Estimating Wisconsin Asthma Prevalence Using Clinical Electronic Health Records and Public Health Data

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Objectives. We compared a statewide telephone health survey with electronic health record (EHR) data from a large Wisconsin health system to estimate asthma prevalence in Wisconsin.

Methods. We developed frequency tables and logistic regression models using Wisconsin Behavioral Risk Factor Surveillance System and University of Wisconsin primary care clinic data. We compared adjusted odds ratios (AORs) from each model.

Results. Between 2007 and 2009, the EHR database contained 376 000 patients (30 000 with asthma), and 23 000 (1850 with asthma) responded to the Behavioral Risk Factor Surveillance System telephone survey. AORs for asthma were similar in magnitude and direction for the majority of covariates, including gender, age, and race/ethnicity, between survey and EHR models. The EHR data had greater statistical power to detect associations than did survey data, especially in pediatric and ethnic populations, because of larger sample sizes.

Conclusions. EHRs can be used to estimate asthma prevalence in Wisconsin adults and children. EHR data may improve public health chronic disease surveillance using high-quality data at the local level to better identify areas of disparity and risk factors and guide education and health care interventions. (*Am J Public Health.* 2014;104:e65–e73. doi:10.2105/AJPH.2013.301396)

Asthma is a complex chronic disease with intermittent symptoms and varying degrees of severity. This often makes it difficult to determine its prevalence in a population. Nationally, asthma is estimated to affect approximately 10% of children aged 17 years and younger and 8% of adults,[1] and is associated with significant morbidity and substantial health care costs. The economic cost of asthma in the United States was estimated at $59.0 billion in 2007, including direct health care costs of $53.1 billion and indirect, or lost productivity, costs of $5.9 billion.[2] These outcomes are largely preventable with targeted interventions.[3] Ideally, asthma surveillance should identify disproportionately affected populations and guide prevention and intervention efforts.

Surveillance data for chronic diseases are traditionally drawn from federally supported health surveys that provide estimates of asthma prevalence at the national and state levels but not at the local level, where many policy decisions are made. The Behavioral Risk Factor Surveillance System (BRFSS) is the only source of data on health-related behaviors and outcomes for many states, and it is the principal source of asthma prevalence data for Wisconsin.[4] The Wisconsin telephone-based BRFSS survey contains self-reported disease and risk factor data for approximately 4500 adults and 1100 children annually. The BRFSS sample depends on available federal funding and may vary widely from year to year. Although data are provided at the county level, the sample size is often too small for direct estimation of disease prevalence at this geographical level.

Electronic health records (EHRs) are increasingly used in research to identify patients with chronic diseases for surveillance and epidemiological studies.[5–7] We compared asthma prevalence estimates in the Wisconsin child and adult population from the traditional statewide BRFSS telephone survey and EHRs from a large Wisconsin health system. We hypothesized that a reliable estimate of asthma prevalence can be made from EHR data at a local level when compared with telephone survey data.

METHODS

We used cross-sectional data from the 2007–2009 Wisconsin BRFSS survey,[4] which consists of 22 945 adult and child residents, to estimate asthma prevalence. The BRFSS is an ongoing, state-based telephone survey that state health departments conduct in collaboration with the Centers for Disease Control and Prevention to assess the health of the civilian noninstitutionalized adult population aged 18 years and older in all 50 states. Data are collected annually from a random sample of adults via a telephone survey employing random-digit dialing. Information on children in the household is collected by proxy through the adult surveyed.

Our research group has developed the University of Wisconsin (UW) Electronic Health Record Public Health Information Exchange (eHealth-PHINEX)—an EHR data exchange between the UW departments of family medicine, pediatrics, and internal medicine clinics (UW clinics) and the Wisconsin Division of Public Health Information Network of all health care visits for patients seen in the UW clinics who had at least 1 encounter identified by a date of service in the clinical EHR between January 1, 2007, and December 31, 2009. During this 3-year period, we followed the health records of 376 054 patients with 5.0 million clinical encounters and 5.6 million associated diagnoses. The database contains extracted clinical care fields, geocoding to the census block group neighborhood level, and detailed sociodemographic data. The data exchange conforms to the Health Insurance Portability and Accountability Act limited data set privacy rule (i.e., public health is blinded to patient- and provider-specific information).

The UW eHealth-PHINEX methodology has been documented previously.[8]

UW clinics are located throughout the state, but the greatest patient density is seen in south central Wisconsin (Dane and surrounding counties, including Sauk, Columbia, Dodge, Jefferson, Iowa, Rock, Green, and Marquette). These clinics provide care for Wisconsin residents of varied socioeconomic strata in both rural and urban settings.

The Esri Business Analyst Premium product[9] contains more than 6000 variables at the census block group on demographics, socioeconomic segmentation, consumer behavior, business locations and type, street data, and market potential. For this study, we examined asthma risk by median household income at the census block group, as calculated by the US Census Bureau.[10]

Measures

The primary outcome of interest was current asthma prevalence. From the BRFSS, we defined current asthma as affirmative responses to the question "Have you ever been told by a doctor, nurse, or other health professional that you have asthma?" and the subsequent question "Do you still have asthma?" We identified patients in the UW eHealth-PHINEX data set as having current asthma by the presence of the *International Classification of Diseases, Ninth Revision* ([*ICD-9*] Geneva, Switzerland: World Health Organization; 1980) code 493 in either a clinic encounter diagnosis or problem list fields of their EHR.

