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Reliability in reporting asthma history and age at asthma onset

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Abstract

Background—Evaluation of the prevalence and incidence of asthma and research into its etiology often rely on self-reported information. We conducted this analysis to investigate reliability in reporting asthma history across categories of demographic and socio-economic characteristics.

Methods—We analyzed data from 3109 participants in the Coronary Artery Risk Development in Young Adults study, a longitudinal study of African-American and white adults. Responses to self-administered questionnaires completed at 15- and 20-year follow-up exams were used to evaluate agreement in reporting asthma history and age at diagnosis and assess variation in agreement across categories of demographic and health-related characteristics.

Results—A history of asthma was reported by 12% of participants at the 15-year exam and 11% of participants at the 20-year exam, with 97% agreement and an overall Kappa coefficient of 0.845 (95% confidence interval: 0.815–0.874). Kappa coefficients were higher among women than men and increased monotonically across categories of educational attainment. One-hundred eight participants (35%) reported exactly the same age at diagnosis at the two time points; for another 120 (39%), the difference in reported ages was ≤2 years. Age at asthma diagnosis reported at the 20-year exam was, on an average, 1 year (SD: 5.2) older than that reported at the 15-year exam.

Conclusions—Five-year reliability in self-reported asthma history is high, and variation in reporting age at diagnosis is low across categories of participant characteristics. Nevertheless, agreement in responses at two times does not guarantee that self-administered questionnaires are sensitive tools for detecting a true asthma history.

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Declaration of interest

The authors declare no conflicts of interest.

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention, the Department of Health and Human Services or the United States government.

Keywords

Questionnaire methodology; reliability; repeatability; survey methods; validity

Introduction

Evaluation of the prevalence and incidence of asthma and research into its etiology often rely on self-reported asthma histories provided by adult research subjects and survey respondents. However, relatively little information is available about the extent to which responses to specific questionnaire items designed to identify men and women with a history of physician-diagnosed asthma truly provide the information about the history of asthma or the timing of its onset that investigators seek. Indeed, one of the major disadvantages of developing and using a questionnaire to identify asthma is the lack of a widely-accepted definition of asthma with which to compare questionnaire responses [1].

Guidelines by the National Heart Lung and Blood Institute provide a working definition of asthma by identifying asthma as a common chronic inflammatory disorder of the airways characterized by variable and recurring symptoms, airway obstruction and bronchial hyperresponsiveness [2]. Developed for clinical use, these guidelines provide parameters for asthma diagnosis and the development of asthma treatment plans. The accuracy with which patients are diagnosed and later recall and report diagnoses made according to such parameters unmistakably affects the use of self-reported asthma history information in epidemiologic research. One evaluation of the validity of questionnaire-based responses to provide the same information generated by non-specific tests of bronchial hyperresponsiveness or clinical diagnoses suggests that self-reported questionnaire responses are generally characterized by low sensitivity and high specificity [1]. That is, the proportion of individuals with asthma identified using survey responses as having asthma is low, while the proportion of individuals without asthma who are identified as not having asthma is high [1,3].

The integration of information reported over time through the repeated use of an asthma questionnaire has been proposed as a means to improve the characterization of asthma, particularly among individuals for whom the manifestation of asthma changes over time [4]. In a recent comparison of asthma classification based on physiologic measures during a clinical exam to self-reported asthma reported 10 years after the clinical exam, Torén et al. describe an observed bias in self-reported asthma attributable to asthma severity [5,6]. Specifically, adults with mild asthma at the beginning of the follow-up period were less likely to self-report their asthma 10 years later. In the absence of a clinical examination, such as that available to Torén et al. and Balder et al. [5,6], adult participants in observational research studies may be asked whether they have ever had asthma, ever been diagnosed with asthma or ever been told by a doctor or nurse that they have asthma.

