Pet keeping in childhood and asthma and allergy among children in Tianjin area, China

Shugang Luo, Yuexia Sun*, Jing Hou, Xiangrui Kong, Pan Wang, Qingnan Zhang, Jan Sundell

Tianjin Key Lab. of Indoor Air Environmental Quality Control, School of Environmental Science and Engineering, Tianjin University, Tianjin, China

* yuexiasun@tju.edu.cn

Abstract

This study aims to find out the relationship between pet keeping in childhood and asthma and allergy among children aged 0–8 years old in Tianjin, China. Parental or guardians reports of 7360 children were analyzed. 1490 (21.6%) families kept pets at the time of the survey (current), among them 4.0% cats, and 14.7% dogs. For the first year of life of children (early), 1196 (18.4%) families kept pets, and among them 3.2% cats, and 13.7% dogs. Exposure to a pet in early childhood significantly increased the risk of current wheeze, current dry cough, and diagnosed rhinitis. 17.9% of parents reported an avoidance behavior, i.e., had removed or refrained a pet due to asthma or allergy in the family. After adjustment for avoidance behavior, the negative effect of pet keeping on children's health became even more obvious, with e.g. an AOR of 3.37 (1.58–7.19) for diagnosed asthma, 3.60 (2.07–6.27) for diagnosed rhinitis, 1.92 (1.31–2.81) for diagnosed eczema. A dose-response relationship between pet keeping at current and current wheeze, current eczema and diagnosed eczema was found. In conclusion, pet exposure in early life of children in Tianjin is a risk factor for asthma and allergies among children aged 0–8 years old.

Introduction

The impact of pet keeping on the development of allergic diseases is discussed [1]. Some studies support the view that pet keeping in early life decreases the risk of asthma and allergies in children. For example, Hesselmar at al [2] found that exposure to pets during the first year of life decreased the risk of allergic rhinitis at 7–9 years and of asthma at 12–13 years. Ownby et al [3] even found that children exposed to two or more dogs or cats had the lowest prevalence of any skin prick test compared with children exposed to less pets. On the other hand, some studies found that pet keeping in early life of children is significantly positively associated with symptoms in later life. For example, Wahn et al [4] found that children who exposure to higher cat allergen (150 ng/gm vs 64 ng/gm) were more likely to get allergy. Lombardi et al [5] found exposure to cat in the first year of life significantly increased the risk of current wheeze. A Swedish study found that the protective effects of pet exposure were due to avoidance behavior [6], i.e., allergic families intend to remove or refrain from pets.
Most of early studies are based on Western populations or populations of industrialized regions. Some studies also have been conducted in Asia. In 1999, Zheng et al [7] conducted a case-control study in Beijing, China and found that dog or cat keeping was an important risk factor for children’s asthma. In 2001, Salo et al [8] conducted a study in Wuhan, China, and revealed that keeping pets at current was positively associated with persistent cough and wheeze; exposure to pets in early life significantly increased the risk of diagnosed asthma. In order to study associations between the home environment and children’s asthma and allergies, a national study “China, Children, Health and Home (CCHH)” has been conducted since 2010. This paper aims to find out the relationship between early exposure to pets and allergic symptoms among children in Tianjin, China.

Methods

Since April 2013, randomly selected kindergartens, daycare centers and primary schools were invited to participate in this study. With the help from the teachers, questionnaires were distributed to parents of children aged 0–8 years old.

The questionnaire was developed from the Dampness in Buildings and Health (DBH) study in Sweden [9], which has been used in many countries and cities respectively [10]. However, questions on building characteristics were modified to better reflect the Chinese housing styles. The questions on children’s asthma and allergy are identical to core questions used in ISAAC (International Study on Asthma and Allergy of Child) study [11]. The good validity and reliability of the questionnaire were tested and reported in previous Chinese studies [12–13]. The entire questionnaire is shown in S1 and S2 Files. It consists of questions on children’s background information, life styles, home environment and health. Children’s health outcomes are wheeze in the last 12 months (current wheeze), dry cough in the last 12 months (current dry cough), diagnosed asthma, rhinitis in the last 12 months (current rhinitis), diagnosed rhinitis, eczema in the last 12 months (current eczema), and diagnosed eczema. With regard to pet keeping, parents were asked whether their family kept pets in the current home and/or in the first year of life of children; and if so, what type of pets: dog, cat, rodent (rabbit, hamster), bird, fish?

