

Does Bedding Affect the Airway and Allergy?

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Abstract

Various cross-sectional and longitudinal studies have suggested that synthetic bedding is associated with asthma, allergic rhinitis and eczema while feather bedding seems to be protective. Synthetic bedding items have higher house dust mite allergen levels than feather bedding items. This is possibly the mechanism involved although fungal and bacterial pro-inflammatory compounds and volatile organic compounds may play a role. In this review we present and discuss the epidemiological evidence and suggest possible mechanisms. Primary intervention studies are required to show whether feather bedding is protective for the development of childhood asthma and allergic diseases while secondary intervention studies are required to potentially reduce symptoms and medication use in subjects with established disease.

Keywords: Asthma; Allergy; House dust mite; Fungi; Volatile organic compounds; Bedding; Synthetic; Feather

Introduction

The International Study of Asthma and Allergies in Childhood (ISAAC) has been instrumental in determining the global prevalence and the severity of asthma symptoms in 6–7-year-old and 13–14-year-old children. The first major findings from the ISAAC studies showed a 20- to 60-fold difference between 155 centres in 56 countries in the prevalence of asthma symptoms and allergic diseases.¹ The latest results from Phase III of ISAAC, with a greater number of children, centres and countries than those of ISAAC Phase I, again showed a wide variation in asthma symptoms worldwide. For instance, prevalence rates of 12-month wheeze in 13–14-year-old children ranged from 0.8% in Tibet, China to 32.6% in Wellington, New Zealand.²

The causative factors for asthma are multi-factorial, but it is increasingly be-

ing recognized that, in addition to genetic susceptibility, the indoor environment is an important factor. The bedroom environment may play an important role given that we spend about one-third of our time in the bed with our airways close to pillows, mattresses and duvets (also known as quilts or comforters) that are significant reservoirs of allergens, fungi and bacteria. In the last 15 years, epidemiological studies have suggested that synthetic bedding is associated with an increased risk of asthma while feather bedding is associated with protection. In this article, we review the epidemiological evidence and suggest potential mechanisms for these associations.

Bedding and Severe Asthma

A questionnaire-based case-control study showed that the use of synthetic pillows was the only indoor environmental fac-

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tor significantly associated with severe wheeze in school-age children.³ Independent associations with severe wheeze (12 or more wheezing attacks or a speech limiting attack of wheeze in the preceding 12 months) and the use of synthetic pillows were seen with an odds ratio (OR) of 2.78 (95% CI: 1.89–4.17). Interestingly, the use of feather pillows was associated with less severe wheeze (OR: 0.36; 95% CI: 0.24–0.53) and remained highly significant even after restricting the analysis to children without a family history of atopy or whose parents did not make any changes in the bedroom. Since then, a number of cross-sectional studies have described associations of asthma symptoms and allergic diseases with synthetic bedding or an apparent protective effect of feather bedding.

Bedding, Asthma and Allergic Diseases

Butland, *et al*, reported an increased prevalence of wheezing of 16% in 8-year-old London school children between 1978 and 1991.⁴ The authors obtained detailed indoor environmental data, including the type of pillow used by the child. Their main finding was that an increased use of non-feather pillows over the 13-year time period (44% in 1978 and 67% in 1991) was the only indoor environmental exposure studied which was associated with the increase in wheezing prevalence over this time period, even when taking into account possible changes in pillow type due to asthma symptoms.

In a study on the prevalence of asthma and allergic diseases in children from East and West Germany, Duhme, *et al*, found that the use of feather bedding by 5–8-year-old children was associated with a reduced prevalence of asthma symptoms, allergic rhinitis and eczema in both East and West Germany.⁵ Adjusted for parental

atopy and allergen avoidance practices, odds ratios for asthma, rhinitis and eczema were 0.48 (95% CI: 0.35–0.66), 0.53 (95% CI: 0.37–0.76) and 0.63 (95% CI: 0.47–0.85), respectively in East Germany and 0.39 (95% CI: 0.31–0.50), 0.58 (95% CI: 0.43–0.77) and 0.64 (95% CI: 0.49–0.83), respectively in West Germany.

