as more than 12 wheeze episodes in the past year. We also examined night wheeze over the past year because bedding was the exposure of interest. Because the data indicated that family history of asthma might be partially determined by exposure (synthetic bedding), family history was not treated only as a confounder; results with and without adjustment for family history are presented. We first evaluated trends by a chi-square test of trend with the categories of synthetic bedding ordered approximately for increasing synthetic upper-bedding volume. A categorical term for increasing number of synthetic items was then used to provide the *P*-value for trend in the multivariate analyses.

We calculated the etiologic fraction of wheeze attributable to synthetic bedding among those using a synthetic pillow or quilt as P (adjusted relative risk [aRR] – 1)/aRR, where P = the proportion of children with synthetic bedding among those with the wheeze outcome and aRR = the relative risk estimate for synthetic bedding and wheeze, after adjustment for the confounders.³³ We conducted the analyses with Stata 7.0.³⁴

Results

The Infant Cohort Study

Among children in the 1995 Tasmanian Asthma Survey who were also included in the cohort study that began in 1988, synthetic pillow use at 1 month of age was strongly associated with night wheeze or frequent wheeze at age 7, but not with moderate wheeze (Table 2). The association between synthetic pillow use and frequent wheeze remained after adjustment for the cohort-entry scoring-system components (male sex, exclusive breast feeding, season of birth, multiple birth, duration of second stage of labour, maternal age and birth weight), as either individual factors or as a set, and further adjustment for more than 20 individual confounders including sibling number, dog or cat as a family pet during infancy, air freshener use or hairspray use in

TABLE 2. Infant Synthetic Pillow Use and Child Asthma Symptoms at Age 7, 1995 Follow-Up Sample

Respiratory Symptom at Age 7	N	Infant Synthetic Pillow Use		Infant Synthetic Pillow Use and Respiratory Symptom		Infant Synthetic Pillow Use and Respiratory Symptom*	
		N	%	RR	95% CI	ARR	95% CI
No wheeze in past year†	599	81	14	1.0		1.0	
Moderate wheeze (1–12 episodes in past year)	190	31	16	1.2	0.9–1.6	1.1	0.8–1.5
Frequent wheeze (more than 12 episodes in past year)	28	9	32	2.8	1.3–6.1	2.5	1.2–5.5
No night wheeze†	671	85	13	1.0		1.0	
Night wheeze	157	34	22	1.6	1.2–2.3	1.5	1.1–2.1

* Adjusted for infant sheepskin use at 1 month, exclusive breastfeeding at 1 month, whether infant exposed to active smoking in the same room, and synthetic pillow use in childhood.

† Reference category.

infant's bedroom, or infant exposure to active smoking in the same room at 1 month of age. The use during infancy of any pillow or synthetic quilts was not associated with any of the outcomes listed in Table 2.

We then examined combined synthetic upper-bedding and pillow use in infancy. The proportion of children with night wheeze at age 7 varied by synthetic upper-bedding use in infancy as follows: no synthetic pillow or quilt, 17%; synthetic quilt only, 17%; synthetic pillow only, 26%; synthetic pillow and quilt, 33% (test for trend: $P = 0.006$). Feather bedding was not commonly used in infancy (feather pillows, $N = 11$; feather quilts, $N = 11$); thus the prospective association between infant feather bedding and child wheeze could not be examined.

Age of onset analysis showed that, among children with asthma, synthetic bedding use in infancy was associated with an earlier onset of asthma symptoms (log-rank test, $P = 0.03$) (Figure 2). We then further examined the effect of synthetic pillow use on age of onset of asthma symptoms by wheeze episode frequency over the past year. Among children with no wheeze or moderate wheeze, synthetic pillow use did not relate to age of onset ($aRR = 1.3$ [CI = 0.7–2.2] and $aRR = 1.3$ [CI = 0.8–2.0], respectively). Among children with frequent wheeze, early synthetic pillow use was strongly associated with earlier symptom onset ($aRR = 3.6$; CI = 1.4–9.3). Thus, the earlier onset of asthma symptoms associated with early synthetic bedding use occurred predominantly among children with frequent wheeze, after adjustment for an at-birth family history and the presence of siblings in childhood.