In this study, the database was divided into four groups of different pet keeping behavior (pet keeping all the time, never, at birth but not current, not at birth but current) to assess the avoidance behavior as Bornehag et al did in Sweden [6]. Moreover, parents were also asked to describe their avoidance behaviors: whether they removed or refrained to have a pet due to asthma or allergy among their families.

Statistics

Logistic regression models were used to evaluate the association of pet exposure with asthma and allergies among children. In the multivariate analyses we adjusted for gender, age, total household income, family allergic history, location, dampness and avoidance behavior. A p-value of less than 0.05 was accepted to be of significance. All statistical analyses were performed with the SPSS (version 22).

Ethical statement

Ethical approval was obtained from the Research Office at Tianjin University. Our participants provided verbal informed consent to participate in this study. This study is anonymous questionnaire survey. It involves no risk to the subjects. The study could not practicably be carried out with written consent. Completed surveys were used to reflect participant consents. These
surveys were stored in a lock cabinet. Research Office at Tianjin University approved this consent procedure.

**Results**

7865 parents answered the questionnaire survey, with a response rate of 78%. Ages were not reported for 204 children, and 295 children were outside 0 to 8 age boundary. Therefore, our final analysis was of 7366 children, among which 3539 resided in inner city, 1483 in suburban, 1755 in rural areas. Demographic information, health outcomes and exposure to pets are summarized in Table 1. The highest prevalence of asthma and allergies was reported by people living in city, followed by suburban and rural areas. Pet keeping had an opposite trend. The highest rate of pet keeping was reported from rural areas. However, people living in city had fish as pets more often. Dog is the most popular pet.

In this study, children who had pets at birth but not currently showed the highest prevalence of diagnosed asthma, current rhinitis, current eczema and diagnosed eczema, while children who had pets currently but not at birth showed the highest prevalence of current wheeze and current dry cough. Children who had pets all the time showed the highest prevalence rate of diagnosed rhinitis (Table 2). S1 Table shows the prevalence of allergic symptoms for different “avoidance behavior”. The highest prevalence of allergic symptoms appeared in the group with an avoidance behavior (followed by the group that had pets at home currently, and the group neither having pets nor having avoidance behavior). And it also revealed that the influence of behavior is more clear in urban areas.

Table 3 shows there is no “protective” effect of neither pet keeping currently nor pet keeping early for asthma and allergies. It indicated that pet keeping especially cats exposure was a significant risk factor for diagnosed asthma and diagnosed eczema. The effect of keeping pets became even more negative after adjusting for avoidance behavior (Table 4).

In order to explore whether there is a dose-response relationship between the number of pets and allergic diseases, furry pets including cats, dogs, rodents and birds were reclassified into two categories: one furry pet, two or more furry pets. Respectively, in current life, 12.9% families had one furry pet, while 4.5% had at least two furry pets. The dose response relationship between the number of furry pets and asthma and allergy in current home is showed in Fig 1. It indicates that pet keeping in current home have a clear dose-responses with current wheeze, current eczema and diagnosed eczema. After stratifying for rural, suburban and urban areas, we found that the dose-response relationship only exists in rural and urban areas (S2 Table).

**Discussion**

Our study investigated the pet exposure in Chinese homes with a big sample size of 7366 children and a good response rate of 78%. We found that pet keeping is a risk factor for children’s health. This is consistent with the findings from the scientific literature review [14]. Most of earlier studies were based on Western populations [15–18], however, some studies from other part of Asia or China have been published in recent year [8, 19–21]. Studies either based on Western populations or based on Asian populations [4, 5, 20] revealed that there are dose-response relationships between pet exposure and allergic sensitizations. Bornehag et al [6] found that the greater number of different types of pets, the higher risk for children to have allergic symptoms. Our study confirmed the dose-response relationship of pet keeping in current homes with current eczema and diagnosed eczema, but not for pet keeping at birth.