The following covariates (preestablished risk factors for asthma) were available from both the BRFSS survey and UW eHealth-PHINEX clinical records: gender, age group, race/ethnicity, adult body mass index (BMI; defined as weight in kilograms divided by the square of height in meters), and adult cigarette smoking. We categorized child BMI from UW eHealth-PHINEX clinical data using BMI-for-age percentiles.[11] Annual household income was available from the BRFSS only. Because household income was not available for the UW eHealth-PHINEX patients, we used the 2010 median annual household income estimate by census block group from ESRI[9] in our analysis.[12] A census block group is defined as a neighborhood area containing 600 to 3000 people. Insurance status was available from the UW eHealth-PHINEX clinical record only. When a UW eHealth-PHINEX patient had more than 1 encounter in the 3-year period, we took data from the earliest encounter.

Analytical Methods

We conducted all analyses separately for children and adults. We calculated descriptive analyses and prevalence by sociodemographic factors for both the Wisconsin BRFSS and UW eHealth-PHINEX data sets. We analyzed gender, age group, race/ethnicity, smoking status, BMI, household income, and insurance status as covariates in the child and adult models when they were available. We analyzed national and Wisconsin BRFSS data with logistic regression models, adjusted for relevant covariates. We analyzed UW eHealth-PHINEX data using adjusted mixed-effects logistic regression, in which census block group was the random effect for median household income. We estimated adjusted odds ratios (AORs) of covariates and 95% confidence intervals (CIs) from all multivariate logistic regression models. Analysis of UW eHealth-PHINEX data using a fixed effect logistic regression model resulted in estimates that were not significantly different in direction or magnitude from the mixed effects regression model (results not shown). We ran multivariate models 2 ways: including missing values as a separate category in analysis and excluding observations with missing values to key covariates. We derived final models from observations with complete covariate data; however, the results did not differ significantly when we included missing values in the analysis (results not shown).

BRFSS analyses incorporated sampling weights that adjusted for the multistage sampling frame and unequal probabilities of selection.[4] In addition, we weighted BRFSS data proportionally to account for differences in sample size between the 3 years. We performed analyses using SAS, version 9.2 (SAS Institute, Cary, NC).

We graphically represented data to illustrate asthma prevalence variation within each census tract in a map of Dane County, Wisconsin. Using a geographic information system, we geocoded the patient address and aggregated individual points to the census tract (2500- and 8000-person county subdivision), providing a count of the overall total number of patients and those with asthma to determine the disease prevalence.

RESULTS

The Wisconsin BRFSS sample consisted of 3882 children younger than 18 years and 19 063 adults aged 18 years or older. The UW eHealth-PHINEX sample contained 93 791 children and 282 263 adults. A statewide comparison of census, BRFSS, and UW eHealth-PHINEX demographics showed that the BRFSS and clinic samples were fairly representative of the Wisconsin statewide population (and were similar to one another), with the following exceptions (Table 1). UW eHealth-PHINEX data contained a significantly larger percentage of females (UW eHealth-PHINEX: 53.09% [95% CI = 52.86, 53.32] vs census: 50.33% [95% CI = 50.28, 50.39] and BRFSS: 50.54% [95% CI = 49.48, 51.59]) and children younger than 5 years (UW eHealth-PHINEX: 8.88% [95% CI = 8.78, 8.98] vs census: 6.43% [95% CI = 6.41, 6.45] and BRFSS: 6.16% [95% CI = 5.63, 6.69]), compared with the census and BRFSS data. Both UW eHealth-PHINEX and BRFSS samples contained significantly more non-Hispanic Whites than did the general population (UW eHealth-PHINEX: 87.99% [95% CI = 87.68, 88.30] and BRFSS: 88.17% [95% CI = 87.35, 88.99] vs census: 85.46% [95% CI = 85.38, 85.53]) and fewer non-Hispanic Blacks and Hispanics.

Prevalence

Child and adult asthma prevalence by select sociodemographic factors are shown in Table 2. Child asthma prevalence among UW eHealth-PHINEX patients was not significantly different from that among Wisconsin BRFSS respondents, either in terms of overall prevalence estimates (8.96% [95% CI = 8.77, 9.15] vs 7.98% [95% CI = 6.01, 9.95], respectively) or for the majority of the estimates by individual sociodemographic factors. However, because of the small sample size within strata, several of the Wisconsin BRFSS child asthma prevalence estimates had wide CIs and a relative SE greater than 30%, which made the estimates less reliable. Smoking status, BMI, and insurance status were not available for children from the Wisconsin BRFSS.