In a small case-control study of under 2-year-old infants, recurrent wheezing was significantly associated with the use of synthetic mattresses, quilts and pillows.⁶ However, wheezing in very young infants is most likely due to viral respiratory infections. Furthermore, the authors did not adjust for potential confounding factors such as a family history of atopy and environmental tobacco smoke exposure, both of which were also associated with recurrent wheezing in that study.

In two separate publications,^{7,8} Zacharasiewicz, *et al*, reported that wheezing in the last 12 months and symptoms strongly suggestive of atopic rhinitis were significantly associated with the use of synthetic bedding with adjusted odds ratios (aOR) of 1.33 (95% CI: 1.18–1.49) and 1.21 (95% CI: 1.09–1.36), respectively. This was a very large study of 6–9-year old children in Austria where about 35 000 took part in the asthma symptoms study⁷ while a subset of about 18 000 who excluded reported allergen avoidance took part in the allergic rhinitis study.⁸

Frosh, *et al*, conducted a questionnaire-based cross-sectional study of about 2500 friends and relatives accompanying patients attending outpatients departments at one London hospital to determine whether ownership of furred animals or the use of non-feather pillows was associated with seasonal or perennial rhinitis.⁹ After excluding subjects who had changed their pillow because of allergies, non-feather pillow use was significantly associated with both perennial rhinitis (aOR: 2.41; 95% CI: 1.32–4.39) and non-

significantly with seasonal rhinitis (aOR: 1.33; 95% CI: 0.93–1.91).

Yemaneburhan, *et al*, determined the prevalence of wheeze and asthma in urban and rural Ethiopia and assessed whether etiological factors were associated with urban/rural differences.¹⁰ Among studied etiological factors was the use of synthetic mattresses and pillows. They found that synthetic foam mattresses and pillows were associated with wheeze of 12 months duration (aOR: 1.48; 95% CI: 1.14–1.91 and 1.40; 95% CI: 1.07–1.84, respectively). Furthermore, the use of synthetic foam mattresses and pillows were also associated with sensitization to the house dust mite *Dermatophagoides pteronyssinus* (aOR: 1.97; 95% CI: 1.16–3.33 and 2.09; 95% CI: 1.22–3.57, respectively).

In a nested case-control study, McNally, *et al*, looked at the association between atopic eczema and a number of indoor environmental factors in primary school children in the UK.¹¹ Among factors studied were the use of synthetic pillows and duvets which was used by 85% and 91%, respectively. Synthetic pillow use was significantly associated with a 1-year period of atopic eczema symptoms (aOR: 1.51; 95% CI: 1.01–2.28) with a population attributable risk (PAR) of 28%. This association remained significant for lifetime atopic eczema symptoms (aOR: 1.50; 95% CI: 1.07–2.11; PAR: 27%). The PAR is a measure of the proportion of cases in the population that can be attributed to the exposure. Synthetic duvet use was also, but non-significantly, associated with an increased risk of atopic eczema (aOR: 1.33; 95% CI: 0.82–2.14 and 1.43; 95% CI: 0.98–2.13, respectively for a 1-year period and lifetime atopic eczema).

An Australian cross-sectional study found that synthetic duvet use was significantly associated with asthma, recent wheeze and allergic rhinoconjunctivitis in atopic children but not in non-atopic

children.¹² When restricting the analysis to children who were sensitized to house dust mites, the association strengthened. But children who were sensitized to other allergens than house dust mites showed no association between synthetic duvets and allergic diseases. Synthetic duvet use was also associated with increased past hospital attendance for asthma and with more frequent rather than infrequent wheezing. The authors postulated that the association between synthetic bedding use and adverse respiratory outcomes was most likely related to the higher allergen content of synthetic bedding. This aspect will be explored further in this review.