There are studies based on western populations that support the view that keeping animals in early life of children will protect against the allergic symptoms [22–27]. In a cross-sectional study, Bornehag et al [6] showed that current pet keeping was ‘protective’, but mainly because
of an avoidance behaviour. In Sweden, there was a public awareness regarding the risks of pet keeping for allergies (due to a national campaign about allergies in 1996), which can explain the high avoidance behaviour. In China and Bulgaria [18], the knowledge among the general population is probably much lower. So, most of parents know little about the risks of pet keeping for children asthma and allergies, and the percentage of people who had an avoidance behaviour was low (In this study 11.0% parents reported an avoidance behaviour towards pets, and in Bulgaria 3.3% had "got rid of" and 10.6% "refrained" from having pets, compared to Sweden 27.3% reported an avoidance behaviour).

### Table 1. Demographic information, health outcomes and exposure to pets of the investigated population, n (%).

| Demographic information | Home location | Total   | Rural | Suburban | Urban   |
|-------------------------|---------------|---------|-------|----------|---------|
|                         |               |         |       |          |         |
| Gender                  |               |         |       |          |         |
| Male                    |               |         |       |          |         |
| Female                  |               |         |       |          |         |
| Age                     |               |         |       |          |         |
| 0–2 years old           |               |         |       |          |         |
| 3–5 years old           |               |         |       |          |         |
| 6–8 years old           |               |         |       |          |         |
| Members of family have asthma or allergies | |       |       |          |         |
| Dampness in home        |               |         |       |          |         |
| Total income (RMB)      |               |         |       |          |         |
| <30 thousand            |               |         |       |          |         |
| 30–50 thousand          |               |         |       |          |         |
| 50–100 thousand         |               |         |       |          |         |
| 100–200 thousand        |               |         |       |          |         |
| >200 thousand           |               |         |       |          |         |
| Health outcomes         |               |         |       |          |         |
| Current wheeze          |               |         |       |          |         |
| Current dry cough       |               |         |       |          |         |
| Diagnosed asthma        |               |         |       |          |         |
| Current rhinitis        |               |         |       |          |         |
| Diagnosed rhinitis      |               |         |       |          |         |
| Current eczema          |               |         |       |          |         |
| Diagnosed eczema        |               |         |       |          |         |
| Pets exposure           |               |         |       |          |         |
| Keeping pets at time of survey (current) | | | | | |
| Cat                     |               |         |       |          |         |
| Dog                     |               |         |       |          |         |
| Rodent                  |               |         |       |          |         |
| Bird                    |               |         |       |          |         |
| Fish                    |               |         |       |          |         |
| Keeping pets in the first year of life (early) | | | | | |
| Cat                     |               |         |       |          |         |
| Dog                     |               |         |       |          |         |
| Rodent                  |               |         |       |          |         |
| Bird                    |               |         |       |          |         |
| Fish                    |               |         |       |          |         |

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Dander, urine and saliva from pets are potential allergens, which can be carried by pet hair, cloth, indoor furniture for several months. Through the quantitative assessment of exposure to dog (Can f 1) and cat (Fel d 1) allergens, Ingram et al [28] revealed that the high prevalence of IgE antibody to cat and dog allergens were positively associated with the presence of cat and/or dog allergens in the houses. The result in our study is consistent with finding that the presence of pet increased the risk of asthma and allergy.

Limitations

There are some limitations in this study. Information about children’s health, pet keeping, and environment of residence in this study were collected by questionnaires, why there may be some recall bias. However, the strong associations between keeping pets, pet avoidance behaviour, and different health outcomes as shown in this study, cannot be explained by such bias.