TABLE 1—Wisconsin Statewide Comparison of Census, BRFSS, and University of Wisconsin eHealth-PHINEX Clinic Demographics: 2007–2009

Variable	Wisconsin Census Data[a]		Wisconsin BRFSS Data		University of Wisconsin eHealth-PHINEX Patients	
	No.	% (95% CI)	No.[a,b]	%[d] (95% CI)	No.[c]	% (95% CI)
Overall	5 627 985		22 945		376 054	
Gender						
Male	2 795 161	49.67 (49.61, 49.72)	9857	49.46 (48.41, 50.52)	176 416	46.91 (46.69, 47.13)
Female	2 832 824	50.33 (50.28, 50.39)	13 027	50.54 (49.48, 51.59)	199 631	53.09 (52.86, 53.32)
Age group, y						
0–4	361 847	6.43 (6.41, 6.45)	859	6.16 (5.63, 6.69)	33 408	8.88 (8.78, 8.98)
5–11	496 694	8.83 (8.80, 8.85)	1230	8.57 (7.98, 9.16)	31 878	8.48 (8.39, 8.57)
12–17	458 426	8.15 (8.12, 8.17)	1573	7.92 (7.43, 8.41)	28 505	7.58 (7.49, 7.67)
18–34	1 284 712	22.83 (22.79, 22.87)	2529	23.05 (21.96, 24.14)	79 801	21.22 (21.07, 21.37)
35–64	2 277 326	40.46 (40.41, 40.52)	11 171	40.75 (39.83, 41.67)	155 120	41.25 (41.04, 41.46)
≥ 65	748 981	13.31 (13.28, 13.34)	5209	13.55 (12.98, 14.11)	47 342	12.59 (12.48, 12.70)
Race/ethnicity						
Non-Hispanic White	4 809 406	85.46 (85.38, 85.53)	19 399	88.17 (87.35, 88.99)	315 730	87.99 (87.68, 88.30)
Non-Hispanic Black	352 101	6.26 (6.24, 6.28)	1870	4.12 (3.67, 4.57)	15 652	4.36 (4.29, 4.43)
Non-Hispanic other	178 549	3.17 (3.16, 3.19)	1041	4.59 (4.04, 5.15)	13 878	3.87 (3.81, 3.93)
Hispanic	287 930	5.12 (5.10, 5.13)	430	3.11 (2.61, 3.62)	13 553	3.78 (3.72, 3.84)

Note. BRFSS = Behavioral Risk Factor Surveillance System; CI = confidence interval; eHealth-PHINEX = Electronic Health Record Public Health Information Exchange.
[a]Average of 3 years of estimates (2007–2009), on the basis of the 2000 census.
[b]Unweighted number.
[c]Because of missing data within each variable, stratified counts may not sum to overall No.
[d]Weighted percentage.

Adult asthma prevalence estimates differed significantly between UW eHealth-PHINEX and Wisconsin BRFSS data. Overall, adult asthma prevalence was lower among the UW eHealth-PHINEX population than the Wisconsin BRFSS population (7.58% [95% CI = 7.48, 7.68] vs 9.41% [95% CI = 8.70, 10.13], respectively). Males in the UW eHealth-PHINEX population had considerably lower asthma prevalence than did male Wisconsin BRFSS respondents. Asthma prevalence was lower among the UW eHealth-PHINEX population's young adults (aged 18–34 years) and older adults (aged ≥ 65 years) than among similarly aged Wisconsin BRFSS respondents. By race/ethnicity, other non-Hispanics in the UW eHealth-PHINEX population had lower asthma prevalence than did Wisconsin BRFSS respondents, whereas asthma prevalence was similar among non-Hispanic Whites and non-Hispanic Blacks. Adult asthma prevalence within strata of household income differed only in the lowest income category. UW eHealth-PHINEX patients had substantially lower asthma prevalence in this category than did Wisconsin BRFSS respondents (7.35% [95% CI = 7.12, 7.58] vs 12.90% [95% CI = 10.84, 14.95], respectively); however, we used median household income by census block group rather than individual patient household income for UW eHealth-PHINEX patients. UW eHealth-PHINEX clinic patients covered by Medicaid had higher asthma prevalence than did patients with commercial or no insurance. Insurance status was not available for adult Wisconsin BRFSS respondents.

Multivariate Analyses

We created multivariable logistic regression models using BRFSS data for child and adult asthma prevalence. We compared estimates from these models with mixed-effects logistic regression using UW eHealth-PHINEX data. AOR estimates for asthma prevalence were similar between Wisconsin BRFSS and UW eHealth-PHINEX models, although the small Wisconsin BRFSS sample size often resulted in nonsignificant estimates with wide CIs. For this reason, estimates from a model derived from US BRFSS data are shown for comparison (Tables 3 and 4). The majority of the national BRFSS estimates were similar in direction and magnitude to the Wisconsin BRFSS estimates. Two exceptions were estimates for non-Hispanic Blacks and those with a household income of less than $50 000.

