

Prospective Study on the Relationship of Obesity to Asthma Impairment and Risk

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What is already known about this topic? Although studies consistently show an association between obesity and increased asthma incidence, the role of obesity in asthma control is less clear.

What does this article add to our knowledge? In a large real-world sample, even after adjusting for many potential confounders, elevated body mass index is associated with subsequent poor asthma control, especially in the risk domain.

How does this study impact current management guidelines? Weight loss should be facilitated in overweight and obese patients with asthma.

BACKGROUND: Although studies consistently show an association between obesity and increased asthma incidence, the role of obesity in asthma control is less clear.

OBJECTIVE: The objective of this study was to evaluate the association between baseline body mass index (BMI) and measures of subsequent asthma control in a large real-world cohort of adults with persistent asthma.

METHODS: In Kaiser Permanente Southern California (KPSC), a large managed care organization, we identified adults with persistent asthma in 2006, continuous health plan enrollment in 2007 and 2008, and a BMI measurement in 2006 or 2007. Each patient's last BMI measure in 2006 or 2007 was categorized into a BMI group: normal (<25 kg/m²), overweight (25-29.9 kg/m²), or obese (≥30 kg/m²). Asthma control outcomes in 2008 included asthma hospitalizations or emergency department visits (EDHO),

oral corticosteroid dispensings linked to an asthma encounter (OCS), and dispensing of ≥7 short-acting beta-agonist canisters (SABA7). Multivariable analyses were conducted to assess the relationships of BMI categories with the risk of the asthma control outcomes after controlling for potential confounders. **RESULTS:** In the 10,233 eligible adults—after adjusting for potential demographic, comorbidity, and prior utilization confounders—we found an increased relative risk (RR) of EDHO in overweight and obese (RR 1.40, 95% CI 1.10-1.78) individuals. Only obesity was associated in adjusted analyses with a significant increased relative risk of SABA7 (RR 1.27, 95% CI 1.15-1.40).

CONCLUSIONS: Elevated BMI, particularly obesity, is associated with subsequent poor asthma control, especially in the risk domain (exacerbations). These findings further support the importance of facilitating weight loss in overweight and obese adults with asthma. © 2015 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2015;3:560-5)

Key words: Asthma; BMI; Overweight; Obesity; Asthma control; Asthma risk; Asthma impairment; Asthma exacerbations; Short-acting beta-agonists

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Obesity is associated with increased asthma incidence, prevalence, and severity.¹ However, studies addressing the role of obesity on asthma control have been conflicting. Although many studies suggest increased asthma impairment in obese patients, others do not.¹⁴⁻¹⁸ Asthma risk has been less studied but again with conflicting results.^{6,8,10,12,14,16,19,20} Most of the studies have been cross-sectional,^{2-9,11,13,16-18} and most have involved less than 500 subjects.^{2,3,5,9-11,13-19}

We previously collected administrative data on 14,856 patients with persistent asthma who were then followed prospectively for asthma outcomes (both impairment and risk).²¹ Because of the conflicting findings described above, the paucity of prospective data, and the relatively small samples in prior

Abbreviations used

BMI- Body mass index
ED- Emergency department
EDHO- Emergency department visits or hospitalizations
GERD- Gastroesophageal reflux disease
HEDIS- Healthcare effectiveness data and information set
ICS- Inhaled corticosteroid
KPSC- Kaiser Permanente Southern California
SABA- Short-acting beta-agonist
SABA7- Dispensing of 7 or more short-acting beta-agonist canisters

studies, we believed that a secondary analysis of our large database would be valuable. The large sample gave us the opportunity to adjust for many potential confounders. We hypothesized that baseline obesity would be associated with worse future asthma control, in both the impairment and risk domains.

METHODS

Patients

This study was approved by the Kaiser Permanente Southern California (KPSC) Institutional Review Board. Using computerized KPSC inpatient, outpatient, pharmacy, and health plan enrollment records, we identified adults aged 18-56 with persistent asthma in 2006 and continuously enrolled in the health plan (no more than one gap of 45 days or less) in 2007 and 2008. The reason for requiring continuous enrollment in these 2 years is that 2007 was the baseline year in which the information on prior asthma exacerbations, asthma medication, and other potential confounders was extracted, and 2008 was the year during which all the asthma outcomes were defined. Persistent asthma was defined based on meeting one or more of the following Healthcare Effectiveness Data and Information Set (HEDIS) criteria: (1) 4 or more asthma medication dispensings, (2) 1 or more emergency department visits or hospitalizations (EDHO) with a principal diagnosis of asthma, or (3) 4 or more asthma outpatient visits with 2 or more asthma medication dispensings. Patients whose body mass index (BMI) measure was not available in 2006 or 2007 were excluded.