Ponsonby, *et al*, examined the relation between feather quilt use and respiratory parameters and atopic sensitization to allergens of the house dust mites *D. pteronyssinus* and *D. farinea*.¹³ Feather quilt and feather pillow use was significantly associated with reduced house dust mite sensitization (aRR: 0.60; 95% CI: 0.45–0.80 and aRR: 0.39; 95% CI: 0.16–0.99, respectively). Sensitized children who slept under feather quilts had smaller weal sizes compared to sensitized children sleeping under other quilt types. Furthermore, feather quilt use was significantly associated with reduced frequent wheeze, defined as >12 wheeze episodes in preceding 12 months (aRR: 0.24; 95% CI: 0.07–0.86) and this was more evident among house dust mite sensitized children. Children who slept under feather quilts used less inhaled steroid medication and had reduced hospital attendance for asthma in the preceding 12 months. All the above protective effects of feather bedding were not affected by a family history of asthma or by allergen avoidance measures.

In a cross-sectional study from Tasmania, Australia, synthetic bedding use by children was significantly associated with frequent wheeze, night wheeze and a

TAKE-HOME MESSAGE

- Epidemiological studies have predominantly shown that synthetic bedding is associated with asthma and allergic diseases while feather bedding appears to be protective.
- The much higher house dust mite allergen load of synthetic bedding has been postulated as the putative mechanism although fungal and bacterial pro-inflammatory compounds and volatile organic compounds may play a role.
- Well-designed primary and secondary intervention studies are required to determine whether feather bedding can reduce the burden of asthma and allergic diseases.

history of asthma ever.¹⁴ Among children with asthma, synthetic bedding use was significantly associated with increased asthma medication use.

Having demonstrated that synthetic bedding use was associated with increased wheeze in their previous studies,¹²⁻¹⁴ Ponsonby, *et al*, then examined whether these adverse effects of synthetic bedding differed by the child's usual sleep position.¹⁵ Synthetic quilt use was significantly associated with frequent wheeze among children who slept in the supine position (aOR: 2.37; 95% CI: 1.08–5.23) but not in the non-supine position (aOR: 1.06; 95% CI: 0.60–1.88). Also, the supine sleeping group using synthetic quilts had lower post-exercise forced expiratory volume in 1 second measures (FEV₁). The authors concluded that in the supine sleeping position the child's airways are in closer proximity to the higher allergen content of synthetic bedding leading to an increase in asthma symptoms.

A few studies conducted in other

countries have also shown associations between bedding type and asthma symptoms or allergic sensitization. In Norway, use of synthetic pillows and comforters was associated with severe asthma.¹⁶ In Belgium use of non-synthetic bedding material was significantly associated with a reduced risk of atopic sensitization (at least one positive skin prick test to seven inhalant allergens) with an OR of 0.67 and was also associated with fewer reported episodes of wheezing.¹⁷ In Hungary, the prevalence of allergic rhinitis in 6–12-year-old school children was reported as being significantly associated with the use of feather bedding (aOR: 0.753; 95% CI: 0.641–0.884).¹⁸ However, it was subsequently pointed out that the authors misinterpreted their results and that feather bedding use appeared to be protective for allergic rhinitis in that study.¹⁹ In Croatia, use of feather pillows was associated with reduced symptoms of allergic disease (wheezing and/or allergic rhinoconjunctivitis and/or atopic eczema).²⁰

Therefore, many studies have shown that synthetic bedding is associated with asthma or allergic diseases or that feather bedding seems to be protective; however, two studies have not. Bisgaard, *et al*, found no association with feather pillow use and early childhood eczema at age three years in a prospective birth cohort study from Denmark.²¹ Behrens, *et al*, argue that most studies looking at bedding type use and its association with asthma and allergic diseases did not fully account for potential changes in bedding by patients.²² In their study, Behrens, *et al*, analyzed data from their ISAAC Phase III cross-sectional survey.²³ In preliminary analyses synthetic bedding (pillows and blankets) were highly associated with a high number of wheezing attacks with adjusted prevalence ratios (aPR) of 4.44 (95% CI: 2.84–6.94) and 3.80 (95% CI:

2.48–5.82), respectively for synthetic pillows and blankets. When they restricted the analysis by excluding subjects who had changed their bedding type due to existing atopic disease or family history of atopy, the positive associations of synthetic bedding with wheezing attacks disappeared. Their results are surprising as the study was a subset of an earlier study where they found significant inverse relations between feather bedding use and wheezing and allergic diseases, adjusted for parental atopy and allergen avoidance practices.⁵

Prospective Studies

Cross-sectional and case-control studies focus on current exposure and outcomes and are vulnerable to selection and information bias. Thus, parents may choose particular types of bedding due to the child's disease status or family history of atopy. Alternatively, the child's atopic status may influence past exposure reporting information. Prospective studies reduce selection bias and eliminate information bias. To date, three full published studies and one study published as an abstract have reported on bedding type use from birth and development of asthma and allergic diseases in infancy.

Nafstad, *et al*, were the first to show that the use of a feather quilt from birth seemed to be protective for developing bronchial obstruction at age two years and asthma and allergic rhinitis at age four years.²⁴ In their cohort study, the authors collected information on the type of duvet the infant was exposed to at 6, 12 and 24 months. Bronchial obstruction at age two years was defined as at least three out of five symptoms or signs (*i.e.*, wheezing, chest recession, rhonchi during auscultation, forced expiration, and rapid breathing), one of which had to be physician diagnosed. Asthma and allergic

rhinitis at age four years was physician diagnosed. Use of feather duvets at age six months was inversely associated with bronchial obstruction at age two years (aOR: 0.59; 95% CI: 0.41–0.86) and physician-diagnosed asthma at age four years (0.38; 95% CI: 0.23–0.64). There seemed to be (non-significant) protective trends of feather duvet use at age six months and allergic rhinitis at age four years (aOR: 0.73; 95% CI: 0.43–1.18). The authors concluded that their results do not support advice against the use of feather bedding by asthmatics.

In Australia, another type of infant bedding relatively popular is the cocoon or baby nest. This is a synthetic material padded sleeping bag with a hood which is normally placed on a flat surface or pram or basinet with the infant inside. Trevillian, *et al*, found that cocoon use in infancy was associated with an increased risk of recent wheeze (aOR: 4.33; 95% CI: 2.08–9.02) and night time wheeze (aOR: 3.35; 95% CI: 1.52–7.39) at age seven years.²⁵ Adjustments for family history, maternal smoking and child's history of asthma did not alter the associations, neither were parents of infants with a family history of asthma selectively using cocoons. If infants were also exposed to synthetic quilts or pillows in infancy, the association between cocoon use and recent wheeze increased (aOR: 4.33; 95% CI: 2.08–9.02).

The Tasmanian (Australia) infant cohort was further studied to investigate the role of composite bedding environment at birth on the development of asthma at age seven years.²⁶ The composite bedding groups were 1) no synthetic bedding or sheepskins; 2) only one synthetic bedding item or sheepskin only or one synthetic bedding item plus sheepskin; and 3) two or more synthetic bedding items with or without sheepskins. The authors found that composite bedding was associated with one or more wheezing episodes in

the last 12 months (at age seven years) and that this association was strengthened with increasing synthetic bedding items. Furthermore, bedroom heating, recent painting of the bedroom and absence of bedroom carpeting increased these effects. Thus, increasing exposure to synthetic bedding in infancy increased wheezing episodes in childhood and was enhanced by certain home environmental conditions.

In a New Zealand infant cohort study we investigated whether use of feather pillows and duvets at age two years was associated with an altered risk of wheeze and asthma at age four years.²⁷ At age two years only 25 out of 524 infants slept with feather pillows and 57 out of 581 infants slept with feather duvets. aOR's for feather pillow use with wheeze at age four years was 0.09 (95% CI: 0.01–0.67) and for doctor diagnosed asthma was 0.18 (95% CI: 0.02–1.36). Comparative aOR's for feather duvet use were 0.32 (95% CI: 0.14–0.72) and 0.52 (95% CI: 0.22–1.17), respectively for wheeze and asthma at age four years. Therefore, feather bedding use early in infancy appeared to be protective for development of wheeze in childhood and there appeared to be a protective trend for asthma development in childhood.