We adjusted the child asthma prevalence model derived from Wisconsin BRFSS data (Table 3) for gender, age group, race, and household income; however, the only significant covariate was race/ethnicity ($P = .041$). Because of the availability of additional sociodemographic variables, the UW eHealth-PHINEX model was more complete and also adjusted for smoking status, BMI, and insurance coverage. Significant independent risk factors for asthma among children in the UW eHealth-PHINEX population included gender, age group, race, smoking status, BMI, and health insurance status (all covariates $P \le .001$). Specifically, male gender, older age, Black race, current or passive smoking, being overweight or obese, and having Medicaid health coverage were associated with higher asthma prevalence among children in the UW eHealth-PHINEX population. Median household income for the census block group was

TABLE 2—Wisconsin BRFSS and University of Wisconsin eHealth-PHINEX Current Asthma Prevalence by Select Sociodemographic Factors: 2007–2009

	Wisconsin BRFSS Data		University of Wisconsin eHealth-PHINEX	
Variable	No.[a]	%[b] (95% CI)	No.	% (95% CI)
Child asthma prevalence				
Overall	130	7.98 (6.01, 9.95)	8403	8.96 (8.77, 9.15)
Gender				
Male	74	8.48 (5.67, 11.29)	4913	10.20 (9.91, 10.49)
Female	56	7.48 (4.68, 10.29)	3490	7.65 (7.40, 7.90)
Age group, y				
0–4	24	6.75[c] (2.76, 10.73)	2080	6.23 (5.96, 6.50)
5–11	46	8.20 (4.90, 11.51)	3396	10.65 (10.29, 11.01)
12–17	59	8.42 (5.29, 11.55)	2927	10.27 (9.90, 10.64)
Race/ethnicity				
Non-Hispanic White	79	7.32 (5.21, 9.42)	6215	8.68 (8.46, 8.90)
Non-Hispanic Black	38	18.02[c] (7.05, 28.99)	1185	17.78 (16.77, 18.79)
Non-Hispanic other	8	11.70[c] (0.77, 22.63)	296	5.57 (4.94, 6.20)
Hispanic	5	4.38[c] (0.01, 9.40)	484	8.09 (7.37, 8.81)
Smoking status				
Never/former	...	...	6176	9.35 (9.12, 9.58)
Current	...	...	256	15.48 (13.58, 17.38)
Passive	...	...	1451	12.52 (11.88, 13.16)
BMI				
Not overweight or obese (< 85th percentile)	...	...	4639	10.50 (10.20, 10.80)
Overweight (85th –94th percentile)	...	...	1173	12.93 (12.19, 13.67)
Obese (≥ 95th percentile)	...	...	1235	16.00 (15.11, 16.89)
Household income, $				
≥ 75 000	48	7.14 (4.44, 9.84)	2641	9.20 (8.85, 9.55)
50 000–74 999	37	7.65 (4.42, 10.88)	3824	8.84 (8.56, 9.12)
< 50 000	37	13.44 (5.96, 20.91)	1443	9.24 (8.76, 9.72)
Payer				
No insurance	...	...	66	2.32 (1.76, 2.88)
Medicaid	...	...	1907	11.62 (11.10, 12.14)
Commercial	...	...	6429	8.63 (8.42, 8.84)
Adult asthma prevalence				
Overall	1744	9.41 (8.70, 10.13)	21 390	7.58 (7.48, 7.68)
Gender				
Male	536	8.08 (6.98, 9.17)	7180	5.60 (5.47, 5.73)
Female	1208	10.71 (9.78, 11.63)	14 210	9.23 (9.08, 9.38)
Age group, y				
18–34	300	11.11 (9.27, 12.94)	6748	8.46 (8.26, 8.66)
35–64	997	8.81 (8.00, 9.63)	12 195	7.86 (7.72, 8.00)
≥ 65	435	8.45 (7.33, 9.57)	2447	5.17 (4.97, 5.37)
Race/ethnicity				
Non-Hispanic White	1358	8.91 (8.18, 9.64)	18 611	7.62 (7.51, 7.73)
Non-Hispanic Black	222	16.56 (12.39, 20.74)	1142	12.71 (11.97, 13.45)
Non-Hispanic other	111	12.02 (7.91, 16.13)	455	5.31 (4.82, 5.80)
Hispanic	33	10.25 (3.55, 16.94)	472	6.23 (5.67, 6.79)

Continued

not significantly associated with asthma prevalence among children ($P = .332$).

We adjusted the adult asthma prevalence model derived from the Wisconsin BRFSS data (Table 4) for gender, age group, race/ethnicity, smoking status, BMI, and household income, with significant covariates including gender ($P \le .001$), age group ($P = .012$), race/ethnicity ($P = .011$), and BMI ($P \le .001$). Similarly, among adult UW eHealth-PHINEX patients, gender, age group, race/ethnicity, and BMI were significant independent risk factors for asthma, as well as smoking, insurance status, and median household income for the patient's census block group (all covariates $P \le .001$). Household income was not a significant covariate in the Wisconsin BRFSS model.