Given the likelihood of low sensitivity and high specificity of questionnaire items related to asthma, evaluation of the reliability of reporting asthma is uncommon and the extent to which study participants provide the same information about their history of asthma when they are asked on more than one occasion is largely unknown, particularly among

participants recruited into general population-based research studies. In an evaluation of initial responses to those provided approximately eight years later by participants in the European Community Respiratory Health Survey, Pattaro et al. reported 96% agreement in responses about a lifetime history of asthma and a mean difference of −0.20 years in the reported age at first asthma attack [7]. The extent to which these results may be generalized across demographic and socio-economic categories is unknown. As in the European Community Respiratory Health Survey, participants in the Coronary Artery Risk Development in Young Adults (CARDIA) study responded to questions about their respiratory health multiple times. In the CARDIA study, identical questionnaire items included at follow-up examinations that occurred five years apart provide a unique opportunity to investigate reliability in reporting a history of asthma and, among adults with a history of asthma, the age at which the asthma diagnosis occurred. We conducted these analyses to extend our understanding of the validity and reliability of self-reported asthma history information by investigating reliability in reporting asthma history and age at asthma onset across categories of demographic, socio-economic and health-related characteristics.

Methods

The CARDIA study

We analyzed publicly available data from the CARDIA study, a prospective, population-based cohort study designed to assess the development of heart disease in African-American and white adults [8,9]. The CARDIA study enrolled a closed cohort of men and women, aged 18–30 years, from four communities in the United States: Birmingham, AL; Minneapolis, MN; Chicago, IL; and Oakland, CA. Initial examination of the study population occurred in 1985–1986 with a baseline exam completed by 5112 participants. At the baseline exam, each participant provided detailed demographic and health-related information. Follow-up examinations occurred 2, 5, 7, 15, 20 and 25 years after the baseline exam. The study design and methods are described in detail elsewhere [8–10]. Selected CARDIA data through the 20-year follow-up exam are publicly available through the Biologic Specimen and Data Repository Information Coordinating Center of the National Heart Lung and Blood Institute [11]. Because we used only these de-identified, publicly-available data, the analyses presented in this study were reviewed and determined to be exempt from Institutional Review Board review at the Centers for Disease Control and Prevention.

Study population

Medical history questionnaires administered at the 15- and 20-year follow-up examinations (hereafter referred to as Y15 and Y20, respectively) contained identical questions about asthma history, and therefore formed the basis for selecting the study population to be included in our analysis. To evaluate the reliability in reporting asthma history and age at asthma onset, we limited our eligible study population to the 3177 CARDIA participants who completed medical history questionnaires at both Y15 and Y20. We excluded one participant with incompatible information about age at the Y20 exam and age at asthma diagnosis and 67 participants with new-onset asthma during the follow-up period – that is, individuals who reported no history of asthma before or at Y15 and who subsequently

reported a history of asthma consistent with the first onset of asthma between Y15 and Y20. Among the 67 excluded, due to new-onset asthma, 27 reported an age at diagnosis consistent with onset between the Y15 and Y20 exams, 38 reported an age at diagnosis younger (range: 1–20 years younger; median: 4.5) than his/her age at the Y15 exam and 2 did not report an age at diagnosis. After these exclusions, our analyses are based on a final study population of 3109 participants.

Asthma history

At the baseline, Y15 and Y20 exams, participants self-reported a history of asthma by responding to the following question: “has a doctor or nurse ever said that you have asthma?” Respondents who indicated that they were “not sure” (at Y15 only: n =14; at Y20 only: n =34; at both: n =2) were categorized as not having been told by a doctor or nurse that they have asthma. Those participants with a history of asthma then reported his/her age at asthma diagnosis by responding to the follow-up question “at what age were you first told this?”.

Other covariates

Each participant reported his/her age, race and sex. We used responses provided at Y20 to categorize participants’ educational attainment, family income, usual source of medical care, cigarette smoking status and body mass index. For participants without valid information about educational attainment or usual source of medical care at Y20, we carried forward responses provided at Y15. Cigarette smoking status was categorized as current smoker, former smoker or lifetime non-smoker. All 24 participants for whom a current smoking status was not reported at Y20 had reported either currently or formerly smoking in earlier exams, therefore, we carried forward to Y20 the last reported current or former smoking status. Body mass index values were categorized: 18.5–24.9 (normal), 25.0–29.9 (overweight) and ≥30.0 (obese). None of the participants’ body mass index values were below the threshold for underweight (<18.5); 14 individuals for whom body mass index values were missing at Y20 were also missing the information at Y15 and are categorized here as having unknown body mass index.

At Y20, 3020 (97%) participants completed spirometry testing. We used participants’ maximum forced expiratory volume in one second (FEV_1), maximum forced vital capacity (FVC) and reference values for the lower limits of normal (LLN) [12] to categorize participants with FEV_1<LLN and FEV_1/FVC<LLN as having airway obstruction at Y20.

