Agreement between asthma questionnaire and health care register data

Running title: *Agreement between questionnaire and health care register data*

Authors

Anna M. Hedman[1],

Tong Gong[1],

Cecilia Lundholm[1],

Elin Dahlén[1,2],

Vilhelmina Ullemar[1],

Bronwyn K. Brew[1],

Catarina Almqvist[1,3].

Affiliations

[1]Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden.

[2]Department of Medicine, Centre for Pharmacoepidemiology, Karolinska Institutet, Stockholm, Sweden

[3]Pediatric Allergy and Pulmonology Unit, Astrid Lindgren Children's Hospital, Karolinska University Hospital, Stockholm, Sweden

Corresponding author:

Anna M. Hedman

Department of Medical Epidemiology and Biostatistics

PO Box 281, Karolinska Institutet, SE-171 77 Stockholm, Sweden

E-mail: anna.hedman@ki.se

Keywords: asthma, health care register, pharmacoepidemiology, questionnaire, agreement study

Key points (take home message):

- Parental-reported question on asthma ever can function as a proxy for asthma medication and diagnosis in research
- Parental-reported current asthma has good agreement with register-based records in the last 18 months

Word count: 3081

Abstract

Purpose: Risk factors and consequences of asthma can be studied using validated questionnaires. The overall objective of this study was to assess the agreement of parental-reported asthma related questions regarding their children against Swedish health care registers.

Methods: We linked a population-based twin cohort of 27,055 children aged 9-12 years, to the Swedish Prescribed Drug Register, National Patient Register and the Primary care register. Parent-reported asthma was obtained from questionnaires and diagnoses and medication were retrieved from the registers. For the agreement between the questionnaire and the registers, Cohen's kappa was estimated.

Results The kappa of the 'reported ever asthma' against a 'register-based ever asthma' was 0.69 and 0.57 between the parental-'reported doctor's diagnosis' and 'register-based doctor's diagnosis' '. The highest agreement between 'reported current asthma' and 'register- based current asthma' with at least one dispensed medication or a diagnosis applied to different time-windows was seen for an 18 month window (kappa=0.70).

Conclusions We found that parent-reported asthma-related questions showed on average good agreement with the Swedish health care registers. This implies that in depth questionnaires with rich information on phenotypes are suitable proxies for asthma in general and can be used for health care research purposes.

Introduction

To study risk factors and consequences of asthma, validated instruments for defining asthma in studies using registers, clinical cohorts and questionnaires are needed. Numerous efforts have been made to ensure that specific questionnaires detecting asthma are standardized, repeatable and can be applied consistently across a range of geographical and cultural settings (1, 2). Both the European Community Respiratory Health Survey (1) and the International Study on Asthma and Allergies in Childhood (ISAAC) (2) were developed, where possible, from pre-existing published questionnaires, where validity had been previously assessed (3, 4).

Several studies have validated questions on 'reported ever asthma' (5-7) and symptom-based outcomes (e.g., wheeze, waking at night, coughing) (8-11), whereas others have focused on doctor's diagnosis (6) or taking asthma medication (6) . Other examples of asthma validation studies include symptoms-based questions against; clinical evaluations (5, 8), structured interviews (12) and patient records of a diagnosis (13). The standardized ISAAC questionnaire (2) has a specific question on 'reported ever asthma' for which validity in other countries has been assessed (5, 7) but not in Sweden. In addition, to our knowledge, no study has assessed the validity of the questions describing 'reported current asthma' and doctor's diagnosis from the ISAAC questionnaire. Furthermore, timing of dispenses has been investigated in a previous study in which agreement between reported and prescribed asthma medication was highest within an 18-months window (14).

Questionnaire studies are relatively low cost, time-efficient, and permit large sample sizes compared to clinical data collections (15, 16). On the other hand, questionnaires are often restricted to specific age groups or specific areas, which can reduce generalizability to other populations (17, 18). Identifying affected individuals often involves retrospective questioning about doctor's diagnosis and previous symptoms, therefore subject to recall bias (19, 20). By using population-based register data for asthma diagnoses and prescriptions, the data are objective and some of the aforementioned errors can be avoided particularly if the coverage of the register is high.

