

A prospective association between cocoon use in infancy and childhood asthma

L. F. Trevillian^a, A. L. Ponsonby^{a,b}, T. Dwyer^b, L. L. Y. Lim^a, A. Kemp^d, J. Cochrane^b and A. Carmichael^c

^aNational Centre for Epidemiology and Population Health, The Australian National University, Canberra, ^bMenzies Centre for Population Health and ^cDepartment of Paediatrics and Child Health, University of Tasmania, Hobart, and ^dDepartment of Allergy, Immunology and Infectious Diseases, The Children's Hospital, Westmead and Discipline of Paediatrics and Child Health, University of Sydney, Sydney, Australia

Summary

Correspondence:

Dr Leigh F. Trevillian,
National Centre for
Epidemiology and Population
Health, The Australian
National University, Canberra
ACT 0200, Australia. E-mail:
leigh.trevillian@anu.edu.au

There is increasing evidence for a role for bedding items in the development of asthma. The use of some forms of synthetic bedding, such as foam mattresses and pillows, is associated with a significantly increased risk of childhood wheeze. Our aim was to examine prospectively whether the use of synthetic cocoon/baby nests in infancy is associated with the subsequent development of wheeze in childhood. Data collected in 1988 as part of the Tasmanian Infant Health Survey were linked to the cross-sectional Childhood Asthma Survey conducted in 1995 in Tasmania, Australia.

We were able to match 863 records out of the 1111 in the 1988 survey. Information including parental, child-care, and the infant's sleeping environment was collected at home interview in 1988 when the infant was 1 month of age. Data including sleep environment and asthma symptoms were available for each child at age 7 years. A generalised linear model was used to calculate the adjusted relative risk (RR) estimates for symptoms of wheeze and infant cocoon use. For children who were placed in a cocoon in infancy, there was an increased risk of recent wheeze (adjusted RR = 4.33 [95% CI 2.08, 9.02]) and night wheeze (adjusted RR = 3.35 [95% CI 1.52, 7.39]) at age 7 years.

In view of the increasing prevalence of childhood asthma, the identification of potentially modifiable environmental factors which might operate in infancy is of importance. The present findings implicate infant bedding choice as a significant factor and further studies on the infant sleeping environment are indicated.

Introduction

Bedding items, and more specifically their material composition, are gaining recognition for their possible role in childhood asthma. The use of synthetic bedding (foam mattresses, pillows, blankets) is associated with a significantly increased risk of childhood wheeze in children from varying world environments.¹⁻⁴

Indoor environmental factors, notably inhalant allergens such as house dust mite (HDM), are well recognised as contributing to childhood asthma.^{5,6} Bedding is a major source of HDM^{7,8} and HDM levels have been shown to vary within different composite bedding materials. Significantly higher levels of dust mite allergens⁹⁻¹¹ are found in synthetic bedding than in feather bedding. *Dermatophagoides pteronyssinus* (Der

p) allergen levels (recorded as geometric means) have been found to be 5-8 times greater in synthetic pillows than in feather pillows.^{10,12}

In addition to mattresses, pillows and doonas or quilts, there are other infant synthetic bedding items such as cocoons/baby nests that might influence asthma development or symptoms. Cocoons are similar to a padded sleeping bag with a hood that comes close to the sides of the baby's head, fully encasing the infant, leaving only the face exposed (Fig. 1). While lying within the cocoon, the infant is then placed on a flat surface or in the cot or pram. A pillow is usually not used in conjunction with a cocoon nor, unless it is exceptionally cold, would it be necessary to place an additional covering on top of an infant lying within a



Figure 1. Infant cocoon.

cocoon. If attached, straps allow the cocoon to be hand carried or tied against the mother's chest. Infants placed in cocoons or baby nests may spend prolonged periods of time with their airways in closer proximity to the cocoon material than if placed on a pillow and/or covered with a quilt, potentially increasing any adverse effect on health mediated by close proximity. There is currently no specific advice with regard to asthma prevention and the use of cocoons containing synthetic materials in infancy.

In this prospective study, we examine the relationship between the use of cocoons/baby nests in infancy and the subsequent development of wheeze in childhood.

Methods

The Tasmanian Infant Health Survey (TIHS)

The TIHS was a cohort study of infants born over an 8-year period 1988–95 in Tasmania, Australia. This study operated from hospitals where approximately 93% of births in Tasmania occurred. Newborn infants were scored to assess the risk of sudden infant death syndrome (SIDS) using perinatal entry criteria based on maternal age, birthweight, gender, breast feeding, season of birth and duration of second stage of labour.¹³ Infants exceeding a scoring cut-off were eligible for inclusion together with all multiple births. The eligibility criteria and study methods are discussed in more detail elsewhere.¹⁴ From 1988 to 1995, a total of 9826 (89%) of eligible infants participated in hospital and home interviews.