Statistical analysis

We evaluated agreement in reporting a history of asthma at Y15 and Y20 by percent agreement and Cohen’s kappa coefficients [13], which are presented with 95% confidence intervals (CIs) generated using asymptotic standard errors. To investigate variations in agreement across categories of demographic, socio-economic and health-related characteristics, we computed metrics of agreement for each stratum of age, race, sex, educational attainment, family income, usual source of medical care, smoking status, airway obstruction and body mass index. Differences in stratum-specific kappa coefficients were examined using the test for equal kappa coefficients.

Following this main analysis of agreement in reporting a history of asthma, we conducted two sensitivity analyses designed to evaluate the impact on our results of two analytic decisions: (1) categorizing as not having a history of asthma 50 participants who indicated that they were not sure whether they had ever been told they had asthma or whose responses to the question were missing and (2) categorizing 38 participants as having new-onset asthma during follow-up despite an age at asthma diagnosis reported as younger than the age at Y15. Our main analysis treated these 38 respondents as if they correctly reported no history of asthma at Y15 and a new history of asthma at Y20, but incorrectly recalled and reported the age at diagnosis as having occurred before the Y15 exam. In contrast, we designed this sensitivity analysis to evaluate the impact of treating these participants as if they incorrectly reported no history of asthma at Y15 then correctly reported a history of asthma and age at asthma diagnosis at Y20. In the sensitivity analysis, we treated larger differences between age at asthma diagnosis and age at Y15 more likely to be false negative responses at Y15 and smaller differences more likely to be true negative responses at Y15 followed by new-onset asthma between Y15 and Y20 and poor recall of age at which the diagnosis occurred. In the absence of a threshold for which differences may be considered false negative asthma histories versus true negatives with poorly recalled age at diagnosis, we evaluated the change in kappa as participants were sequentially added to the study population in descending order of the number of years between the age at Y15 and the age at asthma diagnosis reported at Y20.

Among adults who reported a history of asthma at both Y15 and Y20, we evaluated agreement in reported age at asthma diagnosis using Pearson's product-moment correlation coefficients. The magnitude of discordance in the values of age at asthma diagnosis reported at Y15 and Y20 was computed as the difference in the ages reported at the two time points. We evaluated variations in these differences across strata of age, race, sex, educational attainment, family income, usual source of medical care, smoking status, airway obstruction and body mass index.

Finally, to examine changes in the estimated sensitivity and specificity of self-reporting a history of asthma by age 17 over time, we selected a subpopulation of 2788 CARDIA participants who returned for follow-up exams at years 7, 10, 15 and 20. Responses at the baseline exam and each follow-up exam were used to categorize participants as reporting a history of asthma with onset by age 17. The sensitivity of self-reporting a history of asthma diagnosed at 0–17 years of age was calculated at each of the four follow-up exams by dividing the number of participants whose responses indicated a history of asthma at ≤17 years of age by the number of participants with positive responses at the baseline exam (n =216). Similarly, specificity was calculated by dividing the number of participants whose responses indicated no history of asthma by age 17 by the number of participants with negative responses at the baseline exam (n =2572). At each follow-up exam, positive predictive values were calculated by dividing the number of participants with positive responses at both the baseline and the follow-up exam by the number of participants with positive responses at the follow-up exam; negative predictive values were calculated by dividing the number of participants with negative responses at both the baseline and the

follow-up exam by the number of participants with negative responses at the follow-up exam. All analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC).

Results

A history of asthma was reported by 12% of respondents at the 15-year exam and 11% of respondents at the 20-year exam, with 97% agreement in responses at the two exams and an overall Kappa coefficient of 0.845 (95% CI: 0.815–0.874) (Table 1). Kappa coefficients were higher among women (0.870; 95% CI: 0.836–0.904) than men (0.797; 95% CI: 0.741–0.853), lower among respondents aged 38–40 years at the time of the 20-year follow-up exam (0.751; 95% CI: 0.637–0.864) than adults aged 41–50 years (0.856; 95% CI: 0.825–0.886) and increased monotonically across categories of educational attainment. There was little variation in the magnitude or precision of Kappa coefficients generated across categories of race, family income, usual source of medical care, smoking status or airway obstruction (Table 2).