Mechanisms

Allergens

A number of cross-sectional and longitudinal studies have shown that synthetic bedding may contribute to asthma and allergic diseases while feather bedding seems to be protective. So what are the potential mechanisms for these effects? Strachan and Carey postulated that the three-fold increased risk of severe wheezing in school children associated with the use of synthetic pillows might be due to the release of volatile organic compounds (VOCs) from synthetic pillows, thus, increasing

mucosal permeability to allergens.³ We hypothesized that synthetic pillows might also have a larger allergen load compared to feather pillows. Therefore, we showed that synthetic pillows had about eight-fold higher levels of the house dust mite allergen, Der p 1, than feather pillows.²⁸ Our findings were confirmed in the UK where allergen levels are about 20-fold lower than in New Zealand.²⁹ The UK authors subsequently demonstrated that synthetic pillows contained about 7- to 8-fold higher levels of cat and dog allergens, compared to feather pillows.³⁰ We subsequently studied how quickly new allergen-free pillows accumulate house dust mite allergen. Over a 12-month period, synthetic pillows accumulated Der p 1 at a higher level than feather pillows and accumulation on both types of pillow was strongly governed by the mattress reservoir allergen level.³¹

Differences in allergen levels have also been demonstrated for other synthetic and feather bedding items, such as duvets. Thus, synthetic duvets were shown to have about 15-fold higher Der p 1 content than feather duvets.³² That study also confirmed the previous New Zealand findings of higher allergen levels in synthetic pillows.²⁸ If synthetic duvets are present on beds than composite bedding Der p 1 levels were found to be higher, but lower in the presence of feather duvets.³³ Other studies have also shown higher house dust mite allergen levels on mattresses associated with synthetic pillows³⁴ or lower with feather pillows.³⁵

Why do synthetic bedding items have higher levels of allergens compared to feather bedding items? In order to keep feathers inside feather pillows, manufacturers produce a cover with a tighter weave than with synthetic pillows. We noted that the more open weave of synthetic pillow covers were large enough for house dust mites to penetrate while they could not penetrate feather pillows.³⁶ We seeded

adult life house dust mites on covers of a standard polyester pillow, a newer type of polyester/cotton pillow and a feather pillow and enumerated life house dust mites remaining on top after 24 and 48 hours.³⁷ All house dust mites had penetrated the standard synthetic pillow cover after 24 hours while none had penetrated either the newer type of synthetic pillow cover or feather pillow cover after 48 hours. Additionally, the newer type of synthetic pillow cover and the feather pillow cover were less permeable to house dust than the standard polyester pillow cover and, thus, by implication to allergens. These findings may explain the numerous reports of higher house dust mite allergen levels from synthetic bedding items.

The association of less asthma and allergic diseases associated with feather bedding and their lower levels of house dust mite allergens could be due to the fact that asthma severity is positively correlated to house dust mite allergen levels of bedding, where we spend about a third of our life in close contact with our airways to bedding items.³⁸⁻⁴⁰ New Zealand has some of the highest bedding house dust mite allergen levels in the world⁴¹ and one of the highest prevalence rates of asthma in the world.^{1,2} The latter may be related to the high allergen levels although a secondary intervention study of occlusive bedding covers⁴² and a meta-analysis of allergen reduction⁴³ both failed to show a clinical benefit in asthma. However, both these studies have been criticized about their inclusion and exclusion criteria.^{44,45}