Data were obtained on three occasions. The first interview was conducted in hospital on the fourth day of the infant's life. A home interview was conducted during the fifth postnatal week, and a telephone interview at approximately 10 weeks postnatally. At the home interview, data were collected on a number of parental, infant, environmental and child-care factors. Data were collected on the infant's sleeping environment, including type of pillow, mattress coverings, mattress types and bed. Use of a cocoon at time of interview or intention to use a cocoon in cold weather was recorded, thereby avoiding the effect of current season when interviewed. In 1994, further details regarding cocoons and sleeping bags were collected. At least 84% of cocoons were noted to be either quilted or padded by the research nurse at the 1 month home interview. In addition, infant cocoons manufactured and sold in Southern Tasmania during the study period most commonly comprised outer coverings of cotton or polycotton with a polyester (synthetic) filling.

The 1995 Childhood Asthma Survey

In 1995, a cross-sectional survey was conducted on all children who turned 7 years of age in Tasmania. This survey included 863 (78%) of the 1111 children who were born in 1988 and participated in the TIHS home interview. Children were identified through primary schools, home learning and distance education organisations. Data included sleeping environment and asthma symptoms, using questions from the International Study of Asthma and Allergies in Childhood.¹⁵ The child's age (in completed years) at onset of wheezy breathing or asthma was obtained. We linked the 1995 asthma data of the 863 children for whom a home interview had occurred at 1 month of age in 1988 as part of the TIHS (Fig. 2).

Definitions

Recent wheeze refers to one or more wheeze episodes over the past 12 months. *Nocturnal wheeze* is defined as the child's sleep being disturbed one or more nights per week in the past 12 months due to wheezing. In accordance with ISAAC terminology, a *history of asthma* refers to a positive response to the question, 'Has your child ever had asthma?'¹⁵ A *family history of asthma* was defined as asthma in any of the infant's siblings, parents or grandparents.

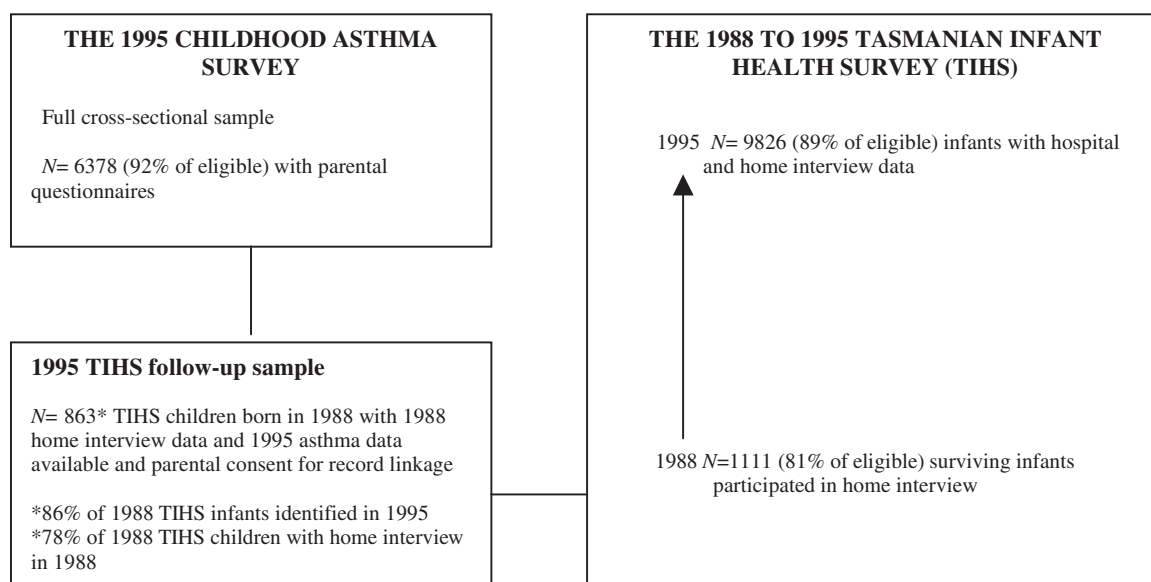


Figure 2. The relation between the Tasmanian Infant Health Survey and the 1995 Childhood Asthma Survey.

Statistical methods

The bedding exposure variable of interest was cocoon use in infancy and was dichotomous for exposure or no exposure. The dichotomous outcome variables were the child's recent wheeze, night wheeze or asthma ever. A generalised linear model with a log link function and binomial error structure was used to control simultaneously for multiple confounders and to obtain confidence intervals for relative risk (RR) estimates.¹⁶

To identify potential confounders, we examined the association between a large number of factors and childhood wheeze (Table 1). We further examined how these factors related to cocoon bedding. We examined more than 40 confounders to see how they each related separately to cocoon use and wheeze. A generalised linear model was then constructed as follows. Each potential confounder¹⁷ was individually added to the model as a covariate if the variable was associated with wheeze in the exposure to outcome analysis, or had been reported to be related to asthma in the literature. We examined the confounding effect of these factors on the exposure-disease association using change-in estimate methods.¹⁸ Those factors that altered the point estimate for the exposure-wheeze association by 10% or more were included in the final model. In addition, we then added in the remaining variables in Table 1 as individual factors into the final model. None of these factors altered the adjusted risk ratios reported in

Table 2 and were not retained in the final confounder set.

