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ORIGINAL ARTICLE

Assessment of pet exposure by self-report in epidemiological studies of allergy and asthma: a systematic reviewChristian Apfelbacher, PhD^{1,2}, Edward Frew, MBBS¹, Ally Xiang, MBBS¹, Alex Apfel, MBBS¹, and Helen Smith, MD¹¹Division of Public Health and Primary Care, Brighton and Sussex Medical School, Brighton, UK and ²Department of Medical Sociology, Institute of Epidemiology and Preventive Medicine, University of Regensburg, Regensburg, Germany**Abstract**

Objective: In epidemiological studies that aim to investigate the relationship between pet exposure and allergy/asthma, pet exposure is often ascertained by means of a questionnaire, but it is unclear which questionnaire items are used. The objective of this study was to systematically review self-reported pet exposure assessment in questionnaires used in epidemiological studies which explore the associations between pets and allergy/asthma. **Methods:** A systematic literature search was conducted in PubMed and papers were selected according to pre-specified eligibility criteria. The pet exposure questions used were classified within a framework including direct pet contact, indirect pet contact (e.g. through carers or grandparents) and avoidance behaviour. Authors were contacted when the questions used were not reported in detail. **Results:** Ninety-six full text papers were systematically reviewed. All studies assessed direct pet contact, but less than half (45%) explicitly assessed whether pets were allowed indoors. The vast majority of studies assessed both pet exposures during the first year of life and after the first year of life. The minority (13%) assessed whether pet(s) were kept at places regularly visited by the child and pet exposure *in utero* (15%). Even fewer studies assessed indirect contact to pets ($n=8$) and avoidance behaviour ($n=10$). **Conclusions:** In epidemiological studies, the ascertainment of pet exposure through questionnaires appears to vary greatly. This variation might partly explain the inconsistent and contradictory results of the effects of pet exposure on the development of allergy and asthma.

Keywords

Allergy, asthma, exposure assessment, epidemiology, pet exposure, questionnaire

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Published online 18 January 2016**Introduction**

Whether pet exposure, especially exposure to cats and dogs in early life, is a protective or a risk factor for the development of atopic disease (asthma, hay fever and eczema) and allergic sensitisation has been a much debated research topic for many years [1,2].

Takkouche et al. investigated the association between exposure to furry pets (cats, dogs and unspecified furry animals) and asthma and allergic rhinitis by meta-analysing data from 32 cohort and case-control studies [3]. Whereas a small protective effect of cat exposure in relation to asthma was found, dog exposure seemed to increase asthma risk. The evidence for unspecified furry animals was inconclusive. A further systematic review also looking at cross-sectional studies included 63 studies the results of which were summarised as contradictory [4]. For instance, while the majority of the birth cohort studies included found no effect of early life cat or dog exposure on incident asthma or wheezing, the majority of prospective studies performed in

school-age children or adults with retrospective exposure assessment found cat exposure to be inversely related to asthma and wheezing. A third systematic review used individual participant data of more than 22 000 children recruited in 11 birth cohort studies in Europe [5]. In pooled analysis, no association was found between pet ownership (cat, dog, bird, rodent and cat/dog combined) in early life and risk of asthma or allergic rhinitis symptoms at age 6–10. However, pet ownership in infancy was inversely associated with sensitisation to aero-allergens.

The conduct of randomised controlled trials to evaluate the effect of pet allergen exposure on the development of asthma or allergy not ethical or feasible, but observational studies of natural variation in pet exposure (magnitude, frequency and duration) are. Besides differing study designs, confounding and selection bias, one reason for this heterogeneity of findings may be information bias originating from the assessment of self-reported pet exposure using questionnaires, often in a retrospective manner.

Previous systematic reviews have focussed on the associations between pet exposures and asthma/allergic diseases. The aim of this study was to systematically review the way in which self-reported pet exposure is assessed by questionnaires in epidemiological studies which

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explore the potential causal associations between pets and allergy/asthma.