Specifically, among adults in the UW eHealth-PHINEX population, females had significantly higher asthma prevalence than did males after adjusting for other variables (AOR = 1.70; 95% CI = 1.64, 1.77). Compared with the youngest adults (aged 18–34 years), older adults (aged 35–64 and ≥ 65 years) had lower asthma risk with AORs of 0.86 (95% CI = 0.82, 0.89) and 0.50 (95% CI = 0.46, 0.55), respectively. Race had a strong effect on asthma prevalence. Non-Hispanic Blacks were almost 50% more likely to have asthma than were non-Hispanic Whites, after adjustment for other variables. Non-Hispanic other racial/ethnic groups and Hispanics both had reduced risk of asthma compared with the reference group (non-Hispanic Whites). Both former and passive smoking were significant risk factors for asthma. Compared with adults who were not overweight or obese, a higher BMI was associated with an increased risk of asthma, with the greatest risk in the morbidly obese (AOR = 2.38; 95% CI = 2.23, 2.53). Insurance status was also a significant predictor of asthma prevalence; specifically, patients with Medicaid and Medicare coverage had a higher risk of asthma than did patients with commercial insurance. Lower household income was associated with reduced asthma risk.

DISCUSSION

We compared data from a traditional public health telephone survey and clinic EHRs to demonstrate that EHRs offer a promising source of health data to estimate asthma

TABLE 2—*Continued*

Smoking status				
Never	799	8.65 (7.68, 9.63)	10 946	8.34 (8.18, 8.50)
Former	574	9.62 (8.44, 10.79)	5881	8.74 (8.52, 8.96)
Current	365	11.14 (9.24, 13.03)	3178	8.25 (7.96, 8.54)
Passive		. . .	225	10.19 (8.86, 11.52)
BMI				
Not overweight or obese (< 25.0)	480	8.75 (7.45, 10.05)	4377	7.32 (7.10, 7.54)
Overweight (25.0–29.9)	514	7.90 (6.79, 9.01)	4820	7.99 (7.76, 8.22)
Obese (30.0–39.9)	528	11.11 (9.70, 12.52)	5133	10.19 (9.91, 10.47)
Morbidly obese (≥ 40.0)	123	17.51 (12.11, 22.90)	1834	15.89 (15.16, 16.62)
Household income, $				
≥ 75 000	473	8.83 (7.69, 9.96)	5729	8.23 (8.02, 8.44)
50 000–74 999	523	8.40 (7.30, 9.49)	9916	7.76 (7.61, 7.91)
< 50 000	579	12.90 (10.84, 14.95)	4097	7.35 (7.12, 7.58)
Payer				
No insurance	. . .	. . .	441	2.44 (2.21, 2.67)
Worker's comp	. . .	. . .	149	5.52 (4.63, 6.41)
Medicaid	. . .	. . .	1791	12.31 (11.74, 12.88)
Medicare	. . .	. . .	2917	6.11 (5.89, 6.33)
Commercial	. . .	. . .	16 092	8.08 (7.96, 8.20)

Note. BMI = body mass index (defined as weight in kilograms divided by the square of height in meters); BRFSS = Behavioral Risk Factor Surveillance System; CI = confidence interval; eHealth-PHINEX = Electronic Health Record Public Health Information Exchange.
[a]Unweighted number.
[b]Weighted percentage.
[c]Relative SE > 30% (unreliable estimate).

prevalence and associated risk factors in Wisconsin. Current surveillance systems have characterized chronic disease at the national and state levels but cannot meet the critical need for data at local levels within the state, where many public health policies and interventions ultimately are designed and implemented.[13] There are also very little data on specific subpopulations such as children and racial and ethnic minorities. Data from EHRs can bridge these gaps in currently available public health information.

In a statewide comparison between UW eHealth-PHINEX demographics and census data, we found that the clinic samples were fairly representative of the Wisconsin statewide population.[8] Furthermore, because the majority of the clinic patient population resided in 7 counties surrounding Dane County, Wisconsin, we also made a demographic comparison with this area (data not shown). In these comparisons, UW eHEALTH-PHINEX demographics also resembled the 7-county population.

We determined asthma prevalence using EHR data from approximately 376 000 patients (30 000 with asthma), compared with 23 000 persons (1850 with asthma) from the Wisconsin BRFSS. Adjusted ORs for asthma were similar in magnitude and direction for the majority of covariates, including gender, age, and race, when comparing Wisconsin BRFSS and UW eHealth-PHINEX EHR models. Our EHR database was more than 16-fold the sample size of the Wisconsin BRFSS, resulting in more precise estimates with tighter CIs and greater power to detect associations with risk factors, especially in children. Furthermore, the EHR database provides the ability to estimate asthma prevalence at the neighborhood level (data available as a supplement to the online version of this article at http://www.ajph.org).