The Cross-Sectional Asthma Survey

The full 1995 cross-sectional sample was similar to the cohort sample with regard to child age, wheeze frequency over the past year, and the proportion of children using synthetic bedding; a lower proportion of children had a history of asthma ever (Table 1). Syn-

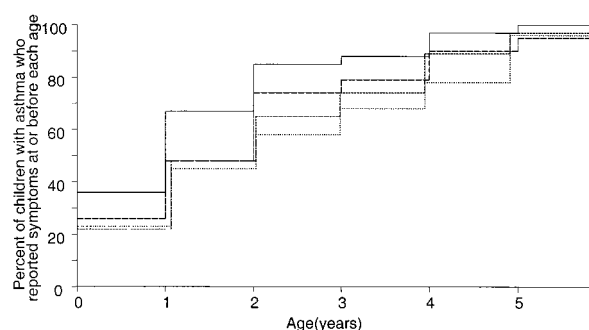


FIGURE 2. Age of onset of asthma or wheezy breathing by synthetic bedding use at 1 month of age. Log-rank test for equality of survivor functions, $P = 0.03$. Solid line indicates synthetic pillow and quilt; dotted line indicates no synthetic pillow or quilt; heavy broken line indicates synthetic pillow, not quilt; light broken line indicates synthetic quilt, not pillow.

thetic bedding use in childhood was associated with a history of asthma ever (aRR 1.3; CI = 1.1–1.6).

Examination of bedding by wheeze frequency found that current synthetic bedding exposure was most strongly related to frequent wheeze (Table 3). There was a significant trend for increased likelihood of wheeze with increasing exposure to synthetic bedding (Table 3). The adjusted associations in Table 3 remained unchanged after further individual adjustment for more than twenty possible confounders. Synthetic quilt use was also significantly associated with night wheeze ($aOR = 1.3$; CI = 1.1, 1.4). Among children with asthma, synthetic bedding was also associated with an increased frequency of asthma medication use (data not shown), which is consistent with the observation of more severe asthma symptoms in this group. This indicates that the increased in symptoms among children using synthetic bedding could not be attributed to an under-utilization of asthma medications.

We then examined bedding composition in further detail. Comparing synthetic to feather pillows, the aRR

TABLE 3. Child Wheeze Frequency over the Past 12 Months by Current Use of Synthetic Bedding, Full 1995 Cross-Sectional Sample

Bedding	N	Distribution of children by number of wheeze episodes (%)			Moderate Wheeze* (1–12 Episodes vs None)		Frequent Wheeze* (More Than 12 Episodes vs None)	
		0	1–12	More Than 12	ARR	95% CI	ARR	95% CI
Neither pillow nor quilt synthetic†	450	82	18	0.6	1.0		1.0	
Only pillow synthetic	3,091	80	19	2.0	1.4	1.2, 1.7	6.0	1.5, 25
Only quilt synthetic	148	76	21	2.7	1.1	0.9, 1.3	4.4	1.1, 18
Both pillow and quilt synthetic	2,373	73	24	2.7	1.2	0.8, 1.8	6.4	1.2, 35

Adjusted for male sex, child exposure to active smoking and household resident number.

* Test for trend across exposure categories: refers to the linear increase in risk if none, one, or two synthetic items were used (for moderate wheeze, $P = 0.0001$; for frequent wheeze, $P = 0.004$).

† Reference category.

for frequent wheeze was 4.4 (CI = 1.1–17.6). Comparing synthetic pillows to other non-feather pillows, the aRR for frequent wheeze was 1.1 (CI = 0.4–2.8). The use of synthetic compared the feather over-bedding related to frequent wheeze (aRR = 1.7; CI = 1.1–2.4) but synthetic overbedding was not significantly associated with frequent wheeze compared to other non-feather over-bedding (aRR = 1.2; CI = 0.7, 2.1). Overall feather quilt use was associated with an aRR of 0.6 (CI = 0.4–0.9) for frequent wheeze.