The overall objective for this study was to assess the agreement between parental-reported childhood asthma questions from the nationwide twin cohort Childhood and Adolescent Twin Study in Sweden (CATSS) and population-based Swedish health care registers (National Patient Register, NPR, which contains all inpatient diagnoses and 75-80% of all outpatient diagnoses since 1987 and 2001 respectively,

Swedish Prescribed Drug Register, SPDR, which contains all prescribed medications that are dispensed at Swedish pharmacies and Stockholm regional health care data warehouse, VAL, which holds all primary care diagnoses from Stockholm county). Our first aim was to assess the agreement between 'reported ever asthma' and a 'register-based ever asthma' algorithm (21) (at least 2 dispenses of asthma medication or an asthma diagnosis) using SPDR and NPR and between 'reported doctor's diagnosis' and 'register-based doctor's diagnosis' from NPR and VAL. Our second aim was to assess the agreement between 'reported asthma medications' and 'register-based asthma medications', with the corresponding data within different time windows in the registers.

Method

Study population

This study included children participating in CATSS (22). CATSS is an ongoing longitudinal twin study targeting all twins born in Sweden since July 1st, 1992 with an overall response rate of 76% until 2012. Since 2004, in connection to the twin's 9th or 12th birthdays, parents are interviewed via telephone regarding the children's somatic, social and mental health (22). CATSS is linked to the Swedish health care registers, NPR, SPDR and VAL. The study was approved by the Regional Ethical Review Board in Stockholm, Sweden. Informed consent was obtained.

Study design and data sources

This is an agreement study comparing parental interview answers with data from registers where no measure was considered gold standard(23). Several national health care registers are held by the Swedish National Board of Health and Welfare such as the SPDR (24) and NPR (25). The SPDR contains the Anatomical Therapeutic Chemical [ATC]-codes, date, number of packages, and when possible, daily defined doses) and age, sex and PIN of the patient since July 2005. Information on primary and secondary diagnoses according to the International Classification of Diseases 10th revision (ICD -10) is included in the NPR since 1997. All data were de-identified prior to analyses and kept on a secure server. Linking data from multiple registers is made possible through the Swedish unique personal identity number (PIN) (26).

Sub-cohorts

The full cohort consisted of N=27,055 twins that were interviewed up until the end of 2012. From this population we derived two sub-cohorts. The first sub-cohort, the National cohort, consisted of twins whose parents had completed the interview since July 1st 2006 (n=18,725). This date was selected because July 1st 2005 was the date that the SPDR was established, covering the whole Swedish population. By selecting this date we were able to retrospectively collect information on dispensed medication from the SPDR for at least one year to assess 'register-based ever asthma'. The second sub-cohort, the Stockholm cohort, included twins that were born from 2001 and who had been living in Stockholm all years between birth and the interview (n=2,226). This subgroup of twins was selected since information on both specialist (NPR) and primary care was available for Stockholm County from 2003 by the VAL registry. The reason we selected individuals born from 2001 was because a child with asthma before the age of two years usually comes in contact with the specialist care and gets a diagnosis in the National Patient Register (NPR).

Measures of ever and current asthma in the National cohort

We defined a 'reported ever asthma' case as a child with a positive answer to the question *'Does he/she have, or has he/she had asthma?'* Everyone that replied positive was then directed to other asthma related questions (see Panel 1). 'Reported current asthma' was then defined as reporting positively to the question *'Does he/she still have asthma?'.*

The 'register-based ever asthma' algorithm based on SPDR and NPR data has been previously described and validated (21). The age-specific positive predicted value (PPV) from that validation study was 0.89 (95% CI: 0.85-0.92) for ages between 4.5-17 years. In brief, the 'register-based ever asthma' is defined as either: 1) asthma medication of ≥ 2 dispenses of ICS (inhaled corticosteroid, ATC code: R03BA) and/or LTRA (leukotriene receptor agonist, ATCcode: R03DC03) and/or β2-ICS (combination of inhaled beta-2 agonist and inhaled corticosteroid, ATCcodes: R03AK06 and R03AK07) independent of time between, and/or 2) ≥ 3 dispenses of ICS and/or LTRA and/or β2-ICS and/or β2 (inhaled beta-2 agonist, ATC code:

R03AC) within a 12-month period (prior to the date of the interview) or 3) an asthma diagnosis (ICD-10 diagnostic codes: J45, and J46) from NPR.

To define 'register-based current asthma' from the SPDR we used the same register-based algorithm as for 'register-based ever asthma' (21) in combination with conditions placed on recent time-windows for asthma diagnosis (ICD-10 diagnostic codes: J45, and J46) from NPR respectively in the last 6, 12, 18 and 24 months prior to the date of the interview. Instead of a recent diagnosis we also conditioned on at least one dispensed medication (ICS, LTRA, B2, β2-ICS) from the SPDR. We wanted to investigate several time windows to see which one captured the 'reported current asthma' question best and to evaluate if it would be enough using only dispensed medication.