Overall prevalence estimates for children and adults differed slightly (nonsignificantly for children and significantly for adults) between the Wisconsin BRFSS and the UW eHealth-PHINEX data. The direction of the UW eHealth-PHINEX estimates is more similar to what other studies have shown, specifically, that asthma prevalence is highest in childhood with a male predominance that reverses in adolescence to a higher prevalence of asthma among adult women.[14–17] One surprising finding was that the UW eHealth-PHINEX asthma prevalence in males was much smaller than was the Wisconsin BRFSS estimate, and it has a much narrower CI. However, UW eHealth-PHINEX prevalence estimates were more similar in magnitude and direction to those obtained from the 2009 National Health Interview Survey, an ongoing national household interview survey conducted by the Centers for Disease Control and Prevention to assess the health of the civilian noninstitutionalized population. In the 2009 National Health Interview Survey, child asthma prevalence was greater than was adult asthma prevalence (9.6%; 95% CI = 8.9, 10.3 and 7.7%; 95% CI = 7.3, 8.1, respectively) and adult male asthma prevalence (5.5%; 95% CI = 5.0, 6.0) was significantly lower than was adult female asthma prevalence (9.7%; 95% CI = 9.1, 10.3).[18]

Although household income was not a significant risk factor for asthma among Wisconsin BRFSS respondents, having an annual household income of less than $50 000 was associated with increased asthma prevalence in the national BRFSS data set. The association of low socioeconomic status with increased asthma risk has been observed in several studies.[19–21] By contrast, the multivariate model derived from the UW eHealth-PHINEX data found a slightly protective association of having a household income of less than $50 000 with asthma risk. There are 2 potential explanations for the seemingly inconsistent result. The first is the narrow socioeconomic spectrum in the UW eHealth-PHINEX population. Compared with the national BRFSS data, this population and even the state BRFSS sample are fairly homogeneous with respect to household income, attenuating any association that may be detected. Second, it is important to highlight that we did indirectly detect poverty as a predictor of asthma through insurance status. In both the child and adult multivariate models, we saw a strong increased risk differential between persons with Medicaid versus those with commercial insurance. Because the models control for insurance status, which is

TABLE 3—US BRFSS, Wisconsin BRFSS, and University of Wisconsin eHealth-PHINEX Multivariate Models for Child Current Asthma Prevalence: 2007–2009

Variable	US BRFSS,[a] No. or AOR (95% CI)	Wisconsin BRFSS,[a] No. or AOR (95% CI)	University of Wisconsin eHealth-PHINEX,[b] No. or AOR (95% CI)
Asthma			
Yes	5353	121	6369
No	53 914	1196	47 230
Gender			
Male (Ref)	1.00	1.00	1.00
Female	0.76 (0.68, 0.85)	0.84 (0.48, 1.45)	0.73 (0.69, 0.77)
Age group, y			
0–4 (Ref)	1.00	1.00	1.00
5–11	1.99 (1.68, 2.34)	1.38 (0.64, 2.98)	1.34 (1.25, 1.44)
12–17	1.77 (1.50, 2.07)	1.39 (0.67, 2.89)	1.30 (1.21, 1.40)
Race/ethnicity			
Non-Hispanic White (Ref)	1.00	1.00	1.00
Non-Hispanic Black	1.60 (1.36, 1.88)	2.74 (1.22, 6.12)	1.96 (1.79, 2.15)
Non-Hispanic other	0.99 (0.80, 1.24)	1.88 (0.64, 5.50)	0.76 (0.66, 0.87)
Hispanic	0.84 (0.72, 0.98)	0.63 (0.18, 2.20)	0.91 (0.81, 1.03)
Smoking			
Never/former (Ref)	...	...	1.00
Current	...	...	1.44 (1.22, 1.70)
Passive	...	...	1.15 (1.07, 1.24)
BMI			
Not overweight or obese (< 85th percentile; Ref)	...	...	1.00
Overweight (85th–94th percentile)	...	...	1.23 (1.14, 1.32)
Obese (≥ 95th percentile)	...	...	1.45 (1.35, 1.56)
Household income, $			
≥ 75 000 (Ref)	1.00	1.00	1.00
50 000–74 999	1.04 (0.90, 1.22)	2.21 (0.99, 4.92)	0.96 (0.89, 1.03)
< 50 000	1.28 (1.13, 1.45)	1.75 (0.93, 3.29)	0.93 (0.85, 1.03)
Insurance status			
Commercial (Ref)	...	...	1.00
Medicaid	...	...	1.21 (1.12, 1.30)
No insurance	...	...	0.29 (0.18, 0.48)

Note. AOR = adjusted odds ratio; BMI = body mass index (defined as weight in kilograms divided by the square of height in meters); BRFSS = Behavioral Risk Factor Surveillance System; CI = confidence interval; eHealth-PHINEX = Electronic Health Record Public Health Information Exchange.
[a]US and Wisconsin BRFSS child asthma models adjusted for gender, age group, race/ethnicity, and household income. Personal or passive smoking status, BMI, and insurance status were not available for children in the BRFSS.
[b]University of Wisconsin eHealth-PHINEX model adjusted for all variables in table, including gender, age group, race/ethnicity, smoking status, BMI, median household income for a patient's census block group, and insurance status.

a measure of socioeconomic status, any remaining effect of household income on asthma risk may be attenuated.

The adult Wisconsin BRFSS models showed a positive association between former and current smoking status and asthma risk, although only former smoking status was associated with asthma in the UW eHealth-PHINEX model. This result may be because of inconsistent or inaccurate smoking status documentation between the EHR and BRFSS. Compared with respondents from an anonymous telephone survey, clinic patients may be more likely to tell their physician during an in-person encounter that they have quit smoking or that they do not smoke when in fact they are smokers. Smoking status documentation will need to be further assessed, as smoking status is an important risk factor for many diseases.