Intriguingly, the importance of the association between sibling number and wheeze also varied by wheeze frequency. For children with moderate wheeze, an increase in household resident number appeared protective (aRR = 0.91; CI = 0.87–0.95) per increase in household resident). However, sibling number appeared less important for children with frequent wheeze (aRR = 1.00; CI = 0.87–1.16) per resident increase. Thus, the protective effect of large family size was only apparent for children with moderate, not frequent wheeze. The percentage of moderate wheeze attributable to synthetic bedding among children exposed to either a synthetic pillow or quilt was low (16%) for moderate wheeze but high for those with frequent wheeze (79%). Thus, it appears that the factors associated with frequent wheeze differ from those associated with moderate wheeze.

Possible Contribution of an At-Birth Family History of Asthma or Early Allergen Avoidance

Among children with asthma at the age of seven, 2% (39/1686) used allergen-occlusive mattress covers. Children with these covers were not more likely to sleep with a synthetic pillow (87% vs. 92% use) or synthetic quilt (47% vs. 48% use). The choice of a non-carpeted bedroom floor was also not associated with synthetic bedding use. These findings suggest that the results in Table 3 do not reflect the parents' introduction of the synthetic bedding as part of an allergen reduction strategy.

It is likely that synthetic bedding choices will be shared within a family. The cohort data suggested the

possibility that synthetic bedding use may have promoted asthma among other family members, such as younger siblings. Among children with no family history at birth, infant synthetic pillow use predicted a positive family asthma history by childhood (RR = 1.5; CI = 1.1–1.9) while among those children who did not use a synthetic pillow, an at-birth family history of asthma was only slightly associated with frequent wheeze (RR = 1.3; CI = 0.5–3.3)). There was no evidence that parents of children with an at-birth family history of asthma were selecting a synthetic pillow as part of a bed allergen reduction strategy. Similarly, there was no indication that they were selectively using a plastic mattress liner (42% vs. 40% use) nor avoiding sheepskins (29% vs. 28% use). Among children with no at-birth family history of asthma, the consistent use of a synthetic pillow (RR = 3.2; CI = 1.0–10.1) or synthetic quilt (RR = 1.9; CI = 1.1–3.2) in both infancy and childhood compared to no use was associated with night wheeze at age seven. Importantly, the associations between bedding and frequent wheeze in Tables 2 and 3 were present with or without further adjustment for family history of asthma.

Discussion

In the cohort analysis, infant synthetic pillow use was associated with an increased risk of frequent childhood wheeze, independently of later exposure to synthetic bedding. A strong association between current synthetic bedding use and frequent wheeze was also observed. Feather bedding was uncommon in early life so the prospective association between infant feather bedding and childhood wheeze could not be reported. However, the findings that infant synthetic pillow was not associated with childhood feather bedding and that controlling for childhood use did not affect the association between infant synthetic pillow use and frequent wheeze suggest that the prospective association between infant synthetic bedding use and frequent wheeze cannot be readily explained by the use of feather bedding in later

childhood. The finding that synthetic infant quilts were not associated with wheeze may be because these items are usually of the coverlet type and thus more frequently washed than pillows or child quilts. We examined non-causal explanations for the striking associations between synthetic bedding and frequent wheeze. The findings argue against a spurious association caused by the selection of synthetic bedding because of asthma or family history. The associations between synthetic bedding and frequent wheeze persisted after adjustment for confounding factors. Several criteria indicative of a causal relationship³³ between synthetic bedding and wheeze were evident, including a high strength of association and dose-response patterns in Table 3. In addition, the prospective measurement here of infant bedding before asthma development and the earlier shift in age of onset with earlier use of synthetic bedding establishes the causal feature of temporality.