Outcomes

The following 2008 asthma outcomes were captured from the computerized data:

Impairment domain: short-acting beta-agonist (SABA) canisters dispensed.

Risk domain: (1) hospitalization with asthma coded (ICD-9 493.xx) as the primary diagnosis or the second diagnosis with another respiratory primary diagnosis, (2) emergency department (ED) visit with asthma coded (ICD-9 493.xx) as the primary diagnosis or the second diagnosis with another respiratory primary diagnosis (risk domain), and (3) oral corticosteroid (OCS) dispensing within 7 days of an inpatient or outpatient encounter coded as an asthma exacerbation or uncontrolled asthma.

Exposure variable and potential confounders

The primary exposure variable of interest was the latest BMI obtained in 2006 or 2007, expressed as normal ($<25 \text{ kg/m}^2$), overweight ($25\text{--}29.9 \text{ kg/m}^2$), or obese ($\geq 30 \text{ kg/m}^2$). The following potential confounders, based on prior literature and data availability, were also captured from the computerized data: (1) age, (2) sex, (3) 2007 asthma hospitalization or ED visit as defined above, (4) 2007

OCS dispensing as defined above, (5) number of SABA canisters dispensed in 2007, (6) 2007 cigarette smoking as indicated in the electronic medical record, (7) an encounter for gastroesophageal reflux disease (GERD) in 2006 or 2007, (8) an encounter for depression in 2006 or 2007, and (9) number of inhaled corticosteroid (ICS) canisters (with or without long-acting beta-agonists) dispensed in 2007.

At KPSC, addresses of health plan enrollees are linked to census block groups, and the census block group level income and education estimates provided by Nielsen, Inc. (www.nielsen.com) were assigned to individual enrollees. The 2 variables we included in this study as potential confounders were: (1) the proportion of the population older than age 25 in the individual's census block group having more than a high school education, and (2) the median household income in the individual's census block group.

Data analysis

Bivariate relationships between BMI categories (and potential confounders) and asthma control outcomes were evaluated by means of χ^2 analysis or one-way ANOVA, as appropriate. Multivariable analyses were conducted by means of Poisson regression with robust error variance, where BMI was a 3-level dependent variable ($<25 \text{ kg/m}^2$, $25\text{--}29.9 \text{ kg/m}^2$, $\geq 30 \text{ kg/m}^2$) with $<25 \text{ kg/m}^2$ as the reference group. Risk ratios and 95% confidence intervals were reported. Nominal 2-tailed statistical significance for all analyses was set at $P < .05$. All analyses were conducted using SAS E.G. version 9.3 (Cary, NC).

RESULTS

Of 2,365,947 SCKP members aged 18 years and older in 2006, 14,856 adults aged 18-56 years met the HEDIS criteria for persistent asthma in 2006 and 12,766 were continuously enrolled in 2007 and 2008. Of these 12,766 patients, BMI measurements were available for 10,233 patients, who are the subjects for this study. In comparison to the 2,533 continuously enrolled patients without BMI measurements, the 10,233 patients with BMI measurements were older, more likely to be female, had lower income and education, were more likely to be smokers, had more comorbidities, and experienced more asthma utilization (see [Table E1](#) in this article's Online Repository at www.jaci-inpractice.org). Of the 10,233 subjects of this report, 50% were obese and another 29% were overweight ([Table I](#)). The mean age was 43 years, 66% were females, and nearly 8% were smokers. Medical utilization for years 2007 and 2008 (≥ 7 SABA dispensings [SABA7], mean ICS canister dispensings, any EDHO, any OCS dispensing linked to an asthma encounter, and ≥ 2 OCS dispensings linked to an asthma encounter) is shown in [Table I](#).

Higher BMI category and increased mean BMI were associated with the 2008 SABA7 impairment outcome ([Table II](#)). The potential confounders that were statistically significantly related to SABA7 at the 95% level in 2008 were sex, geocoded household income and education, smoking status, prior ICS canister dispensings, and prior exacerbations ([Table II](#)). In addition, patients with 2007 SABA7 were more than 6 times more likely to receive SABA7 in 2008 than patients with <7 SABA dispensings in 2007.