Methods

Search strategy

We conducted a systematic literature search in PubMed on 16/04/2012 using the following search algorithm:

(‘‘2000’’[Publication Date]: ‘‘3000’’[Publication Date]) AND
(cross sectional[Title/Abstract] or cohort[Title/Abstract] or case-control[Title/Abstract] or randomised controlled trial[Title/Abstract] or randomized controlled trial[Title/Abstract]) AND
(pet[Title/Abstract] OR animal[title/abstract] OR dog[Title/Abstract] OR cat[Title/Abstract] OR bird[Title/Abstract]) AND
(allergy[Title/Abstract] OR allergic[Title/Abstract] OR wheeze[Title/Abstract] OR asthma[Title/Abstract] OR sensitisation[Title/Abstract] OR sensitization[Title/Abstract] OR allergen[Title/Abstract])
Reference lists were screened for further eligible studies.

Eligibility assessment

Papers were included if the following criteria were met:
(1) study published in peer reviewed journal;
(2) entire paper published in English language;
(3) study collected data of exposure to pets during childhood (0–7 years);
(4) pet exposure was assessed using a questionnaire;
(5) the relationship between pet exposure and allergy or asthma was explored – whether it be an association with disease development or disease control.

Studies that obviously did not meet the inclusion criteria were excluded by inspection of title and abstract. For the remainder, full papers were obtained which were then assessed for eligibility by two reviewers working independently (EF and AX). All conflicts relating to eligibility assessment were resolved through discussions with the first (CA) and/or last (HS) author of this article. If a study reported use of a questionnaire but the questions were not listed in the paper, we wrote to the lead researchers or their department to obtain further information. Where several papers were published that pertained to the same study, only the most recent paper was included in this review.

Data extraction

An analytical framework was developed to record the facets of exposure addressed (e.g. direct contact with pets, indirect contact with pets and avoidance behaviour) and this was used to record the types of questions in each study (Table 1). Data were extracted independently by two reviewers (EF and AX) and recorded on standardised forms which checked eligibility, recorded the exact wording of questions and classified each question according to the analytical framework.

When a conflict about eligibility or data extraction was encountered, these were discussed with CA and HS to achieve consensus. We report absolute and relative frequencies for all

Table 1. Items used to classify pet exposure assessment (yes/no for each item).

Item number	Item content
Direct contact to pets	
1	Pet(s) at home
1a	Number of pets at home
2	Pet(s) allowed indoors
2a	Number of pets allowed indoors
3	Pet(s) allowed within the child’s bedroom
3a	Number of pet(s) allowed within the child’s bedroom
4	Pet(s) owned in places regularly visited
5	Amount of time visiting places with pets
6	Pet exposure <i>in utero</i>
6a	Number of pets <i>in utero</i>
7	Pet exposure during first year of life
7a	Number of pet(s) child is exposed during first year of life
8	Pet exposure after first year of life
8a	Number of pet(s) child is exposed after first year of life
Indirect contact to pets	
9	Pet ownership of those in regular contact with the child
9a	Formal e.g. carer/nanny or informal e.g. grandparents
9b	Contact quantified
Avoidance behaviour	
10	Avoidance of pet ownership due to allergies within the family
11	Getting rid of a pet during pregnancy
12	Getting rid of a pet since the child was born

items of the analytical framework. In addition, we have compared studies assessing pet exposure during the first year of life with studies assessing pet exposure after the first year of life.

Results

Figure 1 illustrates the flow diagram of the processing of the search results, according to the PRISMA statement [6]. The search yielded 449 references. Full text papers were obtained of 155 papers of which 96 were finally included in the systematic review.

All studies assessed direct contact with pets. The vast majority (87%) of these assessed pet contact at home but less than half (45%) of the studies explicitly assessed whether pets were allowed indoors. Few studies assessed the number of pets the children were exposed to at home (16%) or explicitly indoors (16%). Very few assessed whether pets were allowed in the child’s bedroom and no study explicitly assessed the number of pets allowed in the child’s bedroom. Thirteen percent of the studies assessed whether pet(s) were owned in places regularly visited by the child and very few (3%) assessed the amount of time spent visiting these places with pets. Fifteen percent of the studies assessed pet exposure *in utero* but no study assessed the number of pets the mother was exposed to *in utero*. The vast majority of studies assessed both pet exposures during the first year of life and after the first year of life. The number of pets exposed to was assessed in 11 and 17% of the studies that included items on pet

Figure 1. PRISMA flow chart for study selection.