Table 2. Prevalence (n, %) of asthma and allergy among children with different pets keeping status.

|                     | Prevalence, n (%) |
|---------------------|------------------|
| **Group I**, n = 4707 |                  |
| Current wheeze      | 212 (4.7)        |
| Current dry cough   | 611 (13.4)       |
| Diagnosed asthma    | 209 (4.6)        |
| Current rhinitis    | 1362 (30.2)      |
| Diagnosed rhinitis  | 437 (9.8)        |
| Current eczema      | 642 (14.3)       |
| Diagnosed eczema    | 1811 (40.4)      |
| **Group II**, n = 342 |                  |
| Current wheeze      | 22 (6.9)         |
| Current dry cough   | 64 (19.5)        |
| Diagnosed asthma    | 13 (3.9)         |
| Current rhinitis    | 92 (29.1)        |
| Diagnosed rhinitis  | 25 (7.7)         |
| Current eczema      | 47 (14.6)        |
| Diagnosed eczema    | 117 (35.8)       |
| **Group III**, n = 740 |                  |
| Current wheeze      | 25 (3.6)         |
| Current dry cough   | 86 (12.0)        |
| Diagnosed asthma    | 33 (4.7)         |
| Current rhinitis    | 210 (30.4)       |
| Diagnosed rhinitis  | 59 (8.3)         |
| Current eczema      | 128 (18.4)       |
| Diagnosed eczema    | 296 (42.0)       |
| **Group IV**, n = 598 |                  |
| Current wheeze      | 32 (5.8)         |
| Current dry cough   | 67 (11.8)        |
| Diagnosed asthma    | 21 (3.7)         |
| Current rhinitis    | 144 (26.1)       |
| Diagnosed rhinitis  | 57 (10.3)        |
| Current eczema      | 96 (17.4)        |
| Diagnosed eczema    | 214 (39.2)       |

*a* Group I: Never have pets.

*b* Group II: Having pets at current, but not early.

*c* Group III: Having pets at early, but not currently.

*d* Group IV: Having pets all the time.

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Table 3. Adjusted odds ratios of pet keeping for asthma and allergies among children.*

|                     | Current wheeze | Current dry cough | Diagnosed asthma | Current rhinitis | Diagnosed rhinitis | Current eczema | Diagnosed eczema |
|---------------------|----------------|-------------------|------------------|------------------|--------------------|----------------|------------------|
| No pets keeping (reference) | 1              | 1                 | 1                | 1                | 1                  | 1              | 1                |
| Pet keeping currently | 1.28 (0.81–2.04) | 1.04 (0.76–1.43) | 1.13 (0.69–1.83) | 0.99 (0.77–1.28) | 1.21 (0.85–1.72) | 1.25 (0.92–1.70) | 1.24 (0.98–1.58) |
| Cat                 | 1.47 (0.62–3.50) | 1.01 (0.58–1.74) | 3.12 (1.58–6.16) | 1.12 (0.74–1.70) | 1.49 (0.79–2.84) | 1.76 (1.09–2.85) | 1.42 (0.97–2.07) |
| Dog                 | 1.37 (0.85–2.22) | 1.02 (0.76–1.38) | 1.28 (0.79–2.06) | 1.07 (0.85–1.34) | 1.27 (0.89–1.81) | 1.33 (1.00–1.76) | 1.22 (0.99–1.50) |
| Rodent              | 2.22 (0.98–5.07) | 1.34 (0.74–2.45) | 2.74 (1.29–5.82) | 1.08 (0.65–1.79) | 1.56 (0.78–3.14) | 1.55 (0.87–2.77) | 1.42 (0.88–2.28) |
| Bird                | 1.20 (0.43–3.40) | 0.97 (0.50–1.85) | 1.10 (0.39–3.12) | 1.11 (0.68–1.80) | 1.58 (0.80–3.12) | 1.33 (0.73–2.42) | 1.30 (0.83–2.05) |
| Fish                | 1.35 (0.78–2.32) | 0.78 (0.52–1.18) | 0.71 (0.36–1.43) | 1.02 (0.76–1.38) | 1.43 (0.96–2.14) | 1.66 (1.18–2.32) | 1.37 (1.03–1.81) |
| Pet keeping early   | 1.70 (1.07–2.71) | 1.32 (0.96–1.84) | 0.85 (0.48–1.53) | 0.91 (0.69–1.20) | 1.06 (0.71–1.57) | 0.96 (0.68–1.36) | 1.00 (0.77–1.30) |
| Cat                 | 2.57 (1.18–5.62) | 1.39 (0.81–2.40) | 2.86 (1.41–5.82) | 1.27 (0.81–1.99) | 1.87 (0.99–3.54) | 1.60 (0.94–2.73) | 1.16 (0.76–1.77) |
| Dog                 | 1.59 (1.00–2.51) | 1.12 (0.84–1.50) | 0.82 (0.48–1.42) | 0.95 (0.76–1.20) | 1.17 (0.82–1.68) | 1.29 (0.98–1.70) | 1.06 (0.86–1.30) |
| Rodent              | 2.01 (0.59–6.93) | 2.29 (1.04–5.06) | 3.80 (1.37–10.53) | 0.51 (0.21–1.20) | 1.28 (0.42–3.87) | 1.50 (0.64–3.65) | 0.73 (0.35–1.53) |
| Bird                | 4.56 (2.00–10.37) | 1.69 (0.84–3.38) | 3.04 (1.24–7.50) | 0.58 (0.28–1.19) | 1.51 (0.61–3.73) | 1.67 (0.81–3.44) | 0.77 (0.41–1.45) |
| Fish                | 2.08 (1.07–4.03) | 0.87 (0.50–1.52) | 0.43 (0.13–1.39) | 0.89 (0.58–1.34) | 1.44 (0.83–2.50) | 1.36 (0.85–2.18) | 1.02 (0.69–1.50) |