Pearson chi-square test was used to explore further the possible associations between the explanatory variables. Logistic regression was not used because in asthma epidemiological studies, where the proportion of the children with the disease is large, odds ratios will not approximate RRs well.¹⁹ We assessed the relation between infant cocoon use and age of onset of asthma symptoms using discrete proportional hazard modelling.²⁰ The aetiological fraction of asthma in childhood attributable to cocoon use in infancy we calculated as $p(aRR - 1)/aRR$, where p denotes the proportion of children with cocoon use in infancy among those with the outcome of asthma and aRR equals the RR estimate for cocoon use and asthma, after adjustment for the confounders listed in Table 2. We conducted the analysis using statistical software, STATA 7.0.²¹

Results

The 863 subjects (78%) of the TIHS cohort who had a home interview agreed to participate. In 1995 their mean age was 6.9 years (standard deviation = 0.6). Data were available for recent wheeze, night wheeze and asthma ever on 823, 834 and 863 children, respectively. Data on use of cocoon in infancy was available on 802 children. The prevalences of asthma ever and recent wheeze were high, 32.4% (280/863) and 27.0%

Table 1. Identification of potential confounders: unadjusted relative risk (RR) for infant cocoon use and childhood wheeze

	Recent wheeze in 1995 Unadjusted RR [95% CI]	P-value	Cocoon use in infancy Unadjusted RR [95% CI]	P-value
Exposure variables				
Cocoon	2.00 [1.29, 3.12]	0.002	–	
Potential confounding variables				
<i>Parental factors</i>				
Mother smoked during pregnancy	1.41 [1.12, 1.77]	0.003	2.33 [0.89, 6.07]	0.083
Teenage motherhood ^a	1.19 [0.90, 1.56]	0.225	0.86 [0.26, 2.93]	0.814
Family history of asthma at child's birth	1.50 [1.20, 1.88]	<0.001	1.31 [0.53, 3.22]	0.557
Family history of asthma in 1995	2.27 [1.72, 2.99]	<0.001	3.55 [1.03, 12.26]	0.045
Low maternal education at child's birth	1.13 [0.63, 2.03]	0.678	0.66 [0.14, 3.16]	0.602
Low paternal education at child's birth	1.24 [1.04, 1.93]	0.023	0.77 [0.27, 2.18]	0.618
Maternal postnatal smoking at 1 month	1.38 [1.10, 1.73]	0.006	2.66 [1.02, 6.92]	0.037
Maternal smoking at child age 7	1.45 [1.15, 1.81]	0.001	4.42 [1.45, 13.44]	0.004
Duration of second stage labour (5, 15 vs. 0, 5 min) ^a	1.09 [0.85, 1.39]	0.497	2.15 [0.88, 5.22]	0.084
Duration of second stage labour (CS vs. 0, 5 min) ^a	1.00 [0.75, 1.34]	0.989	0.25 [0.03, 1.84]	0.136
Season of birth (May–Jun vs. Mar–Apr) ^a	1.12 [0.88, 1.43]	0.344	0.62 [0.21, 1.86]	0.393
Season of birth (Aug–Feb vs. Mar–Apr) ^a	1.02 [0.81, 1.28]	0.854	2.80 [1.07, 7.29]	0.028
<i>Infant factors</i>				
Male sex ^a	1.42 [1.08, 1.88]	0.010	0.90 [0.35, 2.33]	0.825
Infant first born	1.06 [0.85, 1.33]	0.604	0.50 [0.18, 1.37]	0.166
Low birthweight ^a	0.99 [0.75, 1.30]	0.916	0.64 [0.19, 2.17]	0.467
Intention to bottle feed at birth ^a	1.26 [1.01, 1.58]	0.045	1.79 [0.73, 4.40]	0.199
Multiple births ^a	0.89 [0.62, 1.27]	0.504	0.77 [0.18, 3.30]	0.726
Prematurity	1.06 [0.80, 1.41]	0.673	0.53 [0.12, 2.27]	0.382
Solid food introduced, by phone interview at 10 weeks	1.30 [1.04, 1.72]	0.024	1.36 [0.56, 3.31]	0.494
Infant exclusively breast fed, by phone interview at 10 weeks	0.67 [0.49, 0.92]	0.009	0.18 [0.02, 1.36]	0.060
<i>Childhood factors</i>				
History of eczema	1.75 [1.39, 2.20]	<0.001	1.76 [0.68, 4.56]	0.240
History of hay fever	2.87 [2.34, 3.52]	<0.001	2.03 [0.79, 5.26]	0.137
History of bronchitis	2.58 [2.08, 3.21]	<0.001	1.46 [0.55, 3.89]	0.452
History of pneumonia	1.87 [1.40, 2.50]	<0.001	–	
Child's fish consumption vs. none	0.76 [0.57, 1.02]	0.082	0.75 [0.22, 2.54]	0.642
No siblings in 1995	1.68 [1.18, 2.38]	0.009	–	
<i>Household factors</i>				
Private health insurance at birth	0.71 [0.55, 0.91]	0.005	0.90 [0.36, 2.27]	0.827
Home gas appliance use in infancy	1.25 [0.73, 2.16]	0.439	1.79 [0.25, 12.89]	0.559
No-one smoking in same room as infant	0.72 [0.56, 0.93]	0.009	0.60 [0.22, 1.65]	0.317
More than six residents in household at birth	0.90 [0.65, 1.26]	0.549	0.68 [0.16, 2.90]	0.599
Cat as pet during infancy	1.09 [0.86, 1.37]	0.491	0.53 [0.18, 1.59]	0.249
Paternal full-time employment at child age 7	0.91 [0.72, 1.15]	0.446	0.77 [0.31, 1.93]	0.573
<i>Bedroom factors – infant</i>				
Use of foam pillow at age 1 month	1.27 [0.92, 1.75]	0.159	2.19 [0.74, 6.44]	0.149
Infant sleeping in bedroom alone	0.84 [0.65, 1.09]	0.180	0.44 [0.13, 1.49]	0.171
Carpet in infant's bedroom	0.89 [0.62, 1.28]	0.535	0.30 [0.11, 0.80]	0.013
Humidity in infant's bedroom >75%	1.22 [0.79, 1.88]	0.389	0.87 [0.12, 6.35]	0.888
Window in infant's bedroom open at night	1.05 [0.83, 1.32]	0.690	1.26 [0.52, 3.05]	0.616
Sheepskin underbedding	0.99 [0.78, 1.27]	0.962	0.12 [0.02, 0.91]	0.014
Plastic mattress liner	0.99 [0.79, 1.25]	0.933	0.88 [0.35, 2.22]	0.792
Foam mattress as infant	1.05 [0.83, 1.33]	0.705	1.58 [0.58, 4.35]	0.367

