

The relationship between obesity and asthma severity and control in adults

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Background: The association of obesity with asthma outcomes is not well understood.

Objective: The objective of this study was to examine the association of obesity, as represented by a body mass index (BMI) of greater than 30 kg/m², with quality-of-life scores, asthma control problems, and asthma-related hospitalizations.

Methods: The study followed a cross-sectional design. Questionnaires were completed at home by a random sample of 1113 members of a large integrated health care organization who were 35 years of age or older with health care use suggestive of active asthma. Outcomes included the mini-Asthma Quality of Life Questionnaire, the Asthma Therapy Assessment Questionnaire, and self-reported asthma-related hospitalization. Several other factors known to influence asthma outcomes also were collected: demographics, smoking status, oral corticosteroid use in the past month, evidence of gastroesophageal reflux disease, and inhaled corticosteroid use in the past month. Multiple logistic regression models were used to measure the association of BMI status with outcomes.

Results: Even after adjusting for demographics, smoking status, oral corticosteroid use, evidence of gastroesophageal reflux disease, and inhaled corticosteroid use, obese adults were more likely than those with normal BMIs (<25 kg/m²) to report poor asthma-specific quality of life (odds ratio [OR], 2.8; 95% CI, 1.6-4.9), poor asthma control (OR, 2.7; 95% CI, 1.7-4.3), and a history of asthma-related hospitalizations (OR, 4.6; 95% CI, 1.4-14.4).

Conclusions: Our findings suggest that obesity is associated with worse asthma outcomes, especially an increased risk of asthma-

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Key words: Asthma, quality of life, obesity, hospitalization, inhaled corticosteroids

Asthma and obesity are important public health problems.¹⁻³ Over the past 30 years, asthma prevalence has more than tripled.⁴ The prevalence of obesity also has increased dramatically over the past 30 years. In the late 1990s, Camargo et al⁵ reported the first prospective data linking obesity with risk of adult-onset asthma. Since then, many groups around the world, using a variety of study designs, have confirmed the positive association between body mass index (BMI) and asthma.⁶ Data from uncontrolled observational studies suggest that medical or surgical⁷⁻⁹ weight loss interventions in obese asthmatic patients improve asthma control, and 2 small randomized trials from Finland provide additional support for the causal nature of the obesity–asthma association.^{10,11}

In recent years, investigators have begun to more seriously explore the possibility that asthma is not a single disease but rather a constellation of different diseases or asthma phenotypes.¹² Thus obesity might be associated with a different type of asthma, such as one that is of greater severity or that is more difficult to control. Previous research has found, for example, that obese women with asthma were twice as likely to report hospital admission as their nonobese asthmatic counterparts.⁵ To date, 2 studies have examined the relation of obesity to asthma severity or asthma control.^{13,14} The first is a *post hoc* analysis of 3000 subjects with moderate asthma enrolled in a randomized controlled trial.¹³ The authors found that BMI can influence the natural history of asthma control and might influence response to asthma treatment medications. The second study was an observational study of 400 asthmatic subjects receiving care in 4 university-based French outpatient clinics¹⁴ in which the investigators found that overweight individuals were less likely to transition from unacceptable levels of asthma control to acceptable levels.

Although the association of asthma with obesity is becoming increasingly established, it is not known whether other factors (eg, demographics, smoking status, comorbid gastroesophageal reflux disease [GERD], and medication use) might explain the observed differences in asthma severity and control between obese and nonobese populations.

With this background in mind, our objective was to examine the association of obesity with a comprehensive set of outcome measures, including asthma-specific quality of life, level of asthma control, and asthma-related hospitalizations. We examined these associations with and without adjustment for selected demographic variables, smoking status, use of oral corticosteroids in the past month, current evidence of comorbid

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Abbreviations used

AQLQ: Juniper mini-Asthma Quality of Life Questionnaire
 ATAQ: Asthma Therapy Assessment Questionnaire
 BMI: Body mass index
 GERD: Gastroesophageal reflux disease
 ICS: Inhaled corticosteroid
 OR: Odds ratio

GERD, and regular inhaled corticosteroid (ICS) use in the past month.