*a* No pet keeping was set as reference. Odds ratio was adjusted for gender, age, total income, family allergic history, home location and home dampness.

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The lack of data on other contact accesses to pets’ allergens (e.g. by contacting with pets allergens outside home (like daycares, schools) or contacting with allergens transferred by visitors) is another limitation of our study. However, allergen exposure through other accesses may not change the strong association between pets keeping at home and children’s health. Identification and quantification on pet allergens (Fel d 1, Can f 1) in indoor environment should be investigated in further studies.

Table 4. Adjusted odds ratio of pet keeping for asthma and allergy among children when an avoidance behavior is adjusted*.

|                  | Current wheeze | Current dry cough | Diagnosed asthma | Current rhinitis | Diagnosed rhinitis | Current eczema | Diagnosed eczema |
|------------------|----------------|-------------------|-------------------|------------------|-------------------|----------------|------------------|
| No pet keeping   | 1              | 1                 | 1                 | 1                | 1                 | 1              | 1                |
| Pet keeping currently | 2.13 (1.02–4.47)| 1.32 (0.80–2.16) | 3.37 (1.58–7.19) | 1.72 (1.16–2.54) | 3.60 (2.07–6.27) | 2.53 (1.57–4.08) | 1.92 (1.31–2.81) |
| Cat              | 1.95 (0.72–5.29)| 1.14 (0.61–2.15) | 6.34 (2.75–14.65)| 1.84 (1.14–2.97) | 4.24 (2.02–8.88) | 3.30 (1.86–5.87) | 2.10 (1.35–3.28) |
| Dog              | 1.83 (0.92–3.66)| 1.17 (0.76–1.80) | 2.57 (1.29–5.10) | 1.73 (1.24–2.40) | 3.63 (2.17–6.06) | 2.64 (1.74–4.00) | 1.78 (1.30–2.43) |
| Rodent           | 3.03 (1.15–7.95)| 1.51 (0.76–2.98) | 5.89 (2.38–14.53)| 1.75 (1.00–3.07) | 4.38 (1.99–9.64) | 3.19 (1.66–6.13) | 2.05 (1.21–3.50) |
| Bird             | 1.60 (0.51–5.09)| 1.10 (0.53–2.26) | 2.28 (0.72–7.26) | 1.81 (1.05–3.10) | 4.44 (2.05–9.64) | 2.71 (1.39–5.30) | 1.94 (1.16–3.23) |
| Fish             | 1.82 (0.87–3.82)| 0.86 (0.51–1.45) | 1.53 (0.65–3.60) | 1.66 (1.13–2.43) | 4.00 (2.32–6.88) | 3.35 (2.14–5.27) | 2.00 (1.39–2.88) |
| Pets keeping early| 1.96 (1.18–3.25)| 1.44 (1.02–2.04) | 1.05 (0.57–1.94) | 1.01 (0.76–1.36) | 1.26 (0.83–1.91) | 1.04 (0.72–1.50) | 1.02 (0.77–1.34) |
| Cat              | 2.92 (1.31–6.49)| 1.48 (0.85–2.58) | 3.17 (1.54–6.53) | 1.38 (0.88–2.18) | 2.30 (1.21–4.37) | 1.56 (0.89–2.71) | 1.15 (0.75–1.77) |
| Dog              | 1.70 (1.05–2.75)| 1.19 (0.88–1.62) | 0.91 (0.52–1.60) | 1.00 (0.79–1.27) | 1.38 (0.95–2.00) | 1.31 (0.98–1.75) | 1.06 (0.86–1.32) |
| Rodent           | 2.42 (0.69–8.51)| 2.40 (1.08–5.36) | 4.54 (1.61–12.85)| 0.56 (0.24–1.34) | 1.68 (0.54–5.19) | 1.63 (0.68–3.93) | 0.72 (0.34–1.52) |
| Bird             | 5.53 (2.39–12.80)| 1.82 (0.90–3.70) | 3.80 (1.52–9.49) | 0.63 (0.30–1.30) | 1.90 (0.76–4.71) | 1.57 (0.74–3.37) | 0.76 (0.40–1.44) |
| Fish             | 2.71 (1.33–5.50)| 0.92 (0.52–1.64) | 0.55 (0.17–1.83) | 0.98 (0.64–1.51) | 1.94 (1.09–3.47) | 1.48 (0.91–2.42) | 1.02 (0.68–1.53) |