Table 1. Continued

	Recent wheeze in 1995 Unadjusted RR [95% CI]	P-value	Cocoon use in infancy Unadjusted RR [95% CI]	P-value
Use of feather quilt	0.74 [0.21, 2.57]	0.619	–	
Use of synthetic quilt	1.05 [0.84, 1.33]	0.654	0.19 [0.06, 0.65]	0.003
Use of feather pillow	0.94 [0.35, 2.51]	0.894	3.98 [0.58, 27.28]	0.141
Use of synthetic pillow	1.29 [0.97, 1.72]	0.086	1.51 [0.51, 4.48]	0.455
Use of air freshener in infant's bedroom	1.52 [1.04, 2.22]	0.047	4.25 [1.47, 12.30]	0.005
<i>Bedroom factors – child</i>				
Sleeping on bottom bunk as child	1.11 [0.81, 1.52]	0.509	–	
Use of feather quilt	0.85 [0.68, 1.07]	0.166	0.51 [0.20, 1.33]	0.158
Use of synthetic quilt	1.29 [1.03, 1.61]	0.027	3.06 [1.18, 7.97]	0.016
Use of feather pillow	0.86 [0.53, 1.38]	0.516	0.70 [0.09, 5.14]	0.722
Use of synthetic pillow	1.04 [0.71, 1.54]	0.825	0.58 [0.17, 1.95]	0.375
Carpet in child's bedroom	0.93 [0.58, 1.49]	0.755	0.49 [0.12, 2.06]	0.322

^aThe cohort entry scoring system was based on a composite score derived from these factors.¹³ Multiple births were automatically included.

(222/823), respectively. The prevalence of night wheeze was 19.2% (160/843) and cocoon use in infancy 2.4% (19/802).

Table 1 shows that cocoon use in infancy was associated with recent wheeze in childhood (RR = 2.00 [95% CI 1.29, 3.12]). The use of a cocoon in infancy was associated with both night wheeze (RR = 2.27 [95% CI 1.31, 3.93]) and history of asthma ever (RR = 1.63 [95% CI 1.05, 2.53]) in childhood.

To identify potential confounders, we examined how each factor related separately to the use of cocoon in infancy and also to recent wheeze. The infant factors of most relevance are summarised in Table 1. Potential confounders included: small sibling size,²² infant and child exposure to tobacco smoke²³ and home gas heating,²³ infant synthetic pillow use,²⁴ sheepskin use and

season of birth. An at-birth family history of asthma was not significantly associated with cocoon use in infancy; however, it was related to subsequent development of recent wheeze (RR = 1.50 [95% CI 1.20, 1.88]). Both childhood and infant exposure to maternal smoking were associated with wheeze. In fact, 88% of mothers who smoked when their infant was 1 month of age, were still smoking when their child was aged 7 years. The association between infant and childhood maternal tobacco smoke exposure was highly significant ($P = 0.0001$).