Measures of a doctor's diagnosis in the Stockholm cohort

A parental-'reported doctor's diagnosis' was defined as answering 'yes' to the asthma gated question ('reported ever asthma') plus answering 'yes' to: *'You said that he/she has or has had asthma, has he/she been given that diagnosis by a doctor or nurse?'*

'Register-based doctor's diagnosis' was defined based on at least one primary or secondary diagnosis of asthma up until the time of the interview by ICD-10 codes (J45, and J46) from NPR (inpatient or outpatient) or VAL (primary care).

Measures of asthma medications in the National cohort

Parental-'Reported asthma medications' was defined as answering 'yes' to the asthma gated question plus answering 'yes' to the following question: *'Does your child currently take any asthma-medication (inhalator, spray or tablets)?'* This question was added in 2010 as an update to the original questionnaire, so not included for everyone (n=9860).

'Register-based asthma medications' was defined as at least one dispensed asthma medication (ICS, LTRA, β2, β2-ICS) from SPDR during the last , 6, 12, 18 and 24 months prior to the interview.

Statistical analyses

Agreement between register data and questionnaire data was assessed, using Cohen's kappa statistic, with 95% Confidence Interval (CI). The percentage of overall agreement was also estimated. Cohen's kappa is a measure of agreement beyond what would be expected by pure randomness. A kappa over 0.75 is characterized as excellent, a kappa of 0.40-0.75 is considered fair to good, and 0.40 and below as poor (27).

Statistical Analysis Software 9.4 (SAS Institute, Cary, NC) was used for all analyses.

Results

Table 1 lists the demographic characteristics of the sub-cohorts of the CATSS study; the National and Stockholm cohorts. In general, the characteristics of the smaller Stockholm cohort were very similar to the much larger National cohort. The prevalence of 'reported ever asthma' was slightly higher in the Stockholm cohort (17.4%), compared to the national cohort (14.5%). However, 'reported current asthma' (7.1%) did not differ substantially between cohorts.

'Reported ever asthma'

The kappa statistic of 'reported ever asthma' and 'register-based ever asthma' was 0.69, indicating good agreement. The overall agreement was 92.1% (Table 2).

Doctor's diagnosis

The comparison between the parental 'reported doctor's diagnosis' and the 'register-based doctor's diagnosis' from NPR or VAL showed a kappa of 0.57, indicating a fair to good agreement. The overall agreement was 86.3% (Table 2).

'Current Asthma'

Table 3 shows the agreement between 'reported current asthma' and 'register-based current asthma' with time-specific criteria for at least one dispensed medication or diagnosis within four different time-windows. For 6 months the kappa statistic was 0.59, 0.67 and 0.70 for 12 and 18 months respectively and 0.70 for 24 months. When diagnosis was removed from the 'reported current asthma' definition the agreement just slightly decreased for all of the time-windows with a kappa of 0.56, 0.65, 0.69 and 0.69 respectively. At all time-windows the overall agreement was very high (95% to 96%).

Taking asthma medications

Table 4 shows the agreement between 'reported asthma medications' by parent and 'register-based asthma medications', any asthma medication dispensed from SPDR in different time-windows. The kappa increased from 0.52 for 6 months before the interview to 0.57 for 12 months and then slightly increased for 18 months before the interview to 0.59. For a time-window of 24 months the kappa decreased to 0.55. The overall agreement ranged between 78-80%.

Discussion

We found good agreement between 'reported ever asthma' and 'register-based ever asthma' (kappa=0.69) and fair to good agreement (kappa=0.57) between parental-'reported doctor's diagnosis' and 'register-based asthma diagnosis'. We also found good agreement (kappa= 0.70) between 'reported current asthma' and 'register-based current asthma', conditional on at least one dispensed medication or a diagnosis within the last 18-months. Finally, we found the best agreement between 'reported asthma medications' by parents and 'register-based asthma medications' within the last 18 months (kappa=0.59).

.

Previous and similar studies that assessed the validity of the question on **'reported ever asthma'** against a clinical diagnosis found high sensitivity (i.e., proportion with a diagnosis that are correctly identified as such), 0.87 in one study (7) and good sensitivity, 0.68, in another one (28). Valle et al. used a younger cohort than ours, 6-7 years old children and they used a golden standard (i.e., clinical diagnosis) which could potentially explain why they found a high estimate of sensitivity (0.87) (7). Marco et al.

investigated adults and found good validity (sensitivity of 0.68) while we studied children and found good agreement (kappa =0.69) (28). In addition, among university students the question on 'reported ever asthma' was validated against a variable combining physician's interview, methacholine challenge, skin prick test and specific IgE which reported a low sensitivity (0.40) and a good PPV (0.76) (5). Thus, large heterogeneity in terms of sensitivity, PPV and Kappa exists between the different studies (age-groups and comparison variables) when assessing the validity of 'reported ever asthma' from a questionnaire.