*No pet keeping was set as reference. Odds ratio was adjusted for gender, age, total income, family allergic history, home location, home dampness and avoidance behavior.

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The lack of data on other contact accesses to pets’ allergens (e.g. by contacting with pets allergens outside home (like daycares, schools) or contacting with allergens transferred by visitors) is another limitation of our study. However, allergen exposure through other accesses may not change the strong association between pets keeping at home and children’s health. Identification and quantification on pet allergens (Fel d 1, Can f 1) in indoor environment should be investigated in further studies.

Fig 1. The dose-response relationship between pets keeping in home and allergies among children. *Odds ratios are adjusted for gender, age, total household income, family allergic history, home location, home dampness and avoidance behavior. *Furry pet: cats, dogs, rodents and birds.

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Conclusions

This study assessed the relationship between pet keeping in childhood and asthma and allergy in children aged 0–8 years old. The highest prevalence of asthma and allergies was reported by people living in a city. However, pet keeping had an opposite trend. The highest rate of pet keeping was reported by people from rural areas. For all participants, pet keeping in childhood was positively associated with asthma and allergy, and the children who had pets at current home had 2–3 times higher prevalences of diagnosed asthma, rhinitis and eczema.

Supporting information

S1 File. Questionnaire (Chinese version).
(DOC)

S2 File. Questionnaire (English version).
(DOC)

S1 Table. Prevalence (%) of asthma and allergy among children with different avoidance behaviors.
(DOCX)

S2 Table. Adjusted odds ratio of the number of furry pets keeping and asthma and allergy among children.
(DOCX)

S1 Dataset.
(SAV)

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Author Contributions

Conceptualization: Yuexia Sun, Jan Sundell.

Data curation: Yuexia Sun, Jing Hou.

Formal analysis: Shugang Luo, Yuexia Sun, Jan Sundell.

Funding acquisition: Yuexia Sun.

Investigation: Yuexia Sun, Jing Hou, Xiangrui Kong, Pan Wang, Qingnan Zhang.

Methodology: Yuexia Sun, Jan Sundell.

Project administration: Yuexia Sun.

Supervision: Yuexia Sun, Jan Sundell.

Writing – original draft: Shugang Luo.

Writing – review & editing: Yuexia Sun, Jan Sundell.