The association between cocoon use and recent wheeze remained after adjustment for the perinatal entry criteria as either individual factors or as a set. Adjustment for mattress type and mattress cover type, including sheepskin or plastic mattress cover, had lit-

Table 2. The association between cocoon use in infancy and asthma symptoms in childhood

Respiratory symptom in 1995	<i>n</i>	Cocoon use in infancy	%	RR [95% CI] for cocoon use and respiratory symptom	P-value	aRR [95% CI] for cocoon use and respiratory symptom	P-value
No wheeze	559	9	1.6	1.00 [Reference]		1.00 [Reference]	
Recent wheeze	196	10	5.1	2.00 [1.29, 3.12]	0.002	4.33 [2.08, 9.02]	<0.001 ^a
No night wheeze	626	11	1.8	1.00 [Reference]		1.00 [Reference]	
Night wheeze	148	8	5.4	2.27 [1.31, 3.93]	0.003	3.35 [1.52, 7.39]	0.003 ^b
No asthma ever	539	9	1.7	1.00 [Reference]		1.00 [Reference]	
Asthma ever	262	10	3.8	1.63 [1.05, 2.53]	0.029	2.56 [1.33, 4.92]	0.005 ^c

^{a,b,c}Adjusted for family history of asthma at birth, home gas appliance use in infancy, synthetic quilt use in infancy, synthetic pillow use in infancy, maternal education at birth, maternal smoking at infant 1 month age, no other siblings in 1995. CI, confidence interval.

the effect but additional adjustment for synthetic quilt or pillow use in infancy further increased the association between cocoon use and childhood wheeze (adjusted RR [aRR] = 4.33 [95% CI 2.08, 9.02]) (Table 2). Similarly, the association remained significant between the use of cocoon in infancy and night wheeze (aRR = 3.35 [95% CI 1.52, 7.39]), and with a history of asthma (aRR = 2.56 [95% CI 1.33, 4.92]) (Table 2). The population attributable fraction for recent wheeze in childhood associated with cocoon use in infancy was 4.3%.

We examined the association with family and childhood history of atopic disease. Further adjustment for at-birth family history of asthma did not alter the results in Table 2, and the positive association with cocoon use in infancy and recent wheeze remained significant after adjustment for the child's history of eczema and asthma, and also the family history of asthma in 1995. These positive associations persisted after adjustment for the factors listed in Table 2 and individual adjustment for over 40 possible confounders including those listed above. The parents of infants with an at-birth family history of asthma were not selectively using cocoons (42.1% use vs. 35.6% non-use, $P = 0.56$). Exposure to cocoon was positively associated with recent wheeze (RR = 2.56 [95% CI 1.45, 4.51] $P = 0.001$) even among children without an at-birth family history of asthma. The use of cocoon in infancy did not relate to age of onset of wheeze (aRR = 0.83 [95% CI 0.30, 2.31]) overall nor to wheeze frequency subgroups of moderate (4–12) or frequent (>12) episodes of wheeze.

Discussion

In this birth cohort, the use of cocoon/baby nests in infancy was associated with an increased risk of recent wheeze and nocturnal wheeze in childhood. Close proximity to the airways combined with the infant's prolonged exposure to the cocoon material may have contributed to this finding. The prospective association remained after adjustment for other synthetic bedding items in infancy. Our findings indicate that atopic children were not preferentially using or avoiding the use of cocoons as evidenced by the lack of association with eczema and rhinitis in infancy and an at-birth family history of asthma. The adverse role of synthetic bedding on asthma has been demonstrated in previous studies; however, currently there is no evidence with

regard to the use of cocoons containing synthetic materials in infancy.

The strengths of this study include the availability of prospective infant data, a high participation rate and the ability to control for multiple confounders, including bedding variables and other potential confounding factors operating in either infancy or childhood. The study sample was not representative of all live births in the geographical area; it consisted of infants born at higher risk of SIDS.¹⁴ The eligibility criteria were well defined and the potential effects of the entry scoring system components were taken into account in the multivariate analyses. After controlling for the factors listed in Table 2, further adjustment for these perinatal entry criteria did not alter the results. Thus the TIHS cohort entry criteria are unlikely to affect the generalisability of these results. The children in this study should not differ from other children to any large extent with regard to the biological development of asthma.

As the exposure was measured prospectively and was independent of disease awareness, there was no recall bias. At the time of assessment for wheeze, the nurse was also unaware of the infant bedding status. The results are not likely to be influenced by differential follow-up as the proportion of TIHS children followed up from infancy did not differ by whether they used a cocoon or not. Cocoons manufactured and sold during the study period most commonly comprised synthetic materials. However some infants may have been exposed to cocoons made of natural materials. This could lead to misclassification of the dichotomous exposure. This misclassification would be likely to be non-differential¹⁷ and therefore, if present, it would reduce the study's ability to detect the effect of cocoon use on wheeze.