Until lately, advice to house dust mite sensitized patients was to avoid feather bedding in the belief that this type of bedding was favorable for house dust mites. Nowadays, the feathers used are washed and hot dried (>100 °C) ensuring that dust mites present in raw feathers are killed and their allergens denatured.⁴⁶ True feather allergy is rare and some reports of high

prevalence rates of feather allergy is most likely due to contamination by house dust mite allergens of feather extracts used in skin prick testing.⁴⁷

Fungi and their pro-inflammatory compounds

Fungi in the home environment are associated with respiratory health outcomes⁴⁸ and mould sensitization has been associated with severe asthma requiring hospitalisation.^{49,50} Recently, a UK study examined pillows for fungal contamination and showed that they were substantially contaminated with a great number of different species of fungi.⁵¹ Interestingly, one species, *Aspergillus fumigatus*, was more prevalent on synthetic pillows while another species, *Aureobasidium pullulans*, was more prevalent on feather pillows. A major cell-wall component of fungi is (1-3)- β -D-glucan (beta-glucan) accounting for more than half of its dry weight. Beta-glucan is non-allergenic but pro-inflammatory. Beta-glucan has been associated with the development of respiratory symptoms associated with exposure to indoor fungi⁵² including increased peak expiratory flow variability in children.⁵³ Given the findings of fungal contamination of pillows⁵¹ we examined the beta-glucan content of pillows and whether there were differences in these levels between synthetic and feather pillows. Synthetic pillows were found to contain about 4-fold higher total amounts of beta-glucan than feather pillows.⁵⁴ This was reconfirmed in a follow-up study determining beta-glucan content of bedding items in New Zealand.⁵⁵ Additionally, synthetic duvets had about 7-fold higher beta-glucan content than feather duvets. Thus, higher synthetic bedding levels of beta-glucan together with their higher house dust mite allergen levels may explain the adverse effects of synthetic bedding on asthma symptoms.

Volatile organic compounds

Strachan and Carey postulated that release of volatile organic compounds (VOCs) from synthetic pillows and increased mucosal permeability to allergens leads to worsening of asthma symptoms.³ Indoor emissions of VOCs are known to worsen asthma symptoms⁵⁶ and can lead to the development of bronchial obstruction in children.⁵⁷ Synthetic pillows are made with polyurethane foams that contain isocyanates⁵⁸ and isocyanates are a well-known inducer of occupational asthma caused by high exposure at work or by sensitization.⁵⁹ Thus, it is conceivable that synthetic pillows could release VOCs over time and thus, augment response to their higher allergen levels. To the best of our knowledge, no data has been published on VOCs release from synthetic pillows or lack thereof from feather pillows.

Endotoxin

Endotoxin from Gram-negative bacteria, is present in mattresses and pillows.^{60,61} Higher bedroom endotoxin levels at birth have been associated with increased wheezing in infancy⁶² although other studies have shown a protective effect of endotoxin exposure in early life and the development of asthma.⁶³ However, in those with established asthma, severity of asthma was related to indoor endotoxin exposure.⁶⁴ Furthermore, exposure to high levels house dust mite allergens augments endotoxin-induced airway inflammation in subjects with atopic asthma.⁶⁵ Therefore, if there is a difference in endotoxin from synthetic and feather bedding, this could be another potential mechanism. To the best of our knowledge, there has only been one published study comparing endotoxin levels between synthetic and feather pillows that found no difference.⁶⁶ However, this was a small study and therefore significant differences in endotoxin between

the two types of pillows may have been missed. Also, there are no published studies on endotoxin levels from duvets and this is an area that needs to be explored.

Conclusions

There is now considerable epidemiological evidence from case-control and longitudinal studies that synthetic bedding is associated with asthma and allergic diseases while feather bedding appears to be protective. The mechanisms for these effects are likely to be complex, involving both environmental and genetic influences. The higher allergen and fungal pro-inflammatory compounds levels from synthetic bedding are likely environmental influences. Further work is required to determine whether VOCs from synthetic bedding play a role. What are required now are well-designed primary and secondary randomized-controlled trials of synthetic and feather bedding in the prevention and treatment of asthma and allergic diseases.

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