Our data are limited to patients seen at UW clinics who reside primarily in an area of south central Wisconsin that does not include Milwaukee, which is the largest city in the state and has a large proportion of racial and ethnic minorities. Therefore, the magnitude of disparities in asthma prevalence is attenuated by racial and ethnic categories within our data. However, the data describe the relativity of the difference in asthma prevalence by racial categories, specifically that non-Hispanic Blacks have a higher asthma burden than do other populations. In the national data set, the adjusted estimate for asthma associated with Black race was not significant, whereas both the Wisconsin BRFSS and UW eHealth-PHINEX asthma estimates were significantly elevated. Wisconsin may have more socioeconomic disparities in health outcomes by race than is seen on a national level. For example, the disparity of Milwaukee's Black versus White infant mortality rates is among the worst in the nation.[22,23]

Electronic Health Records Advantages

Public health data collection via telephone survey has several drawbacks in addition to low numbers and inability to assess diseases at the local level. The data are obtained by self-report, which may exclude persons with undiagnosed asthma, and no adjustment is made for variables related to geographical area such as race/ethnicity, which may improve disease estimates. Furthermore, low BRFSS response rates (~50%) might indicate response bias. The 2007–2009 BRFSS sampled only households with landline telephones, potentially resulting in the undersampling of certain populations because of the increasing use of cell phones. Wireless-only households tend to have younger occupants, non-White racial backgrounds, and lower incomes. Thus, the traditional public health telephone survey may not reflect the true prevalence of asthma and may not highlight counties, neighborhoods

TABLE 4—US BRFSS, Wisconsin BRFSS, and University of Wisconsin eHealth-PHINEX Multivariate Models for Adult Current Asthma Prevalence: 2007–2009

Variable	US BRFSS,[a] No. or AOR (95% CI)	Wisconsin BRFSS,[a] No. or AOR (95% CI)	University of Wisconsin eHealth-PHINEX,[b] No. or AOR (95% CI)
Asthma			
Yes	92 828	1492	14 373
No	956 843	14 795	142 005
Gender			
Male (Ref)	1.00	1.00	1.00
Female	1.76 (1.70, 1.82)	1.46 (1.19, 1.79)	1.70 (1.64, 1.77)
Age group, y			
18–34 (Ref)	1.00	1.00	1.00
35–64	0.85 (0.82, 0.88)	0.71 (0.57, 0.90)	0.86 (0.82, 0.89)
≥ 65	0.75 (0.72, 0.78)	0.73 (0.56, 0.94)	0.50 (0.46, 0.55)
Race/ethnicity			
Non-Hispanic White (Ref)	1.00	1.00	1.00
Non-Hispanic Black	0.97 (0.92, 1.02)	1.79 (1.25, 2.55)	1.45 (1.33, 1.58)
Non-Hispanic other	1.08 (1.01, 1.16)	1.20 (0.78, 1.86)	0.74 (0.66, 0.83)
Hispanic	0.65 (0.61, 0.70)	0.81 (0.30, 2.17)	0.83 (0.74, 0.93)
Smoking			
Never (Ref)	1.00	1.00	1.00
Former	1.21 (1.17, 1.26)	1.24 (1.01, 1.52)	1.11 (1.07, 1.16)
Current	1.31 (1.26, 1.36)	1.29 (1.01, 1.66)	0.99 (0.94, 1.04)
Passive	. . .	. . .	1.17 (0.98, 1.40)
BMI			
Not overweight or obese (< 25.0; Ref)	1.00	1.00	1.00
Overweight (25.0–29.9)	1.16 (1.11, 1.20)	1.00 (0.78, 1.28)	1.26 (1.20, 1.32)
Obese (30.0–39.9)	1.63 (1.57, 1.70)	1.41 (1.11, 1.79)	1.61 (1.54, 1.69)
Morbidly obese (≥ 40.0)	2.79 (2.63, 2.95)	2.12 (1.38, 3.25)	2.38 (2.23, 2.53)
Household income, $			
≥ 75 000 (Ref)	1.00	1.00	1.00
50 000–74 999	1.00 (0.95, 1.05)	1.07 (0.80, 1.44)	0.88 (0.83, 0.94)
< 50 000	1.28 (1.24, 1.33)	1.03 (0.79, 1.33)	0.84 (0.78, 0.91)
Insurance status			
Commercial	. . .	. . .	1.00
Medicaid	. . .	. . .	1.39 (1.30, 1.49)
Medicare	. . .	. . .	1.23 (1.13, 1.33)
Worker's comp	. . .	. . .	0.89 (0.71, 1.10)
No insurance	. . .	. . .	0.39 (0.34, 0.46)

Note. AOR = adjusted odds ratio; BMI = body mass index (defined as weight in kilograms divided by the square of height in meters); BRFSS = Behavioral Risk Factor Surveillance System; CI = confidence interval; eHealth-PHINEX = Electronic Health Record Public Health Information Exchange.
[a]US and Wisconsin BRFSS adult asthma models adjusted for gender, age group, race/ethnicity, smoking status, BMI, and household income. Passive smoking status and insurance status were not available for adults in the BRFSS.
[b]University of Wisconsin eHealth-PHINEX model adjusted for all variables in table including gender, age group, race/ethnicity, smoking status, BMI, median household income for a patient's census block group, and insurance status.