Confounding, including that due to infant or child exposure to maternal smoking or family history of asthma, could not explain the identified associations. We included only one variable for maternal smoking, when infant was aged 1 month, as a potential confounder in the final model due to the high collinearity between this variable and the variable for maternal smoking when child was aged 7 years. Limitations of this study included the use of a parental questionnaire and the absence of a biological or physician assessment of asthma. The ISAAC questionnaire, however, is considered a valid instrument for the determination of current asthma symptoms in the past 12 months; the report of 'wheeze' over the past 12 months has a sen-

sitivity of 0.85 and a specificity of 0.81 for the physician diagnosis of asthma in childhood.²⁵ The prospective findings in this study were, however, based on a small number of exposed children and further studies are required to confirm these findings. It is important to note that no study to date has shown a lower wheeze prevalence with exposure to synthetic bedding.¹⁻⁴ Moreover, we have previously reported²⁴ that the association between synthetic upper bedding and frequent wheeze in childhood displayed the features of high strength of association, temporality, dose-response and consistency.¹⁷

Cocoons provide an intimate and prolonged relationship between the cocoon material and the infant's breathing zone. Thus one possibility for the effect noted in this study is that exposure to dust mite allergen in synthetic cocoons could contribute to the increased development of wheeze in children. Bedding items may be particularly relevant to the development or triggering of asthma symptoms due to their proximity to the airway and their prolonged periods of exposure in addition to bedding allergen levels. Air sampling has identified that the bed is a major site of exposure to HDM allergens with airborne HDM allergen levels shown to be 10-fold higher during sleep than in the living room during the day.²⁶ Exposure to HDM allergen is a factor in triggering attacks of asthma in asthmatic subjects,²⁷ with a clear dose-response relation demonstrated between levels of Der p 1 in the home and current asthma symptoms.^{28,29}

Two population-based case-control studies³⁰ investigated the association between childhood wheeze in schoolchildren 7-8 years of age and changes in the home environment between 1978 and 1991 in Croydon, London. The study found that of the potential indoor environmental risk factors examined, the increasing use of non-feather pillows (from 44% in 1978 to 67% in 1991) explained greater than half of the 20% increase in the population prevalence odds of current wheeze (OR = 1.20 [95% CI 1.04, 1.39]). The use of non-feather pillows was positively associated with childhood wheeze (OR = 1.54 [95% CI 1.13, 2.10]). A case-control study of children in Sheffield, UK,³¹ found that pillows with synthetic fillings were a risk factor for severe childhood asthma (OR = 2.78 [95% CI 1.89, 4.17]), after the exclusion of asthmatic subjects whose bedding had been changed because of their disease. These results prompted speculation that the increase in the use of non-feather pillows contributed to the increasing exposure to HDMs, which in turn could

have been partly responsible for the increase in childhood wheezing.³² In a cross-sectional study of children in Canberra, Australia, synthetic quilt use was associated with asthma (AOR = 1.67 [95% CI 1.05, 2.65]) and recent wheeze (AOR = 2.11 [95% CI 1.33, 3.34]) among SPT-positive to aeroallergens, including Der p, children but not SPT-negative children.³³

These results support the view that if the adverse respiratory effect of synthetic bedding such as cocoons, is mediated by the previously documented higher HDM allergens found in synthetic bedding,¹⁰⁻¹² this adverse effect would be more evident among children who were sensitised to aeroallergens rather than non-sensitised children.

Other mechanisms, related to bedding items, may be contributing to childhood wheezing. An increased risk of asthma related to the indoor emissions of volatile organic compounds (VOCs) has been demonstrated in children and adults,³⁴⁻³⁶ and VOCs released in low concentrations close to the breathing zone might increase mucosal permeability to inhaled allergens³¹ or promote sensitisation to HDM within the household environment similar to that which has been observed for indoor gas heating³⁷ or other infant bedding materials.³⁸ Exposure to house dust endotoxin may protect against the development of atopy by enhancing Th1 responses.³⁹ A study⁴⁰ of 61 infants with a high risk for developing asthma in Colorado, USA, showed that allergen sensitised infants had significantly lower house dust endotoxin levels than non-sensitised infants. However recent reports⁴¹ that endotoxin levels were not significantly different between synthetic and feather pillows makes this a less likely mechanism of action. The exposure to the bedding environment may be further increased as the infant is often transported from the bed to other locations while still remaining within the cocoon. In addition, with the close proximity of the synthetic cocoon material to the infant's airway it is likely that exposure to bedding-related factors such as allergens, VOCs or endotoxins occurs in a continuous low dose fashion.

In conclusion, this study adds to the increasing evidence for a role for bedding items in the development of childhood asthma. Our findings suggest that synthetic cocoon use in infancy is associated with an increased subsequent risk of child asthma. However, the number of children exposed to cocoons in this cohort study was small and further studies are now required to confirm these findings. The contribution of infant bedding to the increasing problem of childhood

asthma must be more clearly determined in view of the implications of bedding modification for both primary and secondary preventative measures for childhood asthma.