By re-evaluating agreement when 50 participants who responded that they were not sure whether they had ever been told they had asthma or whose responses to the question were missing were included in a third category (“not sure”), rather than categorized as not having a history of asthma, agreement in responses at the two exams was reduced to 96%, with a weighted Cohen’s kappa of 0.458 (95% CI: 0.369–0.547) among men, 0.676 (95% CI: 0.597–0.754) among women and 0.587 (95% CI: 0.525–0.648) overall. Of the 16 men and women categorized as “not sure” at Y15, 11 (69%) reported no history of asthma at Y20. Although spirometry data are not available for Y15, 13 of 14 who completed spirometry at Y20 were categorized as not having airway obstruction at Y20. Of the 36 participants categorized as “not sure” at Y20, 25 (69%) reported no history of asthma at Y15 and 30 of 33 who completed spirometry at Y20 were categorized as not having airway obstruction. Excluding these, 50 participants generated agreement in responses at the two exams of 97% and a kappa of 0.861 (95% CI: 0.833–0.889) for the remaining population.

Results of analyses designed to consider the impact of excluding participants based on our categorization of new-onset asthma during the five-year follow-up period (i.e. participants who reported no history of asthma at Y15, then reported at Y20 an age at asthma diagnosis that was younger than the age at which the Y15 exam took place) are presented in Figure 1. For these 38 participants, the reported age at asthma diagnosis was an average of 6.3 (SD: 4.9; median: 4.5) years younger than the age at which the Y15 exam was completed. The range of ages at asthma diagnosis reported (range: 25–40 years) may suggest a history of adult-onset asthma that was unreported at Y15. As participants with a greater age differences were sequentially included in the analysis, kappa coefficients declined to 0.759 (95% CI: 0.699–0.818) among men, 0.814 (95% CI: 0.775–0.853) among women and 0.796 (95% CI: 0.763–0.828) overall.

Of the 318 participants who reported a history of asthma at both Y15 and Y20, 308 (97%) also reported an age at asthma diagnosis and were included in our analysis of agreement in the reporting of age at asthma diagnosis. The mean age at asthma diagnosis reported was 18.2 (SD: 12.3) years at Y15 and 19.2 (SD: 12.2) years at Y20 (Table 3). One-hundred eight

participants (35%) reported exactly the same age at asthma diagnosis at both exams; for other 120 (39%) participants, the difference in reported ages was ≤2 years.

Among the 216 participants who, at the baseline exam, reported a history of asthma diagnosed at ≤17 years of age, 151 again reported a history of asthma diagnosed at ≤17 years at the Y7 exam for a sensitivity of 0.70; sensitivity decreased monotonically across subsequent exams: 0.67 at Y10, 0.65 at Y15 and 0.59 at Y20 (Table 4). Among the 2572 participants without a history of asthma at ≤17 years of age, specificity exceeded 0.98 across the four follow-up exams. Across the four follow-up periods, there was little variation in positive and negative predictive values; positive predictive values ranged from 0.79 to 0.81 and negative predictive values ranged from 0.97 to 0.98.

Discussion

Our study, designed to characterize the reliability of self-reported asthma history, suggests that five-year reliability in self-reported history of asthma is high across categories of age, race, sex, educational attainment, family income, source of medical care, smoking status, airway obstruction and body mass index. Agreement in reporting a history of asthma was slightly higher among women than among men and increased across categories of educational attainment. Among adults who reported a history of asthma at both time points, the difference in the ages at which asthma was reportedly diagnosed was less than or equal to two years for nearly 75% of respondents. Overall, these findings indicate that data collected *via* self-administered questionnaire are a reliable source of information about lifetime asthma history and age at asthma diagnosis. Our evaluation of the sensitivity of self-reported asthma among adults who, at the baseline exam, reported a history of asthma that was diagnosed at 0–17 years of age and our finding of decreasing sensitivity between the 7- to 20-year follow-up exams further suggest that while five-year reliability may be high, recall of a history of childhood asthma changes over time.