The higher BMI category was also significantly associated with all 2008 risk outcomes (EDHO, OCS dispensings), as was increased mean BMI ([Tables III and IV](#)). Younger age was associated with an increased risk of EDHO but a lower risk of OCS dispensings. Female sex was not associated with an increased risk of EDHO ([Table III](#)), but was associated with an

TABLE I. Characteristics of 10,233 adults with persistent asthma

Characteristic	Result n (%) or mean (SD)
BMI < 25 kg/m ² , n (%)	2129 (20.8)
BMI 25-29.9 kg/m ² , n (%)	3004 (29.4)
BMI ≥ 30 kg/m ² , n (%)	5100 (49.8)
Mean (SD) BMI in kg/m ²	31.4 (8.0)
Mean (SD) age in years	43.0 (11.0)
Female sex, n (%)	6735 (66.0)
Mean (SD) household income in US dollars*	61,396 (25,968)
Mean (SD) % less than high school education*	45.2 (19.8)
Smoker (2007), n (%)	789 (7.7)
Gastroesophageal reflux, n (%)	2422 (23.7)
Depression, n (%)	2130 (20.8)
Mean (SD) 2007 ICS canister dispensings	3.1 (5.7)
2007 SABA ≥ 7, n (%)	2732 (26.7)
Any 2007 hospitalization or ED visit, n (%)	584 (5.7)
Any 2007 oral corticosteroid, † n (%)	2483 (24.3)
2008 SABA ≥ 7, n (%)	2565 (25.1)
Any 2008 hospitalization or ED visit, n (%)	596 (5.8)
Any 2008 oral corticosteroid, † n (%)	2475 (24.2)
Two or more 2008 oral corticosteroid, † n (%)	855 (8.4)

BMI, Body mass index; ED, emergency department; ICS, inhaled corticosteroids; SABA, short-acting beta-agonists canisters dispensed.

*Geocoded.

†Linked to an asthma encounter.

increased risk of exacerbations based on OCS dispensings (Table IV). Lower socioeconomic status (household income and education) was associated with an increased risk of EDHO and OCS dispensings. Smoking was associated with increased EDHO (Table III), but not OCS dispensings (Tables IV). GERD and depression were associated with all 2008 exacerbation outcomes (Tables III and IV). Although 2007 ICS canister dispensings were not associated with 2008 EDHO (Table III), patients with OCS dispensings received more ICS canisters in the prior year than patients without OCS dispensings (Table IV). Year 2007 exacerbations were associated with markedly increased risk of year 2008 exacerbations (Tables III and IV); likewise, 2007 SABA7 dispensing also was associated with substantially increased risk of all 2008 exacerbation outcomes (Tables III and IV).

In the adjusted analyses, obesity was associated with a 27% increase in 2008 SABA7, but the relationship between overweight and SABA7 was no longer significant (Figure 1). After adjusting for the demographic, comorbidity, and prior utilization factors described above, overweight and obesity remained significantly associated with increased subsequent exacerbations. Being overweight increased the risk of exacerbation outcomes (EDHO, OCS dispensings) from 26% to 40%, whereas obesity increased the risk from 36% to 57% (Figure 1).

DISCUSSION

The relationship between obesity and asthma incidence seems well established,¹ and the high prevalence of overweight and obesity in our sample of asthmatic patients is consistent with this relationship. However, data on the relationship between elevated BMI and impaired asthma control are less clear. The current study supports the hypothesis that overweight or obesity

TABLE II. Relationships of body mass index and other characteristics in 2006 and 2007 to dispensing of 7 or more canisters of short-acting beta-agonists (SABA) in 2008