We have previously validated the register based comparison variable 'register-based ever asthma' against medical records with high positive predictive values (0.89 95% CI: 0.85-0.92) for clinical asthma diagnosis (21). This definition of asthma has been applied in several studies as a proxy for ever/incident asthma (29-33) as well as for current/prevalent asthma (30).. Another study investigating **'reported doctor's diagnosis'** found a moderate PPV of 0.57 when the question of parental-reported doctor's diagnosis was validated against asthma medication reimbursement in a younger cohort (6) . The question of doctor's diagnosis has also been validated against a structured interview among 7-8 years old which found excellent PPV (0.98) and good sensitivity (approx. 0.70) (12). There are many reasons to our fairly low kappa estimate, for example asthma diagnosis in low ages is fairly unspecific and those who answered no to the question on 'reported ever asthma' never got the question on doctor's diagnosis (see Figure 1). In addition, the kappa could be due to both over-(the register may not have coverage) and underreporting since a diagnosis given a long time ago may be forgotten if the child has no current asthma symptoms or medication. However, this does not imply per se that our comparison variable is poor.

We estimated the agreement between **'reported current asthma'** and 'register-based current asthma' with different time windows. We found the 18-month window to be preferable with a kappa of 0.70, which indicates a good agreement. Interestingly, when only using medication data the resulting kappa just decreased slightly giving us confidence that our 'register-based current asthma' including one recently dispensed medication is almost as good a proxy for 'reported current asthma' as when using both medication and diagnosis. Recall bias has shown not to be influential within the last 12 months in a recent study of self-reported hospital admissions compared to administrative records (34). In light of this, it is not surprising that reported 'current' asthma (with no timeframes in the question) equals 'in the last 18 months'. Possible explanations could be purchasing large amounts of medicines irregularly, having mild asthma which does not require medications or sharing medicines with other family members

(14). We were unable to find any other studies that had assessed the validity of 'reported current asthma'. Current wheeze is more common to validate in childhood than current asthma, for example current wheeze (or wheezing symptoms within the last 12 months) is included in the ISAAC questionnaire and applied in other validation studies (6, 7). However, wheeze is a symptom and asthma is a condition/disease and children with wheeze do not necessarily need to have asthma. Therefore those studies using 'current wheeze' are limited in generalizing their findings to asthma.

We found a fair agreement between **'reported asthma medications'** and 'register-based asthma medications' with a kappa ranging from 0.52 to 0.59 depending on time-window. Nwaru et al. validated a question on parental-reported asthma medication during the last 12 months against the asthma medication reimbursement and reported excellent sensitivity and perfect NPV (6). One difference between our study and that of Nwaru et al. was that their question included a clear time-window, while ours was vaguer and left it to the parents to interpret the meaning of 'current'. Koster et al., 2010 found substantial agreement between parental reported ICS use and pharmacy register based ICS use (35). Their study also had an explicit time-period (i.e., 12 months) and differences in prevalence compared to our study, which affects the kappa. We rather chose to estimate agreement between the answers and register-based information on dispensed medications within four different time frames and we found 18 months to have the best agreement. Importantly, the same time-window of 18 months was found preferable in a previous study on the concordance between register data on dispensed drugs and parental-reported use of asthma drugs in adolescents (14). If all patients had complied with the prescribed treatment, we would probably have an even better register-based measure of asthma, which would be more in agreement with the questionnaire information on whether the child have asthma or not.

Strengths and limitations

The CATSS study has nationwide coverage and high response rate which strengthen the generalizability of the findings and decrease possible selection bias. Another strength is that data are retrieved from the Swedish health care registers. Register data enable us to obtain an objective measure based on dispensed medication from the SPDR and diagnoses from the NPR. In addition, in Stockholm County, primary health care centers (PHCC) have reported all diagnostic information (ICD-codes) to VAL since 2003. Therefore we restricted the Stockholm cohort to only include those who were born and lived in

Stockholm all years (and not just temporary). One could argue that being a twin may affect the generalizability of the findings. However, it has been shown in the age-range between 5 to 18 years that the prevalence of asthma is not higher in twins compared to singletons (30). Therefore, including twins should not affect the generalizability of the findings. Another limitation is the smaller sample size for 'reported asthma medications', as this question was added to the interviews in year 2010. In addition, young children with wheeze and shortness of breath might not always end up with an asthma diagnose by a doctor, therefore there may be some under-representation in the parental-reported 'ever asthma'. We were not able to capture those children and their symptoms in the current study. Furthermore, although a binary measure of asthma is very common in registers and questionnaire based-studies, we recognize that a binary outcome does not accurately represent the heterogeneity of asthma phenotypes and persistence. However, since register-based outcomes for asthma are used widely in the Nordic countries and other countries such as Canada, USA and Korea we felt it was important to test the agreements of commonly used binary outcomes. Registers have the advantages of being cost-effective and are population-based therefore improving generalizability and statistical power. In depth questionnaire-based cohort studies can provide more information on the various asthma phenotypes important for clinical applications but can suffer from recall-bias and are often smaller hence providing less power for epidemiological questions, and may be less generalizable.