Acknowledgements

We thank the parents, infants and children who participated in these studies, the research staff for data collection and collation, and the hospitals participating in the infant cohort study. We thank the participating schools, the Department of Education, the Department of Cultural and Community Development, and the Catholic Education Office.

The TIHS was supported by the US National Institutes of Health Grant 001HD28979-01A1, Tasmanian State Government, Australian Rotary Health Research Fund, National Health and Medical Research Council of Australia, National Sudden Infant Death Syndrome Council of Australia, Sudden Infant Death Research Foundation of Victoria, and other constituent organisations, Community Organisations' Support Program of the Department of Human Services and Health, Zonta International, Wyeth Pharmaceuticals, and Tasmanian Sanatoria After-Care Association. Dr Ponsonby held a National Health and Medical Research Council PHRDC Fellowship. The Public Health Research and Development Committee of the National Health and Medical Research Council, Australia funded the asthma study. Part of the analysis of this project was supported by a donation from Coles Supermarkets to the Canberra Region Medical Foundation.

References

- Zacharasiewicz A, Zidek T, Haidinger G, Waldhor T, Suess G, Vutuc C. Indoor factors and their association to respiratory symptoms suggestive of asthma in Austrian children aged 6–9 years. *Wiener Klinische Wochenschrift* 1999; **111**:882–886.
- Yemaneberhan H, Bekele Z, Venn A, Lewis S, Parry E, Britton J. Prevalence of wheeze and asthma and relation to atopy in urban and rural Ethiopia. *Lancet* 1997; **350**:85–90.
- Karaman O, Uguz A, Uzuner N. Risk factors in wheezing infants. *Pediatrics International* 1999; **41**:147–150.
- Nafstad P, Nystad W, Jaakkola JJ. The use of a feather quilt, childhood asthma and allergic rhinitis: a prospective cohort study. *Clinical and Experimental Allergy* 2002; **32**:1150–1154.
- Sears MR, Herbison GP, Holdaway MD, Hewitt CJ, Flannery EM, Silva PA. The relative risks of sensitivity to grass pollen, house dust mite and cat dander in the development of childhood asthma. *Clinical and Experimental Allergy* 1989; **19**:419–424.
- Platts-Mills TA, Rakes G, Heymann PW. The relevance of allergen exposure to the development of asthma in childhood. *Journal of Allergy and Clinical Immunology* 2000; **105** (2 Pt 2):S503–S508.
- Tovey ER, Chapman MD, Wells CW, Platts-Mills TA. The distribution of dust mite allergen in the houses of patients with asthma. *American Review of Respiratory Disease* 1981; **124**:630–635.
- Moscato G, Perfetti L, Galdi E, Pozzi V, Minoia C. Levels of house-dust-mite allergen in homes of nonallergic people in Pavia, Italy. *Allergy* 2000; **55**:873–878.
- Hallam C, Custovic A, Simpson B, Houghton N, Simpson A, Woodcock A. Mite allergens in feather and synthetic pillows. *Allergy* 1999; **54**:407–408.
- Kemp TJ, Siebers RW, Fishwick D, O'Grady GB, Fitzharris P, Crane J. House dust mite allergen in pillows. *British Medical Journal* 1996; **313**:916.
- Crane J, Kemp T, Siebers R, Rains N, Fishwick D, Fitzharris P. Increased house dust mite allergen in synthetic pillows may explain increased wheezing. *British Medical Journal* 1997; **314**:1763–1764.
- Hallam C, Custovic A, Simpson B, Houghton N, Simpson A. House dust mite allergen in feather and synthetic pillows. *Allergy* 1998; **53** (Suppl. 43):27.
- d'Espaignet ET, Dwyer T, Newman NM, Ponsonby AL, Candy SG. The development of a model for predicting infants at high risk of sudden infant death syndrome in Tasmania. *Paediatric and Perinatal Epidemiology* 1990; **4**:422–435.
- Dwyer T, Ponsonby AL, Newman NM, Gibbons LE. Prospective cohort study of prone sleeping position and sudden infant death syndrome. *Lancet* 1991; **337**:1244–1247.
- ISAAC. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. The International Study of Asthma and Allergies in Childhood (ISAAC) steering committee. *Lancet* 1998; **351**:1225–1232.
- Breslow NE, Day N. *Statistical Methods in Cancer Research. Volume 2 – The Design and Analysis of Cohort Studies*. Lyon: International Agency for Research on Cancer, 1987; pp. 135–142.
- Rothman KJ, Greenland S. *Modern Epidemiology*, 2nd edn. Philadelphia: Lippincott-Raven, 1998; pp. 123–125.
- Greenland S. Modeling and variable selection in epidemiologic analysis. *American Journal of Public Health* 1989; **79**:340–349.
- Armitage P, Berry G. *Statistical Methods in Medical Research*, 3rd edn. Oxford: Blackwell Scientific Publications, 1994; pp. 422–436.
- Jenkins SP. Easy estimation methods for discrete-time duration models. *Oxford Bulletin of Economics and Statistics* 1995; **57**:129–138.
- StataCorp. *Stata Statistical Software Release 7.0*. College Station, TX: Stata Corporation, 1999.
- Ponsonby AL, Couper D, Dwyer T, Carmichael A. Cross sectional study of the relation between sibling number and asthma, hay fever, and eczema. *Archives of Disease in Childhood* 1998; **79**:328–333.