METHODS**Study subjects**

Study participants were members of the Colorado and Northwest regions of Kaiser Permanente, a large managed care organization centered in Denver, Colorado, and Portland, Oregon, respectively. Health plan members were eligible for the study if they were at least 35 years of age and had, in the 2-year period preceding the survey, at least 1 documented asthma-related medical encounter and at least a 6-month supply of asthma medication dispensed. These criteria were used to identify a population with persistent asthma and have been reported elsewhere.^{15,16} A search of more than 1,000,000 electronic medical records identified 9420 individuals who met these criteria, and we mailed surveys to a randomly selected subset of 1600 in the fall of 2002, 800 in each region. Of the 1317 (82%) persons who completed the questionnaire, 204 denied having doctor-diagnosed asthma and were excluded from further analysis. Completion of the questionnaires was assumed to indicate consent to participate in the study. The study was approved by both the Kaiser Permanente Colorado and Northwest Regional Institutional Review Boards. Some results from this survey have been reported elsewhere.^{15,16}

Survey

The primary independent variable was BMI, which was calculated from self-reported height and weight. The primary dependent variables were as follows:

1. the 15-question Juniper mini-Asthma Quality of Life Questionnaire (AQLQ),¹⁷ a validated instrument from which one can generate an overall score and 4 domain scores (symptoms, emotions, activity, and environment), each ranging from 1 to 7, with higher scores indicating better quality of life in the last 2 weeks;
2. the 4-question Asthma Therapy Assessment Questionnaire (ATAQ),^{18,19} a validated asthma control tool with scores ranging from 0 to 4, reflecting the number of asthma control problems present in the last month; and
3. self-report of an asthma-related hospitalization in the previous year.

Secondary predictor variables included the following:

1. age, sex, race/ethnicity, highest grade in school completed (less than high school, high school, technical school, college, postgraduate, or professional), and annual family household income (<\$20,000, \$20,000-\$34,000, \$35,000-\$49,900, \$50,000-\$74,999, and ≥\$75,000);
2. smoking status, with never smoking defined as less than 20 packs of cigarettes OR less than 12 oz of tobacco in lifetime OR less than 1 cigarette a day for a year; current smoking defined as smoking cigarettes within the past month; and former smoking defined as ever smokers who have not smoked in the past month;
3. current evidence of GERD, which was defined as a positive response to the question "In addition to asthma, has a doctor ever told you that you have any of the following health conditions" (one of the conditions to which the patient could check "Yes" (vs "No") was "Gastroesophageal Reflux Disease (GERD)");

TABLE I. Characteristics of the population with persistent asthma enrolled in a group model health maintenance organization (n = 1113)

Characteristic	Descriptive statistics
Mean age (y) ± SD	56.8 ± 12.2
Age <65 y (%)	72.6
Male sex (%)	48.6
Race/ethnicity (%)	
White (non-Hispanic)	86.1
Black (non-Hispanic)	3.6
Hispanic	4.8
Other	4.0
Information not available	1.5
Education: highest grade completed (%)	
Less than high school	4.2
High school/GED	40.4
Technical school	12.0
College graduate	29.1
Postgraduate/professional	20.1
Information not available	1.2
Income (%)	
<\$20,000	13.5
\$20,000-\$34,999	17.7
\$35,000-\$49,999	17.1
\$50,000-\$74,999	19.7
≥\$75,000	22.0
Information not available	10.0
BMI (%)	
<25 kg/m ²	26.1
25-29.9 kg/m ²	36.9
≥30 kg/m ²	37.0
Smoking (%)	
Never	45.8
Former	44.1
Current	8.0
Information not available	2.1
Oral corticosteroid use (%)	
Use in past month	14.1
Information not available	2.8
GERD status (%)	
History of GERD	39.4
Information not available	8.9
ICS use (%)	
Use in past month	61.4
Information not available	9.5
Mini-AQLQ	
Mean ± SD	4.98 ± 1.24
Total score <3.9 (%)	20.8
Symptoms domain <3.9 (%)	22.8
Emotions domain <3.9 (%)	25.6
Activity domain <3.9 (%)	15.5
Environment domain <3.9 (%)	36.8
Information not available (%)	0.0
ATAQ	
Mean ± SD	0.89 ± 1.04
Score >1 (%)	27.8
Information not available (%)	1.2
Asthma-related hospitalization	
Hospitalization in past year	5.6
Information not available (%)	1.2