Conclusions

We found that parent-reported asthma-related questions showed on average good agreement with the Swedish health care registers which can be applied for health care research purposes. Valid screening instruments such as questionnaires, registers, clinical cohorts and patient charts can improve epidemiological research to address various questions on risk factors and consequences of asthma.

Acknowledgements

Financial support was provided from the Swedish Research Council through the Swedish Initiative for Research on Microdata in the Social And Medical Sciences (SIMSAM) framework grant no 340-2013-5867, grants provided by the Stockholm County Council (ALF-projects), the Strategic Research Program in Epidemiology at Karolinska Institutet, the Swedish Heart-Lung Foundation and the Swedish Asthma and

Allergy Association's Research Foundation. Bronwyn Brew was supported by a COFAS Marie-Curie post-doc grant from FORTE.

References

1. Burney PG, Luczynska C, Chinn S, Jarvis D. The European Community Respiratory Health Survey. Eur Respir J. 1994;7(5):954-60.
2. 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):483-91.
3. Burney PG, Laitinen LA, Perdrizet S, Huckauf H, Tattersfield AE, Chinn S, et al. Validity and repeatability of the IUATLD (1984) Bronchial Symptoms Questionnaire: an international comparison. Eur Respir J. 1989;2(10):940-5.
4. Shaw RA, Crane J, Pearce N, Burgess CD, Bremner P, Woodman K, et al. Comparison of a video questionnaire with the IUATLD written questionnaire for measuring asthma prevalence. Clinical and experimental allergy : journal of the British Society for Allergy and Clinical Immunology. 1992;22(5):561-8.
5. Kilpelainen M, Terho EO, Helenius H, Koskenvuo M. Validation of a new questionnaire on asthma, allergic rhinitis, and conjunctivitis in young adults. Allergy. 2001;56(5):377-84.
6. Nwaru BI, Lumia M, Kaila M, Luukkainen P, Tapanainen H, Erkkola M, et al. Validation of the Finnish ISAAC questionnaire on asthma against anti-asthmatic medication reimbursement database in 5-year-old children. The clinical respiratory journal. 2011;5(4):211-8.
7. Valle SO, Kuschnir FC, Sole D, Silva MA, Silva RI, Da Cunha AJ. Validity and reproducibility of the asthma core International Study of Asthma and Allergies in Childhood (ISAAC) written questionnaire obtained by telephone survey. The Journal of asthma : official journal of the Association for the Care of Asthma. 2012;49(4):390-4.
8. Redline S, Larkin EK, Kercsmar C, Berger M, Siminoff LA. Development and validation of school-based asthma and allergy screening instruments for parents and students. Annals of allergy, asthma & immunology : official publication of the American College of Allergy, Asthma, & Immunology. 2003;90(5):516-28.
9. Wolf RL, Berry CA, Quinn K. Development and validation of a brief pediatric screen for asthma and allergies among children. Annals of allergy, asthma & immunology : official publication of the American College of Allergy, Asthma, & Immunology. 2003;90(5):500-7.
10. Busi LE, Sly PD, Llancaman L. Validation of a questionnaire for asthma case identification in pre-schools in Latin America. Respirology. 2015;20(6):912-6.
11. Norrman E, Plaschke P, Bjornsson E, Rosenhall L, Lundback B, Jansson C, et al. Prevalence of bronchial hyper-responsiveness in the southern, central and northern parts of Sweden. Respiratory medicine. 1998;92(3):480-7.
12. Ronmark E, Jonsson E, Platts-Mills T, Lundback B. Different pattern of risk factors for atopic and nonatopic asthma among children--report from the Obstructive Lung Disease in Northern Sweden Study. Allergy. 1999;54(9):926-35.
13. Cornish RP, Henderson J, Boyd AW, Granell R, Van Staa T, Macleod J. Validating childhood asthma in an epidemiological study using linked electronic patient records. BMJ Open. 2014;4(4).
14. Dahlen E, Almqvist C, Bergstrom A, Wettermark B, Kull I. Factors associated with concordance between parental-reported use and dispensed asthma drugs in adolescents: findings from the BAMSE birth cohort. Pharmacoepidemiol Drug Saf. 2014;23(9):942-9.
15. Pekkanen J, Sunyer J, Anto JM, Burney P, European Community Respiratory Health S. Operational definitions of asthma in studies on its aetiology. Eur Respir J. 2005;26(1):28-35.