These findings add to accumulating evidence that synthetic bedding may be associated with adverse respiratory outcomes. No study to date has shown a lower wheeze prevalence associated with synthetic bedding. Previous cross-sectional studies have shown positive associations for synthetic or non-feather bedding and child wheeze⁷⁻¹² or rhinitis.¹³⁻¹⁴ Several of the investigators also restricted their analyses to those subjects who did not report that they changed their bedding because of respiratory symptoms or they adjusted for reported allergen avoidance; the positive association between synthetic or non-feather bedding and wheeze or rhinitis persisted.^{7-8, 13-14} In addition, a previous study has implicated synthetic bedding in the increasing incidence of asthma over time. Researchers examined the relation between changes in the home environment and the increase in childhood wheeze between 1978 and 1991 among seven to eight-year-olds in the London Borough of Croydon. They found that, of the environmental risk factors examined, the increasing use of non-feather pillows (from 44% in 1978 to 67% in 1991) was the most important factor, accounting for more than half of the 20% increase in current wheeze between 1978 and 1991.³⁵

Possible mechanisms for the association of synthetic bedding and frequent wheeze include increased exposure to house dust mite or to volatile organic compounds and reduced exposure to endotoxin. Firstly, synthetic bedding may lead to higher allergen exposure. Vacuum extraction studies show synthetic pillows have five to seven-fold higher house dust mite allergen levels compared with feather pillows.^{4,5} The higher allergen levels in synthetic bedding have been postulated to reflect a looser weave for the lining of synthetic, compared to feather, bedding, but the internal bedding microclimate with regard to warmth and humidity or electrostatic properties may also be important. In the Tasmanian environment, the mean *Dermatophagoides pteronyssinus* level in synthetic pillows was 2.7 ug at one month of

age³⁶ and, based on an accumulation study,³⁷ the levels could reach over 20 ug/g after a further year. It has been suggested that exposure to *Dermatophagoides pteronyssinus* allergen levels above 2 ug/g may increase the risk of dust mite sensitisation and levels above 10 ug/g may induce respiratory symptoms in house dust mite-sensitized individuals.³⁸ Previously, three prospective cohort studies have found house dust mite allergen levels in bedding during early life to be predictive of initial house dust mite sensitisation, with a dose-response evident.³⁹⁻⁴¹ House dust mite exposure among house dust mite-sensitized children increased the risk of developing asthma.⁴² Among house dust mite-sensitized children, house dust mite exposure has been associated with bronchial hyper-responsiveness. In an Australian study, bed house dust mite allergen (a composite sample from mattress and upper bedding) was associated with a reduction in minimum morning peak expiratory flow rate, with an increase of one natural log of house dust mite allergen leading to an approximately 15L/min reduction.⁴³ House dust mite allergen levels in bedroom floors were less important than bed house dust mite allergen levels in determining airway responsiveness⁴³ or asthma severity.⁴⁴ This could partly explain why an association between infant bedroom house dust mite levels and asthma has only been found in one of three studies.^{18,45,46} That is, by measuring infant floor dust, rather than infant bedding, these studies may have misclassified inhalational house dust mite allergen exposure during infancy. An inverse association of childhood asthma with farm residence or early life contact with animals, if causal, has been postulated to reflect a higher level of infant exposure to bacterial endotoxins resulting in immune deviation away from atopy.⁴⁷ Synthetic pillows may contain fewer bacterial products than feather¹⁷ but further work is required on this issue. In addition, volatile organic compounds released from synthetics might increase mucosal permeability to inhaled allergens.⁷ The Oslo birth cohort study found an exposure-response relationship between plasticizer-containing surface materials and risk of bronchial obstruction by age two.¹⁹ Thus, the role of chemical emissions from synthetic bedding also requires further evaluation.

In conclusion, the association between synthetic upper bedding and frequent childhood wheeze in the present studies displayed the features of high strength of association, temporality, dose-response, and consistency. These features, together with findings from previous studies, indicate that the association may be causal in nature. However, to fully exclude the possibility that synthetic bedding is associated with lifestyle or other factors that are causally related to frequent wheeze, randomized controlled trials evaluating alternative bedding are required.

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