4. any use of oral steroids in the past month to help manage asthma symptoms; and
5. regular use of ICSs within the past month, defined as use "every day, whether or not I had asthma symptoms."

TABLE II. Bivariate relationships of BMI to demographic characteristics, smoking status, GERD status, and use of asthma medications

Outcome	Sample size	BMI categories			P value*
		Normal, <25 kg/m ²	Overweight, 25-29.9 kg/m ²	Obese, ≥30 kg/m ²	
Mean age (y) ± SD	1113	58.8 ± 13.4	58.2 ± 11.9	54.0 ± 11.1	<.0001
Race/ethnicity (%)					.18
White (non-Hispanic)	958	92.6	91.1	86.5	
Black (non-Hispanic)	40	2.5	3.5	4.7	
Hispanic	53	1.4	2.2	3.5	
Other	45	3.5	3.2	5.4	
Education: highest grade completed (%)					.0007
Less than high school	47	3.5	4.9	4.2	
High school/GED	450	35.6	43.1	42.6	
Technical school	134	7.6	12.6	15.1	
College graduate	324	24.5	20.4	22.3	
Postgraduate/professional	224	28.7	19.0	15.8	
Income (%)					.13
<\$20,000	150	19.1	12.6	14.5	
\$20,000–\$34,999	197	17.6	19.0	21.7	
\$35,000–\$49,999	190	16.0	20.9	19.3	
\$50,000–\$74,999	219	20.7	20.6	23.9	
≥\$75,000	245	26.6	26.8	20.6	
Smoking (%)					.22
Never	510	51.4	45.7	44.6	
Former	491	41.8	47.0	45.3	
Current	89	6.7	7.3	10.1	
Oral corticosteroids in past month (%)	1082	10.0	13.5	17.7	.02
History of GERD (%)	1014	33.6	39.6	43.1	.05
Regular ICS use in past month (%)	1007	63.0	62.5	59.0	.50

*The χ^2 test was used for categorical variables, and the Kruskal-Wallis test was used for continuous variables. Unknown or missing responses were excluded from analysis.

TABLE III. Bivariate relationships of BMI to asthma outcome measures

Outcome	BMI (kg/m ²)			P value*
	<25	25-29.9	≥30	
Mini-AQLQ				
Mean ± SD	5.3 ± 1.2	5.1 ± 1.2	4.6 ± 1.3	<.0001
Score <3.9	14.1%	17.5%	28.6%	<.0001
ATAQ				
Mean ± SD	0.7 ± 0.9	0.8 ± 1.0	1.2 ± 1.1	<.0001
Score >1	18.5%	23.3%	38.9%	<.0001
Asthma-related hospitalization in the past year	3.9%	3.7%	8.8%	.002

For the AQLQ, the minimum score is 1, and the maximum score is 7. A higher score indicates higher quality of life. For the ATAQ, the minimum score is 0 and the maximum score is 4. A higher score indicates more asthma control problems.

*Analysis for continuous variables used ANOVA, whereas analysis for categorical variables used the χ^2 test.