16. Kemp T, Pearce N, Crane J, Beasley R. Problems of measuring asthma prevalence. Respirology. 1996;1(3):183-8.
17. Flohr C, Weinmayr G, Weiland SK, Addo-Yobo E, Annesi-Maesano I, Bjorksten B, et al. How well do questionnaires perform compared with physical examination in detecting flexural eczema? Findings from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase Two. Br J Dermatol. 2009;161(4):846-53.
18. Smeeton NC, Rona RJ, Oyarzun M, Diaz PV. Agreement between responses to a standardized asthma questionnaire and a questionnaire following a demonstration of asthma symptoms in adults. Am J Epidemiol. 2006;163(4):384-91.
19. Ferris BG. Epidemiology Standardization Project (American Thoracic Society). The American review of respiratory disease. 1978;118(6 Pt 2):1-120.
20. Rönmark E, Lundbäck B, Jönsson E, Rönmark E, Lundbäck B, Platts-mills T. Different pattern of risk factors for atopic and nonatopic asthma among children – report from the Obstructive Lung Disease in Northern Sweden Study. Allergy. 1999;54(9):926-35.
21. Ortqvist AK, Lundholm C, Wettermark B, Ludvigsson JF, Ye W, Almqvist C. Validation of asthma and eczema in population-based Swedish drug and patient registers. Pharmacoepidemiol Drug Saf. 2013;22(8):850-60.
22. Anckarsater H, Lundstrom S, Kollberg L, Kerekes N, Palm C, Carlstrom E, et al. The Child and Adolescent Twin Study in Sweden (CATSS). Twin Res Hum Genet. 2011;14(6):495-508.
23. Douglas AG. Practical statistics for medical research. Chapman and Hall/CRC. 1990:624.
24. Wettermark B, Hammar N, Fored CM, Leimanis A, Otterblad Olausson P, Bergman U, et al. The new Swedish Prescribed Drug Register--opportunities for pharmacoepidemiological research and experience from the first six months. Pharmacoepidemiol Drug Saf. 2007;16(7):726-35.
25. Ludvigsson JF, Andersson E, Ekbom A, Feychting M, Kim JL, Reuterwall C, et al. External review and validation of the Swedish national inpatient register. BMC Public Health. 2011;11:450.
26. Ludvigsson JF, Otterblad-Olausson P, Pettersson BU, Ekbom A. The Swedish personal identity number: possibilities and pitfalls in healthcare and medical research. Eur J Epidemiol. 2009;24(11):659-67.
27. Fleiss JL. Statistical Methods for rates and proportions (2nd ed). New York. John Wiley. 1981;ISBN 0-471-26370-2.
28. de Marco R, Cerveri I, Bugiani M, Ferrari M, Verlato G. An undetected burden of asthma in Italy: the relationship between clinical and epidemiological diagnosis of asthma. Eur Respir J. 1998;11(3):599-605.
29. Ullemar V, Magnusson PK, Lundholm C, Zettergren A, Melen E, Lichtenstein P, et al. Heritability and confirmation of genetic association studies for childhood asthma in twins. Allergy. 2016;71(2):230-8.
30. Ullemar V, Lundholm C, Almqvist C. Twins' risk of childhood asthma mediated by gestational age and birthweight. Clinical and experimental allergy : journal of the British Society for Allergy and Clinical Immunology. 2015;45(8):1328-36.
31. Fall T, Lundholm C, Ortqvist AK, Fall K, Fang F, Hedhammar A, et al. Early Exposure to Dogs and Farm Animals and the Risk of Childhood Asthma. JAMA pediatrics. 2015;169(11):e153219.
32. Tedner SG, Lundholm C, Olsson H, Almqvist C. Depression or anxiety in adult twins is associated with asthma diagnosis but not with offspring asthma. Clinical and experimental allergy : journal of the British Society for Allergy and Clinical Immunology. 2016;46(6):803-12.
33. Ortqvist AK, Lundholm C, Kieler H, Ludvigsson JF, Fall T, Ye W, et al. Antibiotics in fetal and early life and subsequent childhood asthma: nationwide population based study with sibling analysis. BMJ (Clinical research ed). 2014;349:g6979.