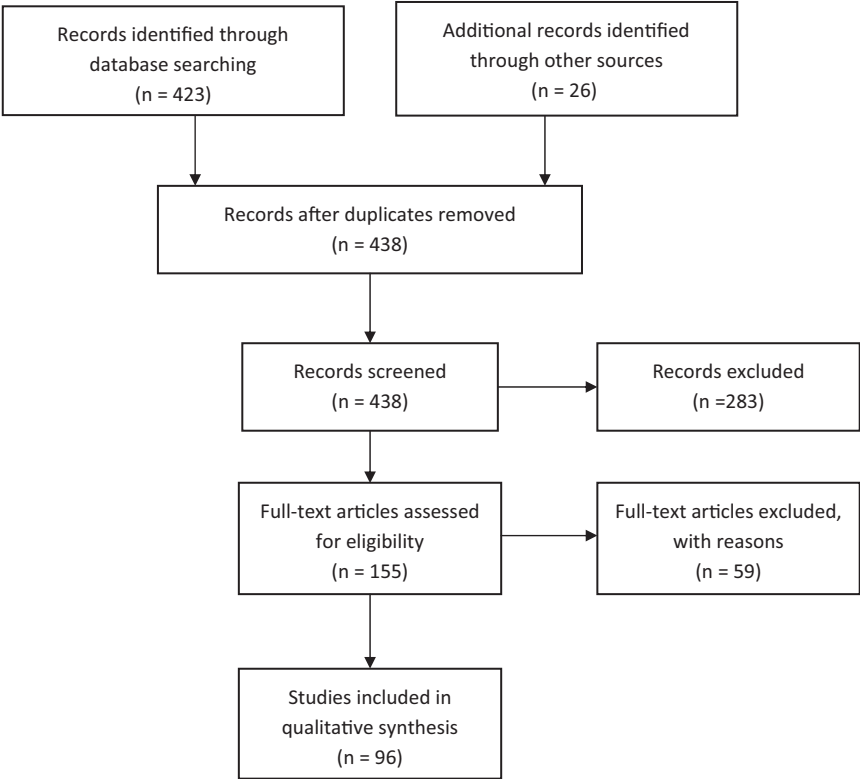


Table 2. Characteristics of studies assessing direct pet contact.

Item	N	n	%
Study assesses pet contact at home	96	83	86.5
If so, study also assesses number of pets	83	13	15.7
Study assesses if pet(s) were allowed indoors	96	43	44.8
Study also assesses number of pets	43	7	16.3
Study assesses that pet(s) were allowed within the child's bedroom	96	5	5.2
If so, study also assesses number of pets	5	0	0
Study assesses pet contact in places regularly visited	96	12	12.5
Study assesses amount of time visiting places with pets	96	3	3.1
Study assesses pet exposure <i>in utero</i>	96	14	14.6
If so, study also assesses number of pets	14	0	0
Study assesses pet exposure during first year of life	96	75	78.1
If so, study also assesses number of pets	75	8	10.7
Study assesses pet exposure after first year of life	96	72	75.0
If so, study also assesses number of pets	72	12	16.7

exposure during the first year of life and after the first year of life, respectively (Table 2).

Eight studies (8% of the total) assessed indirect contact to pets. Five of these assessed pet ownership of those in regular contact with the child, such as a carer or grandparent, but no study attempted to quantify this form of contact.

Ten studies (10% of the total number of studies) assessed pet avoidance. Of these, seven studies assessed avoidance of pet ownership due to allergies within the family. No study assessed discontinuation of pet ownership during pregnancy. However, 9 out of the 10 studies assessed whether families had got rid of a pet after the birth of the index child.

When we compared studies which assessed pet exposure during the first year of life with those who assessed pet exposure after the first year of life, we did find strong differences in the frequency with which items 1–6 were assessed (Table 3). A higher proportion of studies which

assessed pet exposure after the first year of life did assess number of pets with which the child had direct contact. In contrast, a higher proportion of studies that assessed pet exposure during the first year of life did assess pet exposure *in utero*.

Discussion

To the best of our knowledge, this is the first systematic review to focus on how self-reported pet exposure is assessed in epidemiological studies exploring the relationship between pet exposure and asthma/allergy. The findings demonstrate that the assessment of pet exposure in questionnaires is very variable across studies. Some studies ascertain current exposure, while others also capture previous exposure and the intensity of exposure. Some studies collect information on “pets” or “animal” exposures in general while studies

Table 3. Comparison of direct pet exposure assessment between studies assessing pet exposure during and after the first year of life.