References

1. Sundell J. Reflections on the history of indoor air science, focusing on the last 50 years. Indoor Air. 2017; 27: 1–17.
2. Hesselmar B, Åberg N, Åberg B, Eriksson B, Björkstén B. Does early exposure to cat or dog protect against later allergy development? Clin Exp Allergy. 1999; 29: 611–617. https://doi.org/10.1046/j.1365-2222.1999.00534.x PMID: 10231320

3. Ownby DR, Johnson CC, Peterson EL. Exposure to dogs and cats in the first year of life and risk of allergic sensitization at 6 to 7 years of age. JAMA. 2002; 288: 963–972. https://doi.org/10.1001/jama.288.8.963 PMID: 12190366

4. Wahn U, Lau S, Bergmann R, Kulig M, Forster J, Bergmann K, et al. Indoor allergen exposure is a risk factor for sensitization during the first three years of life. J Allergy Clin Immunol. 1997; 99: 763–769. PMID: 9215243

5. Lombardi E, Simoni M, La Grutta S, Viegi G, Bisanti L, Chellini E, et al. Effects of pet exposure in the first year on respiratory and allergic symptoms in 7-year-old children. the SIDRIA-2 study. Pediatr Allerg Immunol. 2010; 21: 268–276. https://doi.org/10.1111/j.1399-3038.2009.00910.x PMID: 20444167

6. Bornehag CG, Sundell J, Hagerhed L, Janson S. Pet-keeping in early childhood and airway, nose and skin symptoms later in life. Allergy. 2003; 58: 939–944. https://doi.org/10.1034/j.1398-9995.2003.00050.x PMID: 12911425

7. Zheng T, Niu S, Lu B, Fan X, Sun F, Wang J, et al. Childhood asthma in Beijing, China: A population-based case-control study. Am J Epidemiol. 2002; 156: 977–983. https://doi.org/10.1093/aje/kwf127 PMID: 12419771

8. Salo PM, Xia J, Anderson Johnson C, Li Y, Avol EL, Gong J, et al. Indoor allergens, asthma, and asthma-related symptoms among adolescents in Wuhan, China. Ann Epidemiol. 2004; 14: 543–550. https://doi.org/10.1016/j.amepi.2003.09.015 PMID: 15350953

9. Bornehag CG, Sundell J, Hagerhed-Engman L, Sigsgaard T, Janson S and Aberg N. 'Dampness' at home and its association with airway, nose, and skin symptoms among 10,851 preschool children in Sweden: a cross-sectional study. Indoor Air. 2005; 15: 48–55.

10. Sundell J, Li BZ, Zhang YP. China, Children, Homes, Health (CCHH). Chinese Sci Bull. 2013; 58: 4179–4181.

11. Asher MI, Keil U, Anderson HR, Beasley R, Crane J, Martinez F, et al. International study of asthma and allergies in childhood (ISAAC): rationale and methods. Eur Respir J. 1995; 8 (3): 483–491. PMID: 7789502

12. Sun YX, Sundell J, Zhang YF. Validity of building characteristics and dorm dampness obtained in a self-administered questionnaire. Sci Total Environ. 2007; 387 (1–3): 276–282. https://doi.org/10.1016/j.scitotenv.2007.07.001 PMID: 17692898

13. Wang H, Li BZ, Yang Q, Yu W, Wang J, Liu YL, et al. Dampness in dwellings and its associations with asthma and allergies among children in Chongqing: a cross-sectional study. Chinese Sci Bull. 2013; 58 (34): 4259–4266.

14. Ahlbom A, Backman A, Bakke J, Foucard T, Hakken S, Kjellman NIM, et al. "NORDPET" Pets indoors—a risk factor for or protection against sensitisation/allergy. Indoor Air. 1998; 8: 219–235.

