Table 4: Comorbidities by body mass index group

	Underweight and normal		Overweight		Class I		Class II		Class III		*P*-value	Sub-analysis
	n	%	*n*	%	*n*	%	*n*	%	*n*	%		
Overall	951		2,011		1,708		830		516			
Race												
White	407	42.8	947	47.1	801	46.9	390	47.0	228	44.2	0.0004	abcdefghij
Black	55	5.8	187	9.3	275	16.1	209	25.2	192	37.2		
Hispanic	10	1.1	10	0.5	9	0.5	4	0.5	0	0.0		
Other	14	1.5	18	0.9	11	0.6	6	0.7	4	0.8		
Unknown	465	48.9	849	42.2	612	35.8	221	26.6	92	17.8		
Age, years											0.0045	bhi
< 45	503	52.9	1,005	50.0	797	46.7	432	52.0	272	52.7		
45-65	393	41.3	876	43.6	806	47.2	358	43.1	230	44.6		
> 65	55	5.8	130	6.5	105	6.1	40	4.8	14	2.7		
Diabetes											0.0004	abcdefghij
None	941	98.9	1,962	97.6	1,618	94.7	775	93.4	440	85.3		
Insulin dependent	2	0.2	7	0.3	12	0.7	15	1.8	16	3.1		
Non-insulin dependent	8	0.8	42	2.1	78	4.6	40	4.8	60	11.6		
Any diabetes	10	1.1	49	2.4	90	5.3	55	6.6	76	14.7	< 0.0001	abcdefgij
Active smoking	89	9.4	212	10.5	209	12.2	110	13.3	55	10.7	0.0474	bcf
Alcohol use	7	0.7	17	0.8	13	0.8	1	0.1	2	0.4	0.1788	
Respiratory disease	5	0.5	26	1.3	45	2.6	42	5.1	51	9.9	< 0.0001	bcdefghij
Hypertension	81	8.5	319	15.9	433	25.4	254	30.6	220	42.6	< 0.0001	abcdefghij
30-day prior wound infection	3	0.3	5	0.2	12	0.7	1	0.1	2	0.4	0.1641	
Heart disease	5	0.5	9	0.4	11	0.6	4	0.5	5	1.0	0.6535	
Weight loss	3	0.3	2	0.1	4	0.2	2	0.2	1	0.2	0.6470	
Bleeding disorder	6	0.6	6	0.3	9	0.5	2	0.2	5	1.0	0.2148	
Preoperative sepsis	1	0.1	0	0.0	0	0.0	4	0.5	1	0.2	NR	
Prior operation within 30 days	0	0.0	6	0.3	1	0.1	1	0.1	0	0.0	NR	
Total comorbidities											< 0.0001	abcdefghij
0	736	77.4	1,385	68.9	978	57.3	419	50.5	204	39.5		
1	184	19.3	517	25.7	547	32.0	295	35.5	182	35.3		
2 or more	31	3.3	109	5.4	183	10.7	116	14.0	130	25.2		

P-value subanalysis key: *P*-value < 0.05 in a (underweight and normal *vs.* overweight), b (underweight and normal *vs.* class I), c (underweight and normal *vs.* class II), d (underweight and normal *vs.* class III), e (overweight *vs.* class I), f (overweight *vs.* class II), g (overweight *vs.* class III), h (class I *vs.* class II), i (class I *vs.* class III), j (class II *vs.* class III). *P*-values are not reported (NR) for any variables with a cell size of 0

cardiac surgery and history of angina), recent weight loss, bleeding disorder, preoperative sepsis, and prior operation within 30 days.

Surgical complications included wound complications, unplanned return to the operating room and graft/flap failure. Wound complications encompassed superficial surgical site infection (SSI), deep SSI, organ/deep space SSI, and wound dehiscence. Medical complications were defined as renal (renal failure and renal insufficiency), neurologic (stroke, coma, peripheral nerve injury), cardiac (myocardial infarction and cardiac arrest), sepsis, death, venous thromboembolism, failure to wean from ventilator, unplanned reintubation, pneumonia, bleeding, and urinary tract infection. Multivariable analysis of postoperative outcomes was performed to control for those preoperative and intraoperative variables with $n > 10$ events, and $P < 0.05$ on bivariate screen.