34. Seidl H, Meisinger C, Kirchberger I, Burkhardt K, Kuch B, Holle R. Validity of self-reported hospital admissions in clinical trials depends on recall period length and individual characteristics. Journal of evaluation in clinical practice. 2016;22(3):446-54.
35. Koster ES, Wijga AH, Raaijmakers JA, Koppelman GH, Postma DS, Kerkhof M, et al. High agreement between parental reported inhaled corticosteroid use and pharmacy prescription data. Pharmacoepidemiol Drug Saf. 2010;19(11):1199-203.

- ***'Reported ever asthma'*:** 'Does he/she have or has he/she had asthma'?

  if **'yes'** then:

  - ***'Reported current asthma'*:** 'Does he/she still have asthma'?
  - ***'Reported doctor's diagnosis':*** 'You said that he/she has or has had asthma, has he/she been given that diagnosis by a doctor or nurse'?
  - ***'Reported asthma medications':*** 'Does your child currently take any asthma medication (inhalator, spray or tablets)'?

Panel 1. Figure of the asthma related questions from the questionnaire

427

428

429

430 Table 1. Participants' characteristics in the two cohorts

	Category	National Cohort* (n=18725)	Stockholm Cohort # (n=2226)
Age at interview (mean± SD[range]); years		9.4±1.0 [8.5-12.6]	9.2±0.4 [8.5-11.5]
Classified as 9 years old n (%)		16561 (88.4)	2226 (100)
Sex	Male	9495 (50.7)	1158 (52.0)
	Female	9230 (49.3)	1068 (48.0)
'Reported ever asthma' from questionnaire	No	15866 (84.7)	1822 (81.9)
	Yes	2720 (14.5)	388 (17.4)
	Missing	139 (0.7)	16 (0.7)
'Reported current asthma' from questionnaire	No	17324 (92.5)	2059 (92.5)
	Yes	1329 (7.1)	158 (7.1)
	Missing	72 (0.4)	9 (0.4)
'Reported doctor's diagnosis' from questionnaire	No	16071 (85.8)	1846 (82.9)
	Yes	2484 (13.3)	360 (16.2)
	Missing	170 (0.9)	20 (0.9)
'Reported asthma medications' from questionnaire (current)§	No	917 (9.3)	254 (11.4)
	Yes	492 (5.0)	116 (5.2)
	Missing	8451 (85.7)	1856 (83.4)
'Register-based ever asthma' Asthma defined[5] by dispensed medications from SPDR[1] and/or a diagnosis from NPR[2]	No	15398 (82.2)	1731 (77.8)
	Yes	2831 (15.1)	496 (21.1)
	Missing	496 (2.63)	26 (1.2)
'Register-based asthma medications' Any asthma medications dispenses ever from SPDR[1]	No	14752 (78.8)	1655 (74.3)
	Yes	3973 (21.2)	571 (25.7)
Any asthma diagnoses from NPR[2] ever	No	16203 (86.5)	
	Yes	2522 (13.5)	
'Register-based doctor's diagnosis' Any asthma diagnoses from NPR[2] or VAL[3] ever	No		1704 (76.6)
	Yes		522 (23.5)
Age at first diagnose (mean± SD); years		4.0 (3.8)	3.8 (3.6)

SES (Socio Economic Status) from LISA[4]	9 y completed	294 (1.6)	42 (1.9)
	10-12 y completed	7278 (38.9)	554 (24.9)
	>12 y completed	10907 (58.3)	1594 (71.6)
	Missing	246 (1.3)	36 (1.6)
Answered questionnaire (mother/father/other)	Biological mother	15827 (84.5)	1818 (81.7)
Migrant background (Mother or father born outside Scandinavia)	No	16421 (87.70)	1808 (81.22)
	Yes	2188 (12.23)	400 (17.97)
	Missing	116 (0.07)	18 (0.81)
	Biological father	2812 (15.02)	382 (17.2)
	Other	86 (0.5)	26 (1.2)
	Missing	0	0

*National cohort included twins in CATSS, whose parents completed the telephone interview since July 1st 2006.
#Stockholm cohort included twins in CATSS, born from 2001 in Stockholm and lived all years in Stockholm
§ This question was added in 2010, in total n=9860 answered the questionnaire after this time-point
[1]=Swedish Prescribed Drug Register (SPDR)
[2]=National Patient Register (NPR)
[3]=Stockholm regional health care data warehouse (VAL)
[4]=Longitudinal integration database for health insurance and labor market studies (LISA) at the year when children were 5 years
[5]=Asthma medication of ≥ 2 dispenses of ICS and/or LTRA and/or B2-ICS independent of time between and/or ≥ 3 dispenses of ICS and/or LRTA and/or B2-ICS and/or B2 within a 12 month period (prior to the date of the interview) and/or a diagnosis from NPR

Table 2. Agreement between 'reported ever asthma' and 'reported doctor's diagnosis' from the questionnaire against SPDR, NPR and VAL in the National and the Stockholm cohort respectively.