Item	Studies assessing pet exposure during first year of life (N = 75) % (N)	Studies assessing pet exposure after first year of life (N = 72) % (N)
Study assesses pet contact at home	88.0 (75)	86.1 (72)
If so, study also assesses number of pets	16.7 (66)	21.0 (62)
Study assesses if pet(s) were allowed indoors	46.7 (75)	50.0 (72)
Study also assesses number of pets	17.1 (35)	19.4 (36)
Study assesses that pet(s) were allowed within the child's bedroom	6.7 (75)	6.9 (72)
If so, study also assesses number of pets	0 (5)	0 (5)
Study assesses pet contact in places regularly visited	13.3 (75)	13.9 (72)
Study assesses amount of time visiting places with pets	4.0 (75)	2.8 (72)
Study assesses pet exposure <i>in utero</i>	18.7 (75)	15.3 (72)
If so, study also assesses number of pets	0 (14)	0 (11)

differentiate between species asking about “cats”, “dogs” and sometimes other pets such as rabbit, hamster or bird. Furthermore few studies acknowledged the concept of “indirect” pet exposure. For example, cat and dog allergen is ubiquitous [7], because cat and dog allergens are dispersed by cat and dog owners into cat- and dog-free environments by means of clothing. Therefore, for an accurate assessment of exposure, it is necessary to look beyond direct contact with pets and assess contact with pet owners too. The minority of studies assessing “indirect” pet contact may have greater validity than those that adopt a limited and less holistic approach. It has been suggested that selective pet avoidance behaviour may introduce selection bias in epidemiological studies looking at the association between pet exposure and allergy. It occurs when pets are selectively avoided because of familial atopy or allergy or early onset of allergic symptoms in a child and may lead to apparent protective effects of animal [8]. It is therefore very important to assess avoidance behaviour but only a minority of studies did assess it.

The strengths of our novel systematic review include the comprehensive search strategy and the rigorous assessment of study eligibility and data extraction by two independent reviewers.

There are at least four aspects of pet exposure assessment that matter [9]:

- Timing of exposure (e.g. *in utero*, in the first year of life or after the first year of life);
- Duration of exposure (number of years or months);
- Dose of exposure (number of pets);
- Type of animal (cat, dog, cat and dog, rodent, etc.).

Viewed against our analytical framework, timing, duration and dose of exposure should encompass both direct and indirect exposure. Assessing these four aspects is important to take into account the two prevailing models of the life-course epidemiology approach [9]. The critical period model assumes that exposure to a certain factor during a specific time window of development leads to disease whereas the cumulative dose model assumes that the cumulative exposure to a factor over time leads to disease [9]. We have assessed timing of exposure (*in utero*, in the first year of life and after the first year of life), dose of exposure (number of pets) and type of pet. We acknowledge that in this review we have not included the assessment of duration of exposure (number of years or months) and this needs to be addressed in future work.

A further limitation of this review is our search strategy, confined to PubMed and articles published in English. However, English is the dominant language for work in this field. The completeness of our review is impaired by authors not reporting the detail of pet exposure assessment in their journal articles and only half of those contacted for further information responding to the requests (47%, N = 38 contact attempts). We may thus have underestimated the detail of the questions asked in reality.

Analysing the relationship between better data collection methodology and the direction of correlations/associations reported in the studies would have been of interest. However, this is a challenging analysis because the studies included in our systematic review are heterogeneous in terms of study design (cross-sectional, case-control and cohort), pet exposure measured and the outcomes measured pertaining to allergy and asthma (as illustrated in Table 4). If one wanted to assess the bias introduced by the different ways in which pet exposure is assessed in questionnaires, one would therefore have to define subsamples of the studies included in this review which are sufficiently homogeneous to conduct meaningful analyses (for instance, only birth cohort studies investigating cat and dog exposure in relation to incident allergic sensitisation or incident asthma). If we then went on to contrast the different pet exposure scenarios, cell counts for these would become very small and being able to draw firm conclusions from such comparisons seems unlikely. Such analyses were not the focus of our systematic review.

In summary, the questions used to assess self-reported exposure to pets in epidemiological studies appear to vary greatly between studies. This variation in precision and validity is likely to introduce noise when the effects of pet exposure on asthma/allergy are investigated. Variations in the ascertainment of exposure may be a factor contributing to the inconsistent and contradictory results of the effects of pet exposure on the development of allergy and asthma. Standardisation of self-reported pet exposure assessment should be aimed for in the future. This requires an international Delphi consensus exercise involving scientific experts from the fields of epidemiology and clinical allergy, as well as those potentially affected, i.e. parents of children with and without allergy/asthma and parents who have got rid of a pet due to atopic predisposition or incident allergy/asthma in the child.