Characteristic	SABA ≥ 7	SABA < 7	P value
BMI < 25 kg/m ² , n (%)	457 (21.5)	1672 (78.5)	<.001
BMI 25-29.9 kg/m ² , n (%)	703 (23.1)	2301 (76.6)	
BMI ≥ 30 kg/m ² , n (%)	1405 (27.6)	3695 (72.5)	
Mean (SD) BMI in kg/m ²	32.4 (8.5)	31.1 (7.8)	<.001
Mean (SD) age in years	43.0 (10.9)	43.0 (11.1)	.98
Male sex, n (%)	1020 (29.3)	2460 (70.7)	<.001
Female sex, n (%)	1545 (22.9)	5208 (77.1)	
Mean (SD) household income in US dollars*	59,470 (24,278)	62,044 (26,482)	<.001
Mean (SD) % of population with less than high school education*	46.7 (19.3)	44.7 (19.9)	<.001
Smoker (2007), n (%)	318 (40.3)	471 (59.7)	<.001
Nonsmoker (2007), n (%)	2247 (23.8)	7197 (76.2)	
Gastroesophageal reflux, n (%)	606 (25.0)	1816 (75.0)	.95
No gastroesophageal reflux, n (%)	1959 (25.1)	5852 (74.9)	
Depression, n (%)	544 (25.5)	1586 (74.5)	.57
No depression, n (%)	2021 (24.9)	6082 (75.1)	
Mean (SD) 2007 ICS canister dispensings	3.83 (4.38)	2.87 (6.00)	<.001
2007 SABA ≥ 7, n (%)	1790 (65.5)	942 (34.5)	<.001
2007 SABA < 7, n (%)	775 (10.3)	6726 (89.7)	
Any 2007 hospitalization or ED visit, n (%)	265 (45.4)	319 (54.6)	<.001
No 2007 hospitalization or ED visit, n (%)	2300 (23.8)	7349 (76.2)	
Any 2007 oral corticosteroid, † n (%)	919 (37.0)	1564 (63.0)	<.001
No 2007 oral corticosteroid, † n (%)	1646 (21.2)	6104 (78.8)	

ED, Emergency department; ICS, inhaled corticosteroids.

*Geocoded.

†Linked to an asthma encounter.

increases the risk of worse asthma control in both the impairment and risk domains. Obesity increased the likelihood of impairment, as measured by a validated SABA threshold,²² by 27% (Figure 1). After adjusting for potential demographic, comorbidity, and prior utilization confounders or mediators, being overweight increased the risk of exacerbations by 26% to 40% and obesity increased the risk of exacerbations by 36% to 57% (Figure 1). The strengths of the current study include its large size, real-world setting, longitudinal ascertainment, and the ability to account for many factors that potentially confound the relationship between BMI and asthma control.

Our study showed a stronger relationship between elevated BMI and the risk domain of control (exacerbations) than between overweight or obesity and the impairment domain of asthma control (SABA dispensings). Only obesity, not overweight, conferred an increased risk of excessive SABA dispensings, and the magnitude of the increased risk (27%) was less than for exacerbations (Figure 1). One explanation for this could be decreased perception of dyspnea in obese patients with asthma. However, obesity has been shown to be related to increased

TABLE III. Relationships of body mass index and other characteristics in 2006 and 2007 to asthma exacerbations defined by an asthma emergency department visit or hospitalization (EDHO) in 2008

Characteristic	EDHO	No EDHO	P value
BMI < 25 kg/m ² , n (%)	89 (4.2)	2040 (95.8)	<.001
BMI 25-29.9 kg/m ² , n (%)	173 (5.8)	2831 (94.2)	
BMI ≥ 30 kg/m ² , n (%)	334 (6.6)	4766 (93.5)	
Mean (SD) BMI in kg/m ²	33.4 (9.3)	31.3 (7.9)	<.001
Mean (SD) age in years	41.8 (11.8)	43.1 (11.0)	.005
Male sex, n (%)	196 (5.6)	3284 (94.4)	.55
Female sex, n (%)	400 (5.9)	6353 (94.1)	
Mean (SD) household income in US dollars*	57,006 (24,041)	61,670 (26,060)	<.001
Mean (SD) % of populations with less than high school education*	49.0 (20)	45.0 (19.7)	<.001
Smoker (2007), n (%)	61 (7.7)	728 (92.3)	.04
Nonsmoker (2007), n (%)	535 (5.7)	8909 (94.3)	
Gastroesophageal reflux, n (%)	160 (6.6)	2262 (93.4)	.04
No gastroesophageal reflux, n (%)	436 (5.6)	7375 (94.4)	
Depression, n (%)	158 (7.4)	1972 (92.6)	<.001
No depression, n (%)	438 (5.4)	7665 (94.6)	
Mean (SD) 2007 ICS canister dispensings	3.35 (4.09)	3.10 (5.74)	.29
2007 SABA ≥ 7, n (%)	292 (10.7)	2440 (89.3)	<.001
2007 SABA < 7, n (%)	304 (4.1)	7195 (95.9)	
Any 2007 EDHO, n (%)	162 (27.7)	422 (72.3)	<.001
No 2007 EDHO, n (%)	434 (4.5)	9215 (95.5)	
Any 2007 oral corticosteroid,† n (%)	286 (11.5)	2197 (88.5)	<.001
No 2007 oral corticosteroid,† n (%)	310 (4.0)	7440 (96.0)	

ICS, Inhaled corticosteroids; SABA, short-acting beta-agonists canisters dispensed.