Without a “gold standard” with which to compare survey responses, agreement in reporting asthma history at two exams does not guarantee that the self-administered questionnaire items are a sensitive tool for detecting a true history of asthma or the timing of its onset. Indeed, without information about an individual’s true asthma status, analysis of sensitivity and specificity of self-report asthma history is limited to the comparison of proxy metrics of true asthma status. As a proxy measure of true asthma status at ages 0–17 years, we used the earliest available responses, which were given at 18–30 years of age. The sensitivity and specificity of subsequent, identical survey questions to provide the same information as the earliest responses shows the extent to which information about asthma history collected using standard questionnaire items changes over time. The declining sensitivity and consistently high specificity and negative predictive values we observed are all consistent with the range of values reported for the validity of self-reported asthma history as a means to identify individuals with positive non-specific bronchial challenge tests [1]. Comparisons of self-reported asthma with other proxy measures of true asthma status suggest that the correlations between self-reported responses and existing records vary by the source of the existing records [14,15]. Comparisons of self-reported, physician-diagnosed asthma to objective metrics of symptoms, airway obstruction or bronchial hyperresponsiveness would

improve our understanding of which features of asthma most influence self-reporting. Our analyses revealed small differences in reliability in self-reported asthma history or age at asthma diagnosis between individuals with or without airway obstruction; nonetheless, complete information about study participants' true asthma status, including variable and recurring symptoms, airway obstruction, bronchial hyperresponsiveness and other indicators of asthma status and severity, would also improve our understanding of the extent to which the previously reported bias by asthma severity [5,6] may differentially affect the reliability of self-reported asthma history.

We measured agreement in reporting a history of asthma using Cohen's kappa coefficient, a metric for evaluating inter-rater reliability while correcting for the probability of agreement by chance [16]. The influence of the prevalence of the outcome on the magnitude of kappa [17] suggests that while the five-year reliability observed in our study is high, the specific kappa coefficients generated using these data may not be applied to studies in which the prevalence of asthma differs considerably from the 11–12% prevalence observed in this general population-based cohort. Thus, while our results provide information about the reliability of reported asthma history and age at asthma diagnosis in a general population-based sample of African-American and white adults, they may not accurately reflect the reliability of information provided by participants of other racial, ethnic or high-risk groups. Our results also do not provide information about the reliability of responses reported in languages other than English or the reliability of information collected using variations in terminology to describe asthma; nor do our findings aid the interpretation of information collected among patients in clinical settings or about other self-reported health conditions. Evaluation of reliability of information provided by a wide range of study participants would further improve our understanding of the reliability of asthma history information collected for epidemiologic research.

Ideally, responses to "have you ever had asthma?", "has a doctor or nurse ever told you that you have asthma?" and "was it confirmed by a doctor?" should all provide the same information. Inconsistent responses may indicate gaps in discussions between patients and healthcare providers. If patients opt not to discuss symptoms with their healthcare providers, if patient-provider discussions do not confirm or refute patients' beliefs about whether they have asthma, or if patients who suspect they have asthma do not seek medical attention for their symptoms, then those patients' responses about whether they have asthma may differ appropriately from their responses about whether a doctor or nurse has ever confirmed the asthma. Improvements in discussions between patients and healthcare providers may very well improve the quality of asthma history information provided in research settings. In prospective research studies, the integration of measurements of bronchial reactivity and self-reported information about respiratory symptoms, asthma diagnosis and age at asthma onset would improve the ability of investigators to interpret information provided at later time points about existing or new respiratory symptoms or conditions.

Interpretation of our results is aided by several notable study strengths: the large numbers of African-American and white men and women in the CARDIA study population, use of identically worded questionnaire items about asthma history and the low attrition indicated by percentages of the surviving cohort re-examined at each follow-up exam (i.e. 81% at Y7;

79% at Y10; 74% at Y15; and 72% at Y20) [18]. In particular, the sufficiently large study population allowed us to conduct two informative sensitivity analyses. First, our analysis of the impact of categorizing respondents who reported that they were “not sure” whether they had been told by a doctor or nurse that they had asthma indicates that these respondents may be categorized as not having asthma, rather than excluded from analysis, with little impact on reliability. Collecting additional information about respiratory symptoms, bronchial hyperresponsiveness and other health indicators among people who respond that they are “not sure” would facilitate the correct categorization of these responses. In our analyses, we evaluated the presence of airway obstruction among participants with uninformative responses about asthma status and identified few participants with airway obstruction; although airway obstruction is not an indicator of asthma status, the low prevalence of airway obstruction in this population does not suggest that impaired lung function may explain these uninformative responses. In the absence of additional information about the symptoms or health of individuals who responded that they were “not sure”, misclassification may be low if these individuals are categorized as not having a history of asthma. Our second sensitivity analysis considered the possibility that we incorrectly identified 38 participants as having new-onset asthma and excluded them from our analysis. Following our analysis, it seems reasonable to conclude that some participants may have incorrectly reported an age at diagnosis as being earlier than it actually occurred; these participants would have been correctly excluded from our main analysis. However, if some participants, particularly those who at Y20 reported an age at diagnosis more than 10 or 20 years ago, incorrectly reported no history of asthma at Y15, then we excluded needlessly from our main analysis participants with discrepant responses, and the reliability we report may be higher than the true reliability in this population. Without an *a priori* hypothesis regarding the number of years before the last data collection time point that we would consider the response to be an incorrectly reported age at asthma diagnosis, we opted to include Figure 1 so that readers may consider for themselves the effects of misclassification of asthma history at Y15 and age at diagnosis reported at Y20 on estimates of reliability among men and women.