Table 4. List of included studies.

References	Study design	Study population	Pet exposure estimated	Outcome
Al-Mousawi et al. [10]	Case-control	Children (9–16 years)	Cat, dog	Asthma, allergic sensitisation
Almqvist et al. [11]	Birth Cohort	Children (4 years)	Cat, dog	Asthma, allergic sensitisation
Almqvist et al. [12]	Birth cohort	Children (5 years)	Cat, dog	Wheeze, current eczema, FEV1, allergic sensitisation
Anyo et al. [13]	Cross-sectional	Children aged 7–12	Cat, dog, rodent, bird	Diagnoses and symptoms of allergic disease (asthma, hay fever, eczema), doctor-diagnosed pet allergy, bronchial responsiveness, allergic sensitisation
Apfelbacher et al. [8]	Cross-sectional	Children aged 6	Cat, dog	Diagnoses and symptoms of allergic disease (asthma, hay fever, eczema), allergic sensitisation
Arif et al. [14]	Cross-sectional	Children aged 16 or younger	Cat/dog	Asthma, wheezing
Arnedo-Pena et al. [15]	Cross-sectional	Children aged 6–7	Cat, dog, other pets	Asthma, wheeze
Arshad et al. [16]	Birth cohort study	Children aged 4	Cat, dog	Allergic sensitisation
Bjerg-Bäcklund et al. [17]	Cohort	Children aged 7–8 and 11–12	Cat, dog, rabbit/hamster/guinea pig, other furred animal, cage bird, other pet	Current asthma, physician-diagnosed asthma, wheeze last 12 months
Batlles-Garrido et al. [18]	Cross-sectional	Children aged 10–11 years	Cat, dog	Allergic rhinitis
Behrens et al. [19]	Cross-sectional	Children aged 6–7 years	Furry and feathery pets (dogs, cats, rodents and birds)	Asthma and respiratory symptoms
Benn et al. [20]	Cohort	Children aged 18 months	Pets	Atopic dermatitis
Bisgaard et al. [21]	Cohort	Children aged 3 years	Cat/dog	Eczema
Boneberger et al. [22]	Case-control	Children 6–15 years	Cat, dog, rabbit [and farm animals: cattle, horses, pigs, goats, sheep or poultry]	Asthma
Boralevi et al. [23]	Case-control	Children aged 3–12 months	Cat and/or dog	Epicutaneous aeroallergen sensitisation in atopic dermatitis
Bornehag et al. [24]	Cross-sectional	Children aged 1–6 years	Cat, dog, hamster/rabbit, bird, fish	Diagnoses and symptoms of allergic disease (asthma, hay fever, eczema)
Bottema et al. [25]	Pooled birth cohort (data pooled from three birth cohorts)	Children at ages 1, 2, 4 and 8 years	Cat and/or dog	Atopy (total and specific IgE)
Braback et al. [26]	Cross-sectional	Children aged 10–11 years	Cat	Parental questionnaire reports of wheezing, asthma, allergic rhino conjunctivitis, hay fever, eczema
Bufford et al. [27]	Birth cohort	Children aged 3 years	Dog	Atopic dermatitis, wheezing, any allergic sensitisation, dog-specific IgE
Campo et al. [28]	Birth cohort	Children aged 1 year	Bird, cat, dog, aquatic pet, guinea pig, hamster, horse, mouse, rabbit, rat, other furry animal, other farm animal	Wheezing, atopy (defined as positive SPT response to at least one aeroallergen and/or food allergen)
Carlsten et al. [29]	Birth cohort	Children aged 7	Dog	Asthma, bronchial hyper-reactivity
Cazzoletti et al. [30]	Cross-sectional	Adults with asthma 20–44 years	Pet ownership	Asthma severity
Celedon et al. [31]	Birth cohort	Children aged 1–5 years	Cat, dog	Wheezing
Chan-Yeung et al. [32]	Birth cohort	Children aged 7 years	Cat, dog	Asthma
Chen et al. [33]	Birth cohort	Children aged 0–6 years	Cat	Sensitisation to cat allergen, symptoms and physician-diagnoses of allergic disease (eczema, hay fever, wheeze/asthma)
Chen et al. [34]	Two birth cohort	Children up to 6 years of age	Dog	Sensitisation to dog, mixed pollen and inhalant allergen, symptoms and physician-diagnoses of allergic disease (eczema, asthma, allergic rhinitis)
Chen et al. [35]	Case-control nested in four birth cohorts	Children aged 2–4 years	Cat	Sensitisation to cat allergen
Clausen et al. [36]	Cross-sectional	Children aged 10–11 years	Cat, dog	Symptoms and diagnoses of asthma, allergic rhinitis and atopic dermatitis, sensitisation to common allergens (SPT)
Civelek et al. [37]	Cross-sectional	Children aged 10–11 years	Animals	Atopic eczema
De Benedictis et al. [38]	Cross-sectional	Children aged 12–24 months	Cat, dog	Total serum IgE and specific IgE to food and inhalant allergens
De Meer et al. [39]	Cross-sectional	Children aged 8–13 years	Pets (cat or dog)	