*Geocoded.

†Linked to an asthma encounter.

dyspnea in asthmatic patients.²³ Several studies have shown that overweight or obese patients report increased impairment as measured by validated asthma control or quality of life tools compared with normal weight asthmatic patients.^{2,3,5,6,8-13} Another explanation for the current findings may be that our assessment of impairment (SABA7) does not adequately capture the range of asthma impairment compared with assessments that include additional clinical information. We did find increased dispensings of SABA in males compared with females (Table II), as has been previously reported,²⁴ although the reasons for this gender difference are not clear.

A number of mechanisms have been suggested to explain a relationship between overweight and obesity and poorer asthma control, including obesity comorbidities (such as GERD and depression),^{25,26} reduced corticosteroid responsiveness,²⁷⁻²⁹ adipokines,^{1,25} obesity effects on pulmonary mechanics,¹ and low vitamin D levels.^{30,31} The current study sheds light on some of those mechanisms. GERD and depression have both been associated with obesity and with poorer asthma outcomes,^{25,26,32} and Boudreau et al²⁶ recently found that the significant

relationship between BMI and reduced asthma control in 798 asthmatic adult patients disappeared when results of the Beck Depression Inventory were included in the model.²⁶ Our study confirms a relationship between GERD and depression and asthma exacerbations (Tables II and III). However, the relationship between overweight and obesity and asthma exacerbations remained significant even after adjusting for these diagnoses (Figure 1). Moreover, obesity, but not GERD or depression, was associated with SABA overuse in the current study. However, an important difference between our study and the study of Boudreau et al²⁶ is that our study adjusted for depression encounter diagnoses, whereas their study adjusted for depression symptoms.

Reduced corticosteroid responsiveness has been reported in obese patients with asthma²⁷⁻²⁹ and could contribute to poorer control. Our finding that the relationship between elevated BMI and poorer asthma control remained significant even after adjustment for ICS canister dispensings would be consistent with, but not definitive for, that mechanism. Our data do not provide information regarding other potential mechanisms.

It should be noted that overweight and obesity increased the risk of poorer asthma outcomes in our study, even after we adjusted for prior adverse outcomes, which is the strongest risk factor for subsequent exacerbations and SABA overuse. Our findings support the clinical recommendation for weight loss in overweight or obese patients with asthma as a means to improve asthma control. We have investigated the possibility of assessing this effect from an observational perspective—comparing outcomes in patients who lost weight versus those who did not over a period of several years. However, a preliminary informal look at this did not find enough patients who exhibited meaningful weight loss over the study period of observation to allow adequate analyses in this regard. Interventional studies do support the role of weight loss in improving asthma outcomes, including asthma control.³³⁻³⁶ Although 2 of these studies involved morbidly obese patients undergoing bariatric surgery,^{34,35} the most recent study³⁶ involved a medical treatment program for moderately obese subjects (mean BMI 39.68) who lost a mean of 7.9 kg during the study. In that study, the Asthma Control Questionnaire improved to a clinically significant degree (>0.5 point) in 11 of the 12 intervention patients who lost the target amount of greater than 10% of their body weight, but in only 3 of 10 intervention patients who lost less weight. Further studies will be necessary to more completely define the amount of weight loss necessary to improve asthma outcomes, especially in less obese and overweight patients.