Analytic approach

BMI status was analyzed as a 3-level categorical measure based on established guidelines for defining normal weight (<25 kg/m²), overweight (25–30 kg/m²), and obesity (≥30 kg/m²).²⁰ All 3 outcome measures were analyzed as dichotomous measures, with poor quality of life defined as an AQLQ score of less than 3.9, poor control defined as 2 or more control problems on the ATAQ score, and any versus no asthma-related hospitalizations in the prior year. The cutoff points for the AQLQ and ATAQ measures were based on previously published studies.^{17–19}

All analyses were performed with SAS software (SAS Institute, Inc, Cary NC). We examined bivariate associations of BMI status with each outcome measure using Pearson χ^2 analysis. Multiple logistic regression models were

TABLE IV. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (all patients)

Models* and BMI level	OR (95% CI), with BMI <25 kg/m ² as reference		
	Low AQLQ score (<3.9)	High ATAQ score (>1)	Asthma-related hospitalization in past year
Model 1	n = 1113	n = 1100	n = 1100
Overweight	1.3 (0.9-2.0)	1.3 (0.9-1.9)	(0.4-2.1)
Obese	2.4 (1.6-3.6)	2.8 (2.0-4.0)	2.4 (1.2-4.8)
Model 2	n = 957	n = 945	n = 948
Overweight	1.7 (1.0-2.7)	1.5 (0.9-2.3)	1.8 (0.6-5.1)
Obese	2.9 (1.8-4.6)	2.7 (1.8-4.1)	4.2 (1.6-11.2)
Model 3	n = 791	n = 791	n = 785
Overweight	1.6 (0.9-2.9)	1.3 (0.8-2.2)	2.0 (0.6-6.6)
Obese	2.9 (1.7-5.2)	2.5 (1.6-4.1)	4.2 (1.3-13.4)
Backward selection	n = 791	n = 791	n = 785
Overweight	1.5 (0.9-2.7)	1.4 (0.9-2.3)	2.3 (0.7-7.5)
Obese	2.8 (1.6-4.9)	2.9 (1.9-4.6)	4.7 (1.6-14.1)

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, sex, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and clinic location. Backward selection started with items in model 3.

constructed to analyze the independent effect of BMI status on asthma outcomes after adjustment for possible confounding factors, where BMI status was treated as a 3-level categorical variable (<25 [reference group], 25.0–29.9, and ≥30 kg/m²). Each outcome measure was regressed on BMI status, adjusting for the following sequence of added covariates: (1) model 1, no additional covariates; (2) model 2, demographics (ie, age, sex, race/ethnicity, education, and income) and smoking status; (3) model 3, model 2 plus oral corticosteroid use; (4) model 4, model 3 plus GERD; and (5) model 5, model

TABLE V. Multiple logistic regression results: Independent effect of BMI status with asthma quality-of-life domains (all patients)

Models* and BMI level	OR (95% CI), with BMI <25 kg/m ² as reference			
	Symptom domain (<3.9)	Emotions domain (<3.9)	Activities domain (<3.9)	Environment domain (<3.9)
Model 1 (n = 1113)				
Overweight	1.4 (0.9-2.1)	1.3 (0.9-1.9)	1.2 (0.8-1.9)	1.0 (0.7-1.3)
Obese	2.5 (1.7-3.7)	1.9 (1.3-2.8)	2.0 (1.3-3.1)	1.8 (1.3-2.5)
Model 2 (n = 957)				
Overweight	1.6 (1.0-2.6)	1.4 (0.9-2.1)	1.4 (0.8-2.4)	1.1 (0.8-1.7)
Obese	2.6 (1.6-4.0)	1.8 (1.2-2.7)	2.4 (1.4-4.0)	2.1 (1.4-3.0)
Model 3 (n = 791)				
Overweight	1.3 (0.8-2.2)	1.3 (0.8-2.1)	1.2 (0.6-2.3)	1.0 (0.7-1.5)
Obese	2.2 (1.3-3.7)	1.7 (1.1-2.7)	2.4 (1.3-4.4)	2.1 (1.4-3.2)

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, sex, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and clinic location.