(continued)

Table 4. Continued

References	Study design	Study population	Pet exposure estimated	Outcome
Dean et al. [40]	Birth cohort	Children aged 0–3 years	Pet ownership	Symptoms and diagnoses of asthma, allergic rhinitis and atopic dermatitis, sensitisation to common allergens (SPT and RAST)
Demir et al. [41]	Cross-sectional	Children aged 6–14 years	Pet ownership, cat, dog, cat or dog, bird	Sensitisation to food and aeroallergens
Diez et al. [42]	Birth cohort	Children aged 1 and 2 years	Pet ownership	Asthma, wheeze, hay fever, eczema
Dong et al. [43]	Cross-sectional	Children aged 7–13 years	Dog, cat, bird, farm animal, other	Obstructive bronchitis, wheezing
Dong et al. [44]	Cross-sectional	Children aged 3–12 years	House pets	Asthma and asthma-related symptoms (doctor-diagnosed asthma, current asthma, current wheeze, persistent cough, persistent phlegm)
Duramad et al. [45]	Birth cohort	Children aged 2 years	Pet ownership (dogs, cats, birds, others)	Asthma and asthma-related symptoms (persistent cough, persistent phlegm, doctor-diagnosed asthma, current asthma, current wheeze, allergic rhinitis)
El-Sharif et al. [46]	Case-control	Children aged 6–12 years	Dog, cat, furry pets	Doctor-diagnosed asthma, maternal report of wheezing (without a cold), doctor-diagnosed eczema, doctor-diagnosed bronchitis/bronchiolitis, doctor-diagnosed pneumonia
Epstein et al. [47]	(Atopic) Birth Cohort	Children aged 4 years	Dog, cat	Wheezing, asthma
Erwin et al. [48]	Nested case-control	Children aged 10–11 years	Pets, Cat	Eczema
Fasce et al. [49]	Cross-sectional	Children aged 8–12 years	Cat	Wheezing
Garcia et al. [50]	Cross-sectional	Children 6–7 and 13–14 years	Cat, dog	Sensitisation, asthma, rhinitis
Gern et al. [51]	Birth cohort	Children aged 0–1 year	dog, cat, hamster/guinea pig/rabbit, bird, other	Asthma symptoms (wheezing, night cough), asthma attacks, asthma
Govaere et al. [52]	Cross-sectional	Children 3.4–14.8 years	Cat, dog, rabbit, guinea pig, other animal	Allergen-specific and total IgE, eosinophilia, food allergy, atopic dermatitis
Hagendorens et al. [53]	Birth cohort	Children aged 0–1 year	Cat, dog	Eczema
Havstad et al. [54]	Birth cohort	Children aged 0–2 years	Pets, cat, dog	Sensitisation, atopic dermatitis, wheezing
Herr et al. [55]	Birth cohort	Children aged 18 months	Furry pet (cat/dog/rodent)	Total IgE
Hölscher et al. [56]	Three consecutive cross-sectional studies	Children aged 5–14 years	Dogs, cats, rodents, birds	Wheezing severity
Hugg et al. [57]	Cross-sectional	Children aged 7–16 years	Pets, cats, dogs, rodents, birds, farm animals (e.g. cattle, pigs, horses, sheep or poultry)	Allergic diseases (asthma, hay fever, eczema), allergic symptoms (wheezing, rhinitis symptoms, itchy rash), sensitisation (RAST: pollen, mite, cat)
Kalyoncu et al. [58]	Cross-sectional	Students	Pet ownership (cat and/or dog and/or bird)	Allergic asthma
Kerkhof et al. [59]	Birth cohort	Children aged 8 years	Cat, dog	Asthma, current wheeze and seasonal rhinitis
Korppi et al. [60]	Cohort	Children aged 4, 7.2 and 12.3 years	Cat, dog	Asthma, wheeze, dry cough at night, dyspnoea
Kramer et al. [61]	Cohort	Children aged 6.5 years	Pet ownership, farm animals	SPT cat, SPT dog, persistent childhood asthma (PCA)
Kurosaka et al. [62]	Cross-sectional	Children aged 6 years	Cat, dog	Wheezing, hay fever symptoms, recurrent itchy rash, positive SPT
Kurukulaaratchy et al. [63]	Birth cohort	Children aged 0–10 years	Pets, dog	Asthma, atopic dermatitis, allergic rhinitis, Japanese cedar pollinosis
Lampi et al. [64]	Birth cohort	Adults aged 31 years	Cat, dog	Wheeze
Lanphear et al. [65]	Cross-sectional	Children aged 6–16 years	Any pet in the house	Atopic sensitisation (SPT to cat, birch, timothy, house dust mite), allergic diseases (doctor-diagnosed asthma ever, allergic rhinitis, allergic conjunctivitis, atopic eczema)
Lau et al. [66]	Birth cohort	Children aged 0–7 years	Pet ownership	Doctor-diagnosed asthma
				Asthma