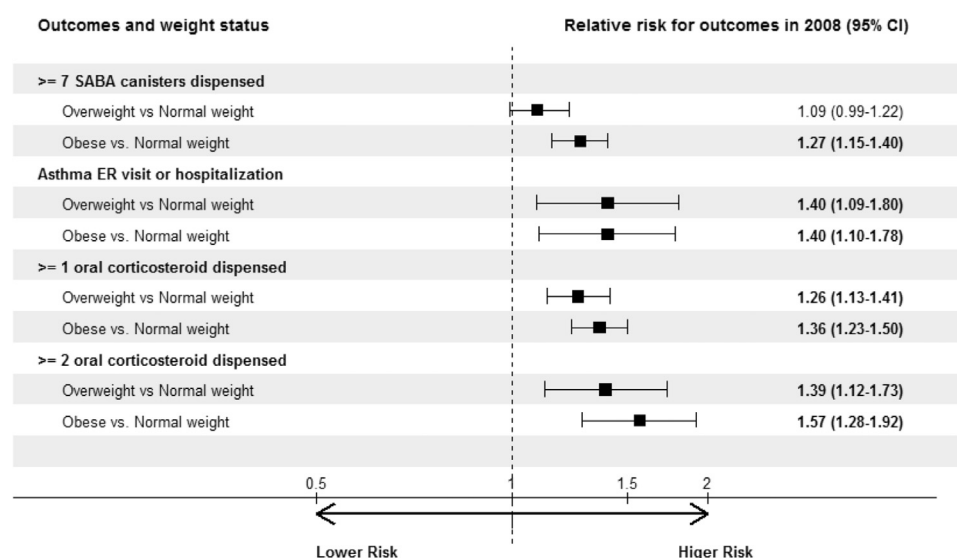
This study does have some potential limitations. The first one relates to the general limitations of administrative versus clinical data, relying primarily on encounter diagnoses and pharmacy dispensings, rather than direct patient or physician reports. The KPSC robust electronic medical record and single medical care program with established practice guidelines should mitigate that limitation to some degree. Moreover, the HEDIS administrative data definition of persistent asthma has been validated against questionnaire data in our system.³⁷ A second limitation of the current study is that spirometric measurements that confirmed a diagnosis of asthma were not obtained. Although spirometry has been recommended for the initial diagnosis of asthma, physician-diagnosed asthma (as indicated by encounter diagnoses in this study) has been shown to be a valid means of identifying asthma in epidemiologic studies.³⁸ There may be a concern that

TABLE IV. Relationships of body mass index and other characteristics in 2006 and 2007 to asthma exacerbation defined by oral corticosteroid dispensings linked to an asthma encounter (OCS) in 2008

Characteristic	Any OCS	No OCS	P value	≥2 OCS	<2 OCS	P value
BMI < 25 kg/m ² , n (%)	374 (17.6)	1755 (82.4)	<.001	109 (5.1)	2020 (94.9)	<.001
BMI 25-29.9 kg/m ² , n (%)	706 (23.5)	2298 (76.5)		236 (7.9)	2768 (92.1)	
BMI ≥ 30 kg/m ² , n (%)	1395 (27.4)	3705 (72.6)		510 (10.0)	4590 (90.0)	
Mean (SD) BMI in kg/m ²	32.7 (8.4)	31.0 (7.8)	<.001	33.4 (8.5)	31.2 (7.9)	<.001
Mean (SD) age in years	44.2 (10.2)	42.7 (11.3)	<.001	44.8 (9.8)	42.9 (11.1)	<.001
Male sex, n (%)	718 (20.6)	2662 (79.4)	<.001	242 (7.0)	3238 (93.0)	<.001
Female sex, n (%)	7157 (26.0)	4996 (74.0)		613 (9.1)	6140 (90.9)	
Mean (SD) household income in US dollars*	60,438 (25,056)	61,704 (26,248)	.04	59,191 (21,137)	61,600 (26,205)	.01
Mean (SD) % of population with less than high school education*	46.9 (19.7)	44.7 (19.8)	<.001	47.9 (19.1)	45.0 (19.8)	<.001
Smoker (2007), n (%)	188 (23.8)	601 (76.2)	.81	67 (8.5)	722 (91.5)	.89
Nonsmoker (2007) active smoking, n (%)	2287 (24.2)	7157 (75.8)		558 (7.5)	7223 (91.7)	
Gastroesophageal reflux, n (%)	673 (27.8)	1749 (72.2)	<.001	267 (11.0)	2155 (88.9)	<.001
No gastroesophageal reflux, n (%)	1802 (23.1)	6009 (76.9)		558 (7.5)	7223 (92.5)	
Depression, n (%)	602 (28.3)	1528 (71.7)	<.001	218 (10.2)	1912 (89.8)	<.001
No depression, n (%)	1873 (23.1)	6230 (76.9)		637 (7.9)	7466 (92.1)	
Mean (SD) 2007 ICS canister dispensings	3.55 (5.77)	2.98 (5.61)	<.001	3.71 (4.40)	3.06 (5.75)	.001
2007 SABA ≥ 7, n (%)	952 (34.9)	1780 (65.2)	<.001	382 (14.0)	2350 (86.0)	<.001
2007 SABA < 7, n (%)	1523 (20.3)	5978 (79.7)		473 (6.3)	7028 (93.7)	
Any 2007 hospitalization or ED visit, n (%)	264 (45.2)	320 (54.8)	<.001	132 (22.6)	452 (77.4)	<.001
No 2007 hospitalization or ED visit, n (%)	2211 (22.9)	7438 (77.1)		723 (7.5)	8926 (92.5)	
Any 2007 OCS, n (%)	1137 (45.8)	1346 (54.2)	<.001	514 (20.7)	1969 (79.3)	<.001
No 2007 OCS, n (%)	1338 (17.3)	6412 (54.2)		341(4.4)	7409 (95.6)	