(census block groups), or census tracts with the highest prevalence of asthma.

The EHR offers a rich source of high-quality population health data to study asthma or any other chronic disease. The objective diagnoses and measurements contained in clinical data can be linked with sociodemographic databases to describe risks in detail at the neighborhood level, allowing better insight into areas of interest, such as where asthma is prevalent and uncontrolled. Local data can guide public health policy goals and the targeting of health services delivery while providing a baseline for evaluation and quality improvement efforts.[24,25] Using the EHR can greatly increase sample size, particularly among certain age, racial, and ethnic subgroups critical to community health assessments, and alleviate the inherent recall and response bias of traditional telephone surveys. EHR data can also disclose additional disease risk factors not found in BRFSS, such as BMI, tobacco smoke exposure, and insurance coverage for children.

EHRs are readily available for epidemiological analysis to study disease control and to perform longitudinal surveillance in a timely manner. Costs are limited mainly to disease definition, identification of outcomes, and data extraction. With medical providers' recent widespread adoption of EHRs, EHRs may offer a more sustainable data source, as other systems may be less available because of recent and anticipated government budget cuts. Thus, clinical EHR data exchange can be a robust method of partnering public health agencies with medical care organizations to inform mutual population health priorities.[26–34] Indeed, the federal government awarded grants in 2010 to all the states to facilitate electronic health information exchange among health care providers, hospitals, and public health agencies.[35] Public health departments can work with these organizations to ensure that data exchange also supports public health surveillance priorities.[35]

Electronic Health Records Challenges and Opportunities

There are challenges that arise in implementing a new method of disease surveillance. EHR data are limited to patients seen in participating clinics, and patients may not have a medical home within a single health system.[27] The EHR may have missing values and inconsistent quality, which requires the use of modeling techniques to account for missing data and attention to definitions of disease used to acquire data. There is also a potential introduction of bias through the misclassification of patients, even when disease identification has good sensitivity and specificity.[36]

In this study, a physician's diagnosis of asthma was the sole case definition criterion (i.e., presence of *ICD-9* code 493 in encounter diagnosis or problem list fields of EHR). This may be problematic because there is no consensus on asthma diagnosis.[37] For example, 1 study compared asthma status by *ICD-9* code and criteria-based medical record review. It found that *ICD* code-based asthma ascertainment underidentified asthma cases when compared with a gold standard of manual record review. The authors concluded that "ICD codes may be useful for etiologic research but may not be suitable for asthma surveillance or studying asthma epidemiology."[37(p83)] The problems of detection and subsequent documentation in EHRs would also likely affect self-report in the BRFSS telephone survey. In the BRFSS, participants respond to the question "Has a doctor ever told you that you have asthma?" But if a person is not diagnosed, it is unlikely that the physician will tell the patient that she or he has asthma. Thus EHR asthma cases that could be found by chart review, but not *ICD-9* codes, would also be cases that would be undetected by BRFSS. The BRFSS has been the mainstay for statewide surveillance of ambulatory chronic disease states. But as with asthma, in many instances disease detection depends on self-report or physician recognition. In our study, the EHR-BRFSS prevalence estimate comparisons are for the most part remarkably similar, and the dependence on physician recognition in both data systems may largely explain this finding. This, then, points to an additional advantage of EHRs and shortcoming of BRFSS. It is impossible to apply additional clinical criteria within BRFSS to find undetected cases. But along with diagnosis, other clinical indicators could be included in an EHR case definition. In this way, EHRs may improve asthma case detection sensitivity in a way that is impossible with the BRFSS. Indeed, we have a research study under way that will compare the asthma *ICD-9* code definition to one that includes additional clinical criteria present on the EHR.

Finally, EHR data are voluminous and very detailed and it is unclear how to best analyze and display these data for public health consumption.

Conclusions

EHRs can be used to estimate asthma prevalence in Wisconsin adults and children, and they provide estimates that are comparable to the traditional health telephone survey without many of its limitations. The development of EHR databases provides exciting opportunities to improve the surveillance and prevention of asthma and other chronic diseases, to highlight areas of disparity, and to improve the targeting of education and public health interventions. ■

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Contributors

C. D. Tomasallo led the writing of the article and the data analysis. L. P. Hanrahan and T. W. Guilbert developed the conceptual framework for the analysis and participated in data interpretation and the writing of the article. A. Tandias and T. S. Chang participated in data interpretation and refinement of analysis. K. J. Cowan participated in writing the article. All authors reviewed and helped revise the article.

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Human Participant Protection

This study was approved by the University of Wisconsin, Madison, School of Medicine and Public Health institutional review board (research protocol M2009-1273, family medicine/public health data exchange).

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