15. Medjo B, Atanaskovic-Markovic M, Nikolic D, Spasojevic-Dimitrijeva B, Ivanovski P, Djukic S. Association between pet-keeping and asthma in school children. Pediatr Int. 2013; 55: 133–137. https://doi.org/10.1111/ped.12071 PMID: 23421334

16. Pyrhönen K, Näyhät S, Läärä E. Dog and cat exposure and respective pet allergy in early childhood. Pediatr Allergy Immunol. 2015; 26: 247–255. https://doi.org/10.1111/pai.12369 PMID: 25735463

17. Apelberg BJ, Aoki Y, Jaakkola JJK. Systematic review: exposure to pets and risk of asthma and asthma-like symptoms. J Allergy Clin Immunol. 2001; 107: 455–460. https://doi.org/10.1067 mai.2001.113240 PMID: 11240945

18. Naydenov K, Popov T, Mustakov T, Melikov A, Bornehag CG, Sundell J. The association of pet keeping at home with symptoms in airways, nose and skin among Bulgarian children. Pediatr Allergy Immunol. 2008; 19: 702–708. https://doi.org/10.1111/j.1399-3038.2008.00721.x PMID: 18266829

19. Fukao T, Fukutomi O, Hirayama K, Teramoto T, Kaneho K, Kondo M, et al. Questionnaire-based study on the relationship between pet-keeping and allergic diseases in young children in Japan. Allergol Int. 2005; 54: 521–526. https://doi.org/10.2332/allergolint.54.521

20. Dong GH, Ma YN, Ding HL, Jin J, Cao Y, Zhao YD, et al. Pets keeping in home, parental atopy, asthma, and asthma-related symptoms in 12,910 elementary school children from northeast China. Indoor Air. 2009; 19: 166–173. https://doi.org/10.1111/j.1600-0668.2008.00576.x PMID: 19076246

21. Wang L, Qu F, Zhang Y, Weschler LB, Sundell J. Home environment in relation to allergic rhinitis among preschool children in Beijing, China: A cross-sectional study. Build Environ. 2015; 93: 54–63. https://doi.org/10.1016/j.buildenv.2015.02.010
22. Roost HP, Künnli N, Schindler C, Jarvis D, Chinn S, Perruchoud AP, et al. Role of current and childhood exposure to cat and atopic sensitization. J Allergy Clin Immunol. 1999; 104: 941–947. https://doi.org/10.1016/S0091-6749(99)70072-2 PMID: 10550736

23. Leynaert B, Neukirch C, Jarvis D, Chinn S, Burney P, Neukirch F. Does living on a farm during childhood protect against asthma, allergic rhinitis, and atopy in adulthood? Am J Respir Crit Care Med. 2001; 164: 1829–1834. https://doi.org/10.1164/ajrccm.164.10.2103137 PMID: 11734431

24. Remes ST, Castro-Rodriguez JA, Holberg CJ, Martinez FD, Wright AL. Dog exposure in infancy decreases the subsequent risk of frequent wheeze but not of atopy. J Allergy Clin Immunol. 2001; 108: 509–515. https://doi.org/10.1067/mai.2001.117797 PMID: 11590373

25. Heinrich J. Exposure to pets and allergies in children. Pediatr Allergy Immunol. 2002; 13: 334–341. https://doi.org/10.1034/j.1399-3038.2002.20026.x PMID: 12431192

26. Perzanowski MS, Rönmark E, Platts-Mills TAE, Lundbäck B. Effect of cat and dog ownership on sensitization and development of asthma among preteenage children. Am J Respir Crit Care Med. 2002; 166: 696–702. https://doi.org/10.1164/rccm.2201035 PMID: 12204868

27. Campo P, Kalra HK, Levin L, Reponen T, Olds R, Lummus ZL, et al. Influence of dog ownership and high endotoxin on wheezing and atopy during infancy. J Allergy Clin Immunol. 2006; 118: 1271–1278. https://doi.org/10.1016/j.jaci.2006.08.008 PMID: 17157656

28. Ingram JM, Sporik R, Rose G, Honsinger R, Chapman MD, Platts-Mills TAE. Quantitative assessment of exposure to dog (Canf1) and cat (Feld1) allergens: Relation to sensitization and asthma among children living in Los Alamos, New Mexico. J Allergy Clin Immunol. 1995; 96: 449–456. https://doi.org/10.1016/S0091-6749(95)70286-5 PMID: 7560654