(continued)

References	Study design	Study population	Pet exposure estimated	Outcome
Lin et al. [67] Marinho et al. [68] McConnell et al. [69]	Nested case-control study Birth cohort Cohort	Children 5–17 years Children aged 5 years Children (age range not reported)	Any pet in house Cat ownership, dog ownership Cat ownership, dog ownership	Asthma Current rhino conjunctivitis Bronchitic symptoms (chronic cough, phlegm production, bronchitis)
Mgeladze et al. [70] Miller et al. [71] Mitchell et al. [72]	Retrospective case-control Cross-sectional Birth cohort	Children aged 6–10 years Monozygotic twins Children aged 3.5 years; children aged 7 years	Cat Cat, dog Cat, dog, bird	Atopic dermatitis Asthma Wheeze
Morass et al. [73]	Cross-sectional	Children with mean age of 5.5 years	pets	Wheezing in the past 12 months, doctor diagnosed asthma
Myers et al. [74]	Birth cohort	Children followed-up until age 3	Cat, dog	Eczema, allergic sensitisation (SPT)
Nafstad et al. [75]	Birth cohort	Children followed until age 4	Any pet, cat, dog	Bronchial obstruction, asthma, allergic rhinitis, atopic eczema
Naydenov et al. [76]	Cross-sectional	Children aged 2–7 years	Pets, including dog, aquarium fish, cat, bird, rodent	Symptoms in last 12 months: wheezing, rhinitis, rhinitis on pet exposure, eczema; doctor diagnoses: asthma, allergic rhinitis
Oberle et al. [77]	Cross-sectional	Children aged 5–7 years	Dogs, cats, hamsters, guinea pigs, rabbits, birds, fishes	Doctor's diagnosis of asthma, doctor's diagnosis of asthma/atopic asthma, any wheeze in the last 12 months, atopic wheeze in the last 12 months, doctor's diagnosis of hay fever, runny nose and itchy eyes in the last 12 months
Olivieri et al. [78]	Cohort	Adults, mean age 34.5 ± 7.1 years	Cat	Sensitisation to cat (cat-specific IgE)
Oryszczyn et al. [79]	Case-control	Adults (mean age cases: 39.8 ± 13.4 years; mean age controls: 42.1 ± 12.7 years)	Cat, dog	Allergy markers (total IgE, specific IgE and SPT to common aeroallergens, eosinophilia)
Ownby et al. [80]	Birth cohort	Children with a mean age of 6.7 years	Cat, dog	Atopy (SPT positivity to six common aeroallergens), seroatopy (positive allergen-specific IgE test for same six common aeroallergens)
Pekkanen et al. [81]	Birth cohort	Adults aged 31	cat	Atopic asthma (asthma with positive SPT), non-atopic asthma
Perzanowski et al. [82]	Cohort	Children aged 7–8 to 10–11 years	Cat, dog	Ever asthma, physician-diagnosed asthma, wheeze in last 12 months, allergic sensitisation (SPT)
Perzanowski et al. [83]	Birth cohort	Children aged 2, 3 and 5 years	Cat	Anti-cat IgE, current wheeze, current rhinitis
Phipatanakul et al. [84]	Birth cohort	Children in the first year of life	Cat, dog	Physician- or nurse-diagnosed eczema
Piippo-Savolainen et al. [85]	Cohort	Children at ages 3–6 years, 8–10 years, 13.5–16 years, 18–20 years	Cat, dog	Recurrent wheezing, asthma, allergic rhino conjunctivitis
Pohlabeln et al. [86]	Birth cohort	Children aged 2 years	Cat, dog, bird	Symptoms of allergic disease (asthma, eczema, hay fever)
Purvis et al. [87] Remes et al. [88]	Case-control Birth cohort	Children aged 3.5 years Children aged 0–13 years	Cat, dog Cat, dog	Atopic dermatitis Frequent wheezing, allergic sensitisation (SPT, serum total IgE)
Rennie et al. [89] Salam et al. [90]	Case-control Case-control	Children aged 6–13 years Children diagnosed with asthma before age 5 years	Cat, dog Pets	Wheeze, current asthma Physician-diagnosed asthma
Salo et al. [91]	Cross-sectional	Ninth grade students (mean age 15.2 years, SD 0.6 years)	Dog, cat, farm animals (chicken, duck, cow, pigs), other types of animals	Cough without colds in the past 12 months, wheeze in the past 12 months, doctor-diagnosed asthma ever
Sandin et al. [92]	Birth cohort	Children aged 1 and 4 years	Cat, dog	Allergic sensitisation (SPT), transient wheezing, persistent wheezing, late onset wheezing
Sandini et al. [93]	Birth cohort	Children until the age of 5 years	Cat, dog	Allergic disease (food allergy, eczema, asthma or allergic rhinitis), allergic disease with IgE sensitisation, eczema, atopic eczema