Obese and non-obese patients were then 1:1

Table 5: Complications and body mass index group

	Underweight and normal		Overweight		Class I		Class II		Class III		*P*-value	Sub-analysis
	n	%	*n*	%	*n*	%	*n*	%	*n*	%		
Overall	951		2,011		1,708		830		516			
Any complication	42	4.4	115	5.7	105	6.1	53	6.4	63	12.2	< 0.0001	dgij
Surgical complication	14	1.5	33	1.6	20	1.2	16	1.9	17	3.3	0.0214	dgi
Wound complication	27	2.8	79	3.9	81	4.7	40	4.8	48	9.3	< 0.0001	bcdgij
Medical complication	3	0.3	11	0.5	9	0.5	7	0.8	8	1.6	0.0739	
Return to operating room	14	1.5	33	1.6	19	1.1	16	1.9	17	3.3	0.0156	dgi
Superficial SSI	26	2.7	56	2.8	62	3.6	27	3.3	37	7.2	< 0.0001	dgij
Deep SSI	0	0.0	15	0.7	8	0.5	5	0.6	1	0.2	NR	
Organ/space SSI	0	0.0	0	0.0	2	0.1	2	0.2	0	0	NR	
Wound dehiscence	1	0.1	8	0.4	13	0.8	6	0.7	14	2.7	< 0.0001	bdgij
Venous thromboembolism	2	0.2	2	0.1	2	0.1	2	0.2	0	0	NR	
Unplanned reintubation	0	0.0	1	0.1	0	0	0	0	1	0.2	NR	
Urinary tract infection	0	0.0	3	0.1	1	0.1	3	0.4	1	0.2	NR	
Other bleeding	1	0.1	3	0.1	6	0.4	1	0.1	4	0.8	0.1024	
Hospital length of stay, median and range	0	0-234	0	0-31	0	0-32	1	0-6	1	0-15	< 0.0001	bcdefghij

P-value subanalysis key: *P*-value < 0.05 in a (underweight and normal *vs.* overweight), b (underweight and normal *vs.* class I), c (underweight and normal *vs.* class II), d (underweight and normal *vs.* class III), e (overweight *vs.* class I), f (overweight *vs.* class II), g (overweight *vs.* class III), h (class I *vs.* class II), i (class I *vs.* class III), j (class II *vs.* class III). *P*-values are not reported (NR) for any variables with a cell size of 0. SSI: surgical site infection

propensity score matched to control for preoperative and intraoperative variables, in order to isolate the effect of obesity on postoperative outcomes. Patient characteristics were matched if $n > 10$ (i.e., greater than 10 events) and $P < 0.05$ on bivariate screen. Based on these criteria, matched characteristics included the following: age; diabetes mellitus; active smoking; alcohol use; hypertension; respiratory disease; heart disease; history of transient ischemic attack or stroke; bleeding comorbidity; preoperative wound infection; steroid or immunosuppressant use; recent weight loss > 10% of total body weight in 6 months prior to surgery; total number of comorbidities (none, one, or two or more); American Society of Anesthesiologists (ASA) class; inpatient versus outpatient status; operative time; and total work relative value units.

Statistical analysis

Characteristics of the sample were summarized using descriptive statistics. Medians and ranges were reported for continuous variables; frequencies and percentages are reported for categorical variables. The chi square test, Fisher's exact test and the Kruskal-Wallis test were used to determine association between BMI groups and various demographic, comorbidity and outcome variables. If a statistically significant association was detected between a BMI group and a variable, a subgroup analysis was performed using the same tests to determine which of the groups were significantly different from each other. Multivariable analysis of postoperative outcomes was performed for those preoperative and intraoperative variables with $n > 10$ events, and $P < 0.05$ on bivariate screen.