4 plus regular ICS use in the past month. In these models age was analyzed as a continuous measure, whereas sex, race/ethnicity (white vs nonwhite), education (less than college vs more than college), income (<\$35,000 vs >\$35,000), smoking status (current vs former/never), oral corticosteroid use (yes vs no), GERD (yes vs no), and regular ICS use (yes vs no) were analyzed as dichotomous measures.

RESULTS

Sample characteristics

As shown in Table I, study participants were well educated (nearly 50% with a college degree or higher), primarily of white race/ethnicity (86%), and equally split between men and women. In addition, nearly 40% were obese, approximately half were current or former smokers, and nearly 40% reported a history of GERD. The mean age of the cohort was 56.8 years, and 73% were younger than 65 years.

Approximately 14% of the cohort reported any use of oral corticosteroids in the past month, whereas 60% reported regular ICS use in the past month. These data are consistent with quality-of-care reporting within the 2 Kaiser Permanente study regions during the observed study periods (unpublished data). Representing an asthma population in relatively good health, only 21% reported poor AQLQ scores, 28% reported poor asthma control, and 6% reported hospitalizations within the past year.

Association of BMI status with demographics and other predictor measures

Obese individuals were younger and less well educated than those with "normal" BMIs (<25 kg/m²), but obesity was not related to other demographic factors (Table II). Obese individuals also were significantly more likely to report use of oral corticosteroids in the past month and GERD.

Association of BMI status with outcome measures

BMI status was significantly associated with study outcome measures in both unadjusted and multivariate analyses (Tables III and IV). For each of the 3 study outcome measures, obese individuals reported significantly worse outcomes than did those with normal BMIs, whereas overweight individuals did not differ

from those with normal BMIs. For AQLQ (odds ratio [OR], 2.8; 95% CI, 1.6-4.9) and ATAQ (OR, 2.7; 95% CI, 1.7-4.3) scores, the univariate associations reported in Table III persisted after adjustment for a variety of potentially confounding factors (Table IV). The risk of hospitalization (OR, 4.6; 95% CI, 1.4-14.4) increased among obese individuals after adjusting for demographic characteristics, smoking status, GERD status, and use of asthma medications, possibly indicating that the association of obesity with asthma-related hospitalizations might be confounded by these factors. Obesity was also significantly associated with each AQLQ domain individually (Table V). Results did not change significantly when stratifying results by sex (see Tables E1 and E2 in this article's Online Repository at www.jacionline.org) or when regressing outcomes measure on BMI status, with BMI expressed as a continuous measure (see Tables E3-E6 in this article's Online Repository at www.jacionline.org).

DISCUSSION

This study found that obese individuals with persistent asthma were significantly more likely than those with normal BMIs to report worse asthma-related quality of life, worse asthma control, and more asthma-related hospitalizations. We also found that being overweight (BMI, 25.0-30 kg/m²) was not associated with adverse study outcomes. The results suggest that being overweight might not be associated with more severe or difficult-to-control asthma. Our finding regarding obesity status and control problems is similar to the findings in other published research. The present study is unique in reporting an association of obesity with asthma-specific outcomes across different geographic areas within the United States while also adjusting for several covariates that are independently associated with study outcomes.

Higher asthma morbidity among obese individuals with asthma has been reported in other studies.^{13,14,21-23} Our finding that obese adults were more likely to have asthma-specific hospitalizations compared with nonobese adults might, in part, be driven by more acute severity and control problems in the obese population. It is important to note that other factors, such as genetic predispositions to more severe asthma exacerbations, might explain differences in adverse outcomes among obese and nonobese populations.

Worse outcomes among obese adults might, in part, be driven by differential response to asthma medications, including ICSs and perhaps bronchodilators, during severe exacerbations. However, the cross-sectional study design did not allow us to fully examine this issue in our study population. Future prospective randomized trials are needed to better understand whether obese populations respond differently than nonobese populations to short- and long-term treatment asthma medications and, if so, why.