Conclusions

These results extend our understanding of the validity of self-reported asthma [5,6] by showing that among African-American and white adult study participants in the United States, reliability is high across categories of demographic and socio-economic characteristics. The modest, but clear, differences observed in reliability by sex and across categories of education attainment suggest that misclassification of asthma status may be influenced by demographic and socio-economic factors and that when asthma history is of interest, attention to the potential for such misclassification may improve the use of asthma history information provided by study participants. Evaluation of self-reported asthma among adults who, at the baseline exam, reported a history of asthma that was diagnosed at 0–17 years of age and our findings of stable specificity, positive predictive value and negative predictive value over time accompanied by decreasing sensitivity suggest that while five-year reliability may be high, recall of a history of childhood asthma may change over time.

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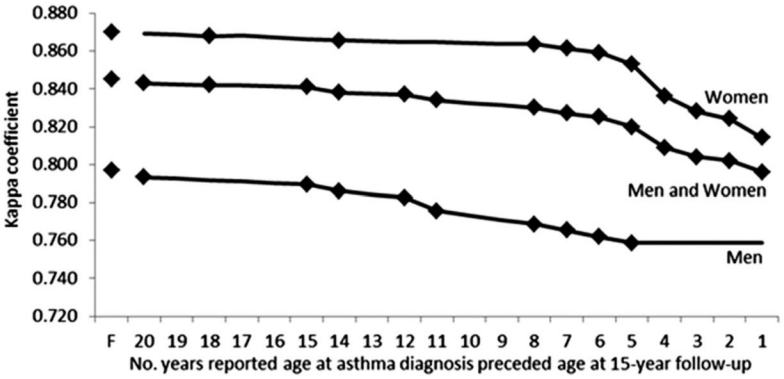

Figure 1.

Changes in Kappa coefficients as participants categorized as having new-onset asthma were added to the final study population (marked "F"; *n* =3109) in the order of decreasing years that reported age at asthma diagnosis preceded participant age at the 15-year follow-up. Diamond symbols show where one or more participants were added to the study population.

Table 1

Responses to the question “has a doctor or nurse ever said that you have asthma?” and Kappa coefficient of agreement in responses provided at the 15- and 20-year follow-up exams.

	Asthma reported at 20-year follow-up exam		
	No	Yes	
Asthma reported at 15-year follow-up exam	*N* (%)	*N* (%)	Kappa (95% CI)
No	2690 (86.5)	32 (1.0)	0.845 (0.815–0.874)
Yes	69 (2.2)	318 (10.3)	

Table 2

Characteristics of the CARDIA study population at the 20-year follow-up exam and agreement in reporting a history of asthma at 15- and 20-year follow-up exams.