(continued)

Table 4. Continued

References	Study design	Study population	Pet exposure estimated	Outcome
Schuttelaar et al. [94]	Birth cohort	Children until the age of 8 years	Cat	(eczema with IgE sensitisation), asthma (IgE associated), allergic rhinitis, respiratory allergy (IgE associated) Allergic sensitisation (assessed by specific IgE level for food and inhalant allergens), atopic eczema (eczema with sensitisation) non-atopic eczema, asthma, hay fever
Shah et al. [95]	Birth cohort	Young adults aged 19–21 years	Pet exposure (cat, dog)	Total IgE, allergen-specific IgE, blood eosinophilia, spirometry, asthma, atopic dermatitis, allergic rhinitis
Smedje & Norback [96]	Cohort	Children aged 7–13 years, followed up over 4 years	Cat, dog, other furry pet	Physician-diagnosed asthma, self-reported allergy
Sorensen et al. [97]	Case–control	Children aged eighteen months	Furred pet	Recurrent wheeze (at least four episodes)
Tamay et al. [98]	Cross-sectional	Children aged between 6 and 12 years	Cat, dog	Allergic rhinitis
Tepas et al. [99]	Birth cohort	Children with a median age of 7.0 years	Cat, dog	Airway hyper-responsiveness (AHR)
Ungar et al. [100]	Retrospective cohort study	Children aged 1–18 years, followed for 1 year	Cat, dog	Asthma ED visits and hospitalisations
Vargas et al. [101]	Cross-sectional	Adults with a median age of 25 years	Cat, dog	Rhinitis, wheeze, asthma attacks, waking with breathlessness, atopy (assessed by SPT), bronchial hyper-responsiveness
Wegienka et al. [9]	Birth cohort	Teenagers followed-up at age 18 years	Cat, dog	Serum total and allergen-specific IgE
Wickens et al. [102]	Cross-sectional	Children aged 7–10 years	Cat, dog, poultry, pigs	Hay fever ever, current allergic rhinitis, asthma ever, current wheeze, AEDS (atopic eczema/dermatitis syndrome) ever, allergic sensitisation (SPT)
Zheng et al. [103]	Case–control	Children aged 6–10 years	Pets: Cat, dog, others; birds, pigeons	Asthma

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Declaration of interest

The authors declare that they have no competing interests.

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