Several factors not collected in the patient survey might have explained differences in asthma-related outcomes among obese adults with persistent asthma. Such factors as medication adherence, self-efficacy to perform self-management behaviors, and patient activation might explain differences in asthma-related outcomes. A recent study examining the Kaiser Permanente population found higher levels of self-efficacy and patient activation to be associated with improved outcomes among adults with chronic conditions.²⁴ It is possible that obese adults with persistent asthma differed in self-efficacy and patient activation compared with nonobese adults with persistent asthma, thus possibly explaining differences in the study outcomes.

The study does have several potential limitations. First, height and weight were self-reported rather than measured during medical office visits. However, published studies have found that self-reported height and weight have acceptable levels of sensitivity and specificity compared with information collected through office visits.²⁵ A second limitation of this study is that spirometric measurements were not obtained. FEV₁ is an important measure of asthma control²⁶ that has been shown to reflect a different dimension than symptoms or quality of life.²⁷ The importance of the lack of spirometry in this study is mitigated by the fact that AQLQ and ATAQ scores do not require spirometry. Third, the cross-sectional design of the study limits our ability to understand the causal association of obesity status with asthma outcomes. Fourth, data were not available regarding nonrespondents. Finally, this study was set in a large group model integrated delivery system. It is possible that results are not generalizable to obese adults with asthma in other health delivery systems. The Kaiser Permanente population, however, has been shown to be representative of the demographics within the regions that it serves,²⁸ which might increase the generalizability of these findings.

Notwithstanding these limitations, the results have important implications for policy and practice. More research is needed to understand the prospective association of obesity with asthma outcomes. In addition, more research is needed to understand the effectiveness of asthma medications in obese populations, especially long-term control medications. Moreover, the fact that obesity is associated with increased asthma-related hospitalization is of interest to quality organizations, health plans, and payers.

Substantial weight loss among obese patients with asthma might result not only in improved patient-centered measures, such as improved quality of life and fewer asthma control problems, but also might result in substantial cost reductions through decreased asthma-related hospitalizations. Future research is needed to develop, implement, and evaluate interventions to promote weight loss within the obese asthmatic population and then determine whether such interventions improve asthma-specific outcome measures.

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Clinical implications: Obese patients with asthma might need more intense monitoring and treatment to improve outcomes.

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TABLE E1. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (female subjects)

Models* and BMI level	OR (95% CI), with BMI <25 kg/m ² as reference		
	Low AQLQ score (<3.9)	High ATAQ score (>1)	Asthma-related hospitalization in past year
Model 1	N = 570	n = 563	n = 562
Overweight	1.1 (0.6-1.9)	1.3 (0.8-2.3)	1.8 (0.5-6.1)
Obese	2.2 (1.4-3.6)	3.0 (1.9-4.8)	2.8 (0.9-8.5)
Model 2	N = 478	n = 471	n = 473
Overweight	1.4 (0.7-2.6)	1.6 (0.9-2.9)	3.2 (0.6-16.2)
Obese	2.7 (1.5-4.7)	3.2 (1.8-5.4)	5.7 (1.2-26.8)
Model 3	N = 400	n = 400	n = 396
Overweight	1.2 (0.6-2.6)	1.5 (0.7-2.9)	2.2 (0.4-12.3)
Obese	2.6 (1.3-5.1)	2.8 (1.5-5.2)	4.5 (0.9-23.1)

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.