ED, Emergency department; ICS, inhaled corticosteroids; SABA, short-acting beta-agonists canisters dispensed.

*Geocoded.

**FIGURE 1.** Multivariable analysis of the relationship between 2007 body mass index category and 2008 asthma outcomes (models adjusted for age, sex, income, educational level, smoking, gastroesophageal reflux, depression, and 2007 inhaled corticosteroid canister dispensings, EDHO, OCS and SABA7).

misdiagnosis of asthma without pulmonary function confirmation may be a bigger problem in obese versus nonobese patients. However, it has also been shown that overdiagnosis of asthma is similar in obese and nonobese adults.³⁹ A third potential limitation is that impairment was assessed in this study by means of

SABA canister dispensings, rather than patient-reported information. However, the SABA cutoff used in this study has been shown to reflect impairment as measured by several patient-reported outcome tools.²² Another limitation is that we did not capture activity level which could be a confounder of the

observed relationship between increased BMI and worse asthma outcomes.

There are also some potential limitations regarding the generalizability of our findings. First, approximately 20% of our continuously enrolled patients with persistent asthma did not have a BMI measurement, and our results may not generalize to these patients. However, the included cohort with BMI measurements did represent higher risk patients compared with those without BMI measurements (see Table E1 in this article's Online Repository at www.jaci-inpractice.org). Second, our findings may not be applicable to obese and overweight asthmatic patients outside of the Kaiser Permanente health care system. However, the Kaiser Permanente population has been shown to be representative of the demographics within the region that it serves.⁴⁰ Finally, our cohort had persistent asthma, and the current findings may not generalize to patients with intermittent asthma.

In summary, this study has shown that overweight and obesity increase the risk of subsequent poor asthma control in a large, real-world sample. Adjustment for many relevant confounders did not eliminate most of the relationships observed. These data and a number of interventional studies to date suggest that weight loss management would improve asthma control in a large number of asthmatic patients and that physicians managing overweight and obese patients with asthma should actively encourage and facilitate these interventions.

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TABLE E1. Comparison of characteristics of 10,233 adults with persistent asthma with body mass index (BMI) measurement available to those of 2,533 adults with persistent asthma with no BMI measurement available

Characteristic	BMI available (n = 10,233)	No BMI available (n = 2,533)	P value
Mean (SD) age in years	43.6 (11.0)	40.8 (12.0)	<.0001
Female sex, n (%)	6753 (66)	1185 (47)	
Mean (SD) household income in US dollars*	61,397 (25,968)	63,494 (28,125)	<.001
Mean (SD) % less than high school education*	45.2 (19.8)	43.1 (20.4)	<.0001
Active smoking, n (%)	789 (7.7)	133 (5.3)	<.0001
Gastroesophageal reflux, n (%)	2422 (23.7)	190 (7.5)	<.0001
Depression, n (%)	2130 (20.8)	217 (8.6)	<.0001
Mean (SD) 2007 ICS canister dispensings	3.11 (5.65)	2.54 (3.54)	<.0001
2007 SABA $\geq$ 7, n (%)	2732 (26.7)	587 (23.2)	<.001
Any 2007 hospitalization or ED visit, n (%)	584 (5.7)	99 (3.9)	<.001
Any 2007 oral corticosteroid†, n (%)	2483 (24.3)	189 (7.1)	<.0001

ED, emergency department; ICS, inhaled corticosteroids; SABA, short-acting beta-agonists canisters dispensed.

*Geocoded.

†Linked to an asthma encounter.

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