- 23 Ponsonby AL, Couper D, Dwyer T, Carmichael A, Kemp A, Cochrane J. The relation between infant indoor environment and subsequent asthma. *Epidemiology* 2000; **11**:128–135.
- 24 Ponsonby AL, Dwyer T, Kemp A, Cochrane J, Couper D, Carmichael A. Synthetic bedding and wheeze in childhood. *Epidemiology* 2003; **14**:37–44.
- 25 Jenkins MA, Clarke JR, Carlin JB, Robertson CF, Hopper JL, Dalton MF, *et al.* Validation of questionnaire and bronchial hyperresponsiveness against respiratory physician assessment in the diagnosis of asthma. *International Journal of Epidemiology* 1996; **25**:609–616.
- 26 Sakaguchi M, Inouye S, Yasueda H, Shida T. Concentration of airborne mite allergens (Der I and Der II) during sleep. *Allergy* 1992; **47**:55–57.
- 27 Sporik R, Chapman MD, Platts-Mills TA. House dust mite exposure as a cause of asthma. *Clinical and Experimental Allergy* 1992; **22**:897–906.
- 28 Peat JK, Tovey E, Toelle BG, Haby MM, Gray EJ, Mahmic A, *et al.* House dust mite allergens. A major risk factor for childhood asthma in Australia. *American Journal of Respiratory and Critical Care Medicine* 1996; **153**:141–146.
- 29 Custovic A, Taggart SC, Francis HC, Chapman MD, Woodcock A. Exposure to house dust mite allergens and the clinical activity of asthma. *Journal of Allergy and Clinical Immunology* 1996; **98**:64–72.
- 30 Butland BK, Strachan DP, Anderson HR. The home environment and asthma symptoms in childhood: two population based case-control studies 13 years apart. *Thorax* 1997; **52**:618–624.
- 31 Strachan DP, Carey IM. Home environment and severe asthma in adolescence: a population based case-control study. *British Medical Journal* 1995; **311**:1053–1056.
- 32 Custovic A, Woodcock A. Feather or synthetic? That is the question. *Clinical and Experimental Allergy* 1999; **29**:144–147.
- 33 Ponsonby AL, Gatenby P, Glasgow N, Mullins R, Hurwitz M, McDonald T. The association between synthetic bedding and adverse respiratory outcomes among skin-prick test positive and skin-prick test negative children. *Allergy* 2002; **57**:247–253.
- 34 Jaakkola JJ, Oie L, Nafstad P, Botten G, Samuelsen SO, Magnus P. Interior surface materials in the home and the development of bronchial obstruction in young children in Oslo, Norway. *American Journal of Public Health* 1999; **89**:188–192.
- 35 Norback D, Bjornsson E, Janson C, Widstrom J, Boman G. Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. *Occupational and Environmental Medicine* 1995; **52**:388–395.
- 36 Wieslander G, Norback D, Bjornsson E, Janson C, Boman G. Asthma and the indoor environment: the significance of emission of formaldehyde and volatile organic compounds from newly painted indoor surfaces. *International Archives of Occupational and Environmental Health* 1997; **69**:115–124.
- 37 Ponsonby AL, Dwyer T, Kemp A, Couper D, Cochrane J, Carmichael A. A prospective study of the association between home gas appliance use during infancy and subsequent dust mite sensitization and lung function in childhood. *Clinical and Experimental Allergy* 2001; **31**:1544–1552.
- 38 Trevillian LF, Ponsonby AL, Dwyer T, Lim LL, Kemp A, Cochrane J, *et al.* An association between plastic mattress covers and sheepskin underbedding use in infancy and house dust mite sensitization in childhood: a prospective study. *Clinical and Experimental Allergy* 2003; **33**:483–489.
- 39 Martinez FD, Holt PG. Role of microbial burden in aetiology of allergy and asthma. *Lancet* 1999; **354** (Suppl. 2):SII12–15.
- 40 Gereda JE, Leung DY, Thatayatikom A, Streib JE, Price MR, Klinnert MD, *et al.* Relation between house-dust endotoxin exposure, type 1 T-cell development, and allergen sensitisation in infants at high risk of asthma. *Lancet* 2000; **355**:1680–1683.
- 41 Hall K, Crane J, Siebers R. Endotoxin from synthetic and feather pillows. *Journal of Allergy and Clinical Immunology* 2002; **110**:811.