TABLE E2. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (male subjects)

Models* and BMI level	OR (95% CI), with BMI <25 kg/m ² as reference		
	Low AQLQ score (<3.9)	High ATAQ score (>1)	Asthma-related hospitalization in past year
Model 1	n = 539	n = 533	n = 534
Overweight	1.9 (1.0-3.9)	1.5 (0.8-2.6)	0.7 (0.2-1.9)
Obese	3.0 (1.5-6.0)	2.6 (1.4-4.6)	2.5 (1.0-6.4)
Model 2	[n = 479]	[n = 474]	[n = 475]
Overweight	2.3 (1.0-5.0)	(0.7-2.4)	(0.3-5.0)
Obese	3.3 (1.5-7.4)	2.1 (1.2-4.0)	3.6 (1.0-13.4)
Model 3	n = 391	n = 391	n = 389
Overweight	2.7 (1.0-7.3)	1.4 (0.6-2.6)	2.1 (0.3-14.9)
Obese	3.7 (1.4-10.3)	2.3 (1.1-4.6)	4.7 (0.7-31.7)

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.

TABLE E3. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (all patients)

Models* (BMI continuous)	OR (95% CI)		Asthma-related hospitalization in past year
	Low AQLQ score (<3.9)	High ATAQ score (>1)	
Model 1	1.06 (1.04-1.08), n = 1113	1.07 (1.05-1.09), n = 1100	1.03 (0.99-1.07), n = 1100
Model 2	1.07 (1.05-1.10), n = 957	1.06 (1.04-1.09), n = 945	1.05 (1.01-1.10), n = 948
Model 3	1.08 (1.04-1.11), n = 791	1.06 (1.03-1.09), n = 791	1.05 (1.00-1.10), n = 785

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.

TABLE E4. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (female subjects)

Models* (BMI continuous)	OR (95% CI)		
	Low AQLQ score (<3.9)	High ATAQ score (>1)	Asthma-related hospitalization in past year
Model 1	1.05 (1.03-1.08) [n = 570]	1.06 (1.04-1.09) [n = 563]	1.03 (0.98-1.07) [n = 562]
Model 2	1.06 (1.03-1.10), n = 478	1.06 (1.03-1.09), n = 471	1.05 (0.99-1.11), n = 473
Model 3	1.06 (1.02-1.10), n = 400	1.05 (1.01-1.08), n = 400	1.04 (0.97-1.10), n = 396

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.

TABLE E5. Multiple logistic regression results: Independent effect of BMI status with asthma outcome measures (male subjects)

Models* (BMI continuous)	OR (95% CI)		Asthma-related hospitalization in past year
	Low AQLQ score (<3.9)	High ATAQ score (>1)	
Model 1	1.08 (1.04-1.12), n = 539	1.07 (1.04-1.12), n = 533	1.06 (0.99-1.12), n = 534
Model 2	1.08 (1.04-1.14), n = 479	1.06 (1.02-1.11), n = 474	1.07 (1.00-1.15), n = 475
Model 3	1.10 (1.04-1.16), n = 391	1.08 (1.03-1.13), n = 391	1.09 (0.99-1.19), n = 389

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.

TABLE E6. Multiple logistic regression results: Independent effect of BMI (continuous) with asthma quality-of-life domains (all patients)

Models* and BMI (continuous)	OR (95% CI), with BMI <25 kg/m ² as reference			
	Symptom domain (<3.9)	Emotions domain (<3.9)	Activities domain (<3.9)	Environment domain (<3.9)
Model 1 (n = 1113)	1.06 (1.03-1.08)	1.04 (1.02-1.06)	1.06 (1.03-1.08)	1.05 (1.03-1.07)
Model 2 (n= 957)	1.06 (1.03-1.08)	1.03 (1.01-1.06)	1.08 (1.05-1.11)	1.06 (1.03-1.08)
Model 3 (n = 791)	1.05 (1.02-1.08)	1.03 (1.01-1.06)	1.07 (1.04-1.11)	1.06 (1.04-1.09)

*Model 1, unadjusted; model 2, adjusted for demographic factors (age, nonwhite race, education less than college, income <\$35,000, and smoking status [current vs former/never]); model 3, adjusted for the above plus oral corticosteroids, history of gastroesophageal reflux, and regular ICS use in the past month and region location.