Questionnaire, q	**Registers, r**	**Overall agreement %(n)**	**q^+r^- n**	**q^-r^+ n**	**q^+r^+ n**	**q^-r^- n**	**Kappa, (95% CI)**
National cohort (n=18725)							
'Reported ever asthma' (questionnaire)	'Register-based ever asthma', Asthma defined by dispensed medications (SPDR) [a] or a diagnosis from NPR	92.09 (16675/18107)	646	786	2003	14672	0.69 (0.68-0.71)
Stockholm Cohort (n=2226)	'Register-based doctor's diagnosis',						

'Reported doctor's diagnosis' (questionnaire)	Any asthma diagnosis from NPR or VAL	86.31 (1904/2206)	78	224	282	1622	0.57	(0.53-0.61)

Table 2 shows the National cohort and the number of participants who were either positive or negative on the questionnaire variable, q+ and q- respectively and positive or negative on the register variable, r+ and r- respectively.
[a]=Asthma medication of ≥ 2 dispenses of ICS and/or LTRA and/or B2-ICS independent of time between and/or ≥ 3 dispenses of ICS and/or LRTA and/or B2-ICS and/or B2 within a 12 month period (prior to the date of the interview)
SPDR=Swedish Prescribed Drug Register
NPR=National Patient Register
VAL=Stockholm regional health care data warehouse
CI=Confidence Interval

Table 3. Agreement between 'reported current asthma' from the questionnaire and SPDR and NPR in the National cohort, n=18725

Questionnaire, q	**Registers, r**	**Overall agreement %(n)**	**q^+r^- n**	**q^-r^+ n**	**q^+r^+ n**	**q^-r^- n**	**Kappa (95% CI)**
'Reported current asthma' (questionnaire)	'Register-based current asthma', Asthma defined by dispensed medications (SPDR)[a] or a diagnosis from NPR with at least one dispensed medication (any) or a diagnosis in the last:						
	6m	95.50 (17814/18653)	671	168	658	17156	0.59 (0.56-0.61)
	12m	95.94 (17896/18653)	472	285	857	17039	0.67 (0.65-0.69)
	18m	96.05 (15873/16526)	314	339	846	15027	0.70 (0.68-0.72)
	24m	95.76 (13946/14563)	225	392	799	13147	0.70 (0.68-0.72)
'Reported current asthma' (questionnaire)	'Register-based current asthma', Asthma defined by dispensed medications (SPDR)[a] or a diagnosis from NPR with at least one dispensed medication in the last:						
	6m	95.30 (17777/18653)	726	150	603	17174	0.56 (0.53-0.58)
	12m	95.78 (17865/18653)	522	266	807	17058	0.65 (0.63-0.67)

	18m	96.00 (15865/16526)	347	314	813	15052	0.69 (0.67-0.71)
	24m	95.76 (13945/14563)	249	369	775	13170	0.69 (0.67-0.72)

[a]=Asthma medication of ≥ 2 dispenses of ICS and/or LTRA and/or B2-ICS independent of time between and/or ≥ 3 dispenses of ICS and/or LRTA and/or B2-ICS and/or B2 within a 12 month period (prior to the date of the interview
CI=Confidence Interval
SPDR=Swedish Prescribed Drug Register

Table 4. Agreement between 'reported asthma medications' from the questionnaire and SPDR in the National cohort, n=18725

Questionnaire, q	**Registers, r**	**Overall agreement % (n)**	**q^+r^- n**	**q^-r^+ n**	**q^+r^+ n**	**q^-r^- n**	**Kappa (95% CI)**
'Reported asthma medications' (Questionnaire)[a] current	'Register-based asthma medications', At least one asthma medication dispenses (SPDR)[b] in the last:						
	6 m	79.49 (1120/1409)	215	74	277	843	0.52 (0.47-0.56)
	12m	80.48 (1134/1409)	137	138	355	779	0.57 (0.53-0.62)
	18m	80.13 (1129/1409)	83	197	409	720	0.59 (0.54-0.63)
	24m	77.93 (1098/1409)	59	252	433	665	0.55 (0.52-0.60)

[a]=This question was added in 2010, in total n=9860 answered the questionnaire after this timepoint
[b]=Swedish Prescribed Drug Register (SPDR)
CI=Confidence Interval