Characteristics of study participants at the 20-year follow-up exam	*N* (%)	Kappa (95% CI)	Test for equal kappa coefficients[a]
Total	3109 (100.0)	0.845 (0.815–0.874)	
Age, in years			χ^2 =9.93, 5 df, *p* =0.077
38–40	404 (13.0)	0.751 (0.637–0.864)	
41–42	372 (12.0)	0.876 (0.807–0.945)	
43–44	448 (14.4)	0.821 (0.743–0.899)	
45–46	527 (17.0)	0.844 (0.771–0.916)	
47–48	627 (20.2)	0.916 (0.862–0.971)	
49–50	731 (23.5)	0.832 (0.770–0.893)	
Race			χ^2 =0.308, 1 df, *p* =0.579
Black	1384 (44.5)	0.836 (0.793–0.879)	
White	1725 (55.5)	0.853 (0.812–0.893)	
Sex			χ^2 =4.786, 1 df, *p* =0.029
Female	1747 (56.2)	0.870 (0.836–0.904)	
Male	1362 (43.8)	0.797 (0.741–0.853)	
Educational attainment, in years			χ^2 =5.946, 3 df, *p* =0.114
≤12	724 (23.3)	0.800 (0.733–0.868)	
13–15	839 (27.0)	0.841 (0.787–0.895)	
16	816 (26.2)	0.842 (0.781–0.902)	
≥17	730 (23.5)	0.901 (0.849–0.952)	
Family income			χ^2 =6.418, 7 df, *p* =0.492
$12 000–$15 999	297 (9.6)	0.829 (0.743–0.916)	
$16 000–$24 999	154 (5.0)	0.791 (0.629–0.952)	
$25 000–$34 999	198 (6.4)	0.919 (0.841–0.997)	
$35 000–$49 999	386 (12.4)	0.786 (0.685–0.887)	
$50 000–$74 999	594 (19.1)	0.847 (0.780–0.914)	
$75 000–$99 999	485 (15.6)	0.815 (0.723–0.906)	
≥$100 000	952 (30.6)	0.869 (0.819–0.919)	
Not reported	43 (1.4)	0.870 (0.696–1.000)	
Usual source of medical care			χ^2 =1.581, 3 df, *p* =0.664
None	282 (9.1)	0.783 (0.646–0.920)	
Private or personal physician[b]	2390 (76.9)	0.847 (0.814–0.881)	
Other clinic, by appointment	212 (6.8)	0.823 (0.711–0.935)	
Other	225 (7.2)	0.880 (0.793–0.967)	
Cigarette smoking status			χ^2 =2.645, 2 df, *p* =0.267
Lifetime nonsmoker	1911 (61.5)	0.832 (0.792–0.872)	
Former smoker	618 (19.9)	0.836 (0.768–0.904)	
Current smoker	580 (18.7)	0.886 (0.832–0.941)	

Characteristics of study participants at the 20-year follow-up exam	*N* (%)	Kappa (95% CI)	Test for equal kappa coefficients[a]
Airway obstruction			χ^2 =3.140, 2 df, p =0.208
No	2902 (93.3)	0.834 (0.800–0.867)	
Yes	118 (3.8)	0.858 (0.762–0.953)	
No spirometry data	89 (2.9)	0.927 (0.828–1.000)	
Body mass index			χ^2 =0.227, 2 df, p =0.893
18.5–24.9 (normal)	895 (28.8)	0.855 (0.798–0.912)	
25.0–29.9 (overweight)	1031 (33.2)	0.837 (0.782–0.892)	
≥30.0 (obese)	1169 (37.6)	0.839 (0.794–0.885)	
Unknown	14 (0.5)	1.000 (1.000–1.000)	

[a] Chi-squared test for equal unweighted Kappa coefficients. Chi-squared test statistics (χ^2) are shown with degrees of freedom (df) and p values.

[b] Including care available through health maintenance organizations (HMOs).

Table 3

Mean age at asthma diagnosis reported by CARDIA study participants at 15- and 20-year follow-up exams.

Characteristics of study participants the 20-year follow-up exam	No.	Age at asthma diagnosis, in years			
		At 15-year exam Mean (SD)	At 20-year exam Mean (SD)	Pearson's correlation *r*	Difference[a] Mean (SD)
Total	308	18.2 (12.3)	19.2 (12.2)	0.9111	1.0 (5.2)
Age, in years					
38–40	28	15.2 (10.8)	17.3 (10.7)	0.8886	1.8 (5.1)
41–42	47	15.7 (10.8)	16.2 (10.8)	0.9572	0.4 (3.2)
43–44	52	17.0 (11.5)	18.4 (11.7)	0.9238	1.4 (4.5)
45–46	50	18.8 (12.4)	19.3 (12.2)	0.9829	0.5 (2.3)
47–48	55	18.6 (12.7)	19.4 (11.7)	0.8482	0.7 (6.8)
49–50	76	20.9 (13.6)	22.1 (14.0)	0.8873	1.2 (6.6)
Race					
Black	154	17.7 (13.4)	18.8 (13.0)	0.8734	1.1 (6.7)
White	154	18.8 (11.1)	19.6 (11.4)	0.9637	0.8 (3.1)
Sex					
Female	206	20.0 (13.0)	20.9 (13.1)	0.9072	1.1 (4.1)
Male	102	14.7 (9.9)	15.8 (9.4)	0.9091	0.9 (5.6)
Educational attainment, in years					
≤12	68	19.1 (12.7)	21.4 (12.1)	0.8874	2.3 (5.9)
13–15	94	18.7 (12.6)	19.5 (12.3)	0.9003	0.8 (5.6)
16	76	17.7 (12.1)	18.3 (12.3)	0.8975	0.7 (5.5)
≥17	70	17.4 (12.0)	17.7 (12.1)	0.9721	0.3 (2.9)
Family income					
$12 000–$15 999	38	18.6 (14.5)	21.2 (11.2)	0.7180	2.5 (9.0)
$16 000–$24 999	12	22.1 (13.9)	23.0 (14.4)	0.9741	0.9 (3.3)
$25 000–$34 999	26	16.0 (14.4)	16.8 (11.5)	0.9376	0.8 (4.3)
$35 000–$49 999	34	19.3 (13.3)	19.2 (12.2)	0.9174	−0.1 (5.3)
$50 000–$74 999	59	19.5 (12.9)	20.8 (13.2)	0.9607	1.3 (3.7)
$75 000–$99 999	37	16.1 (11.4)	16.5 (12.1)	0.9629	0.4 (3.3)
≥$100 000	93	18.0 (11.8)	18.6 (12.1)	0.9336	0.6 (4.4)

Characteristics of study participants the 20-year follow-up exam	No.	Age at asthma diagnosis, in years		Pearson's correlation *r*	Difference[a] Mean (SD)
		At 15-year exam Mean (SD)	At 20-year exam Mean (SD)		
Not reported	9	16.6 (13.2)	20.1 (11.2)	0.7571	3.6 (8.7)
Usual source of medical care					
None	18	16.7 (10.8)	17.8 (9.5)	0.8847	1.1 (5.0)
Private or personal physician[b]	237	18.5 (12.5)	19.2 (12.7)	0.9318	0.8 (4.7)
Other clinic, by appointment	25	18.5 (11.2)	21.6 (11.0)	0.7896	3.2 (7.2)
Other	28	17.1 (13.1)	17.7 (11.1)	0.8462	0.6 (7.0)
Cigarette smoking status					
Lifetime nonsmoker	177	17.8 (12.7)	18.5 (12.3)	0.9436	0.7 (4.2)
Former smoker	60	21.3 (12.4)	22.6 (12.3)	0.8271	1.3 (7.3)
Current smoker	71	16.6 (11.1)	18.1 (11.6)	0.8914	1.5 (5.3)
Airway obstruction					
No	252	18.9 (12.5)	19.8 (12.4)	0.9092	0.9 (5.3)
Yes	41	15.0 (10.4)	15.7 (10.5)	0.9168	0.7 (4.3)
No spirometry data	15	15.7 (12.8)	18.9 (13.4)	0.9256	3.1 (5.1)
Body mass index					
18.5–24.9 (normal)	77	18.0 (11.3)	18.6 (10.9)	0.9388	0.6 (3.9)
25.0–29.9 (overweight)	92	15.4 (11.5)	16.9 (12.1)	0.9245	1.5 (4.6)
≥30.0 (obese)	135	20.4 (13.0)	21.1 (12.8)	0.8891	0.7 (6.1)
Unknown	4	15.5 (15.9)	20.0 (15.7)	0.9407	4.5 (5.4)

[a] Difference in age at asthma diagnosis reported at 15- and 20-year follow-up exams, calculated as age reported at 20-year follow-up minus age reported at 15-year follow-up.

[b] Including care available through health maintenance organizations (HMOs).

Table 4

Changes in sensitivity and specificity of self-reported asthma diagnosed at ≤17 years of age.

		Follow-up year			
	Baseline	**7**	**10**	**15**	**20**
Asthma diagnosed at ≤17 years of age					
Yes					
No. reported	216	151	145	140	127
Sensitivity		0.70	0.67	0.65	0.59
Positive predictive value		0.81	0.79	0.81	0.79
Age at asthma diagnosis, in years					
Mean (SD)[a]	5.9 (4.5)	7.1 (3.5)	6.8 (3.6)	6.7 (3.6)	7.4 (3.3)
Median	5	6	6	6	7
Minimum–maximum	0–17	3–17	1–17	1–17	2–17
No					
No. reported	2572	2536	2533	2539	2538
Specificity		0.99	0.98	0.99	0.99
Negative predictive value		0.98	0.97	0.97	0.97

[a] SD, standard deviation