Data were then separated into two groups: patients who were obese (BMI of 30 or more) and patients who were not obese (BMI below 30). Patients were matched on a 1:1 basis using propensity scores from a logistic regression model (as described above). Outcomes were then compared between the matched cohorts using McNemar's test and the Wilcoxon signed rank test. Statistical significance is indicated by $P < 0.05$.

RESULTS

Overall

Between 2005 and 2013, the NSQIP datasets identified a total of 6,016 patients who underwent primary reduction mammaplasty with 30-day postoperative follow-up. The patients were predominantly white, comprising 46.1% of the cohort, and 15.3% were black. Fifty percent were younger than 45 years of age, 44.3% were between 45 and 65 years, and only 5.7% were older than 65 years.

From the total group of patients, 28.7% had at least one preoperative comorbidity, and 9.5% had two or more. Common comorbidities included hypertension (21.7%), active smoking (11.2%), and diabetes (4.7%) [Table 1]. Other factors to assess preoperative risk included ASA classification, with 28.0% in class 1, 60.4% in class 2, 11.4%

Table 6: Complications and obesity status - unmatched analysis

	Obese		Non-obese		*P*-value
	n	%	*n*	%	
Overall	3,054		2,962		
Any complication	221	7.2	157	5.3	0.0024
Surgical complication	53	1.7	47	1.6	0.7263
Wound complication	169	5.5	106	3.6	0.0004
Medical complication	24	0.8	14	0.5	0.1706
Return to operating room	52	1.7	47	1.6	0.8011
Superficial SSI	126	4.1	82	2.8	0.0050
Deep SSI	14	0.5	15	0.5	0.9342
Organ/space SSI	4	0.1	0	0.0	0.1251
Wound dehiscence	9	0.3	33	1.1	0.0005
Venous thromboembolism	4	0.1	4	0.1	1.0000
Unplanned reintubation	1	0.0	1	0.0	1.0000
Urinary tract infection	5	0.2	3	0.1	0.7266
Other bleeding	11	0.4	4	0.1	0.1357
Hospital length of stay, median and range	1	0-32	0	0-234	< 0.0001

The rates of overall complication ($P = 0.0024$), wound complication ($P = 0.0004$), superficial surgical site infection (SSI) ($P = 0.0050$), and wound dehiscence ($P = 0.0005$) were found to be different between obese and non-obese patients. The distribution of the total hospital length of stay was also found to differ by obesity status ($P < 0.0001$).

in class 3, and 0.2% in class 4. A majority of cases (85.4%) were outpatient, and median operative time was 148 min, with a range of 13 to 739 min [Table 2].

Overall complications within the early postoperative period were rare, at a rate of 6.3%. These were comprised mostly of wound complications (4.6% of total, 72.8% of all complications). The most common wound complication was superficial SSI, occurring in 3.5%. Surgical complications occurred in 1.7%, and medical complications occurred in only 0.6% [Table 3].

Analysis by WHO obesity classification

BMI data were then assessed according to WHO obesity classification. Overall, 3,054 of the patients (50.8%) were obese, with 1,708 (28.4%) classified as class I, 830 (13.8%) as class II, and 516 (8.6%) as class III. Analysis among the non-obese, overweight, and three classes of obesity showed statistically significant differences in demographic values and several comorbidities. Black patients comprised an increasingly large proportion with each class of obesity (5.8% underweight/normal, 9.3% overweight, 16.1% class I, 25.2% class II, and 37.2% class III) [Table 4].

Regarding comorbidities, there was a significant increase in the rate of diabetes with increased obesity class: 1.1% in the underweight/normal, 2.4% in the overweight, 5.3% in class I, 6.6% in class II, and 14.7% in class III ($P < 0.0001$). Hypertension (8.5% underweight/normal, 15.9% overweight, 25.4% class I, 30.6% class II, and 42.6% class III) and respiratory disease (0.5% underweight/normal, 1.3% overweight, 2.6% class I, 5.1% class II, 9.9% class III) increased as well ($P < 0.0001$). As the class of obesity increased, there were greater total comorbidities (3.3% of underweight/normal patients had at least two comorbidities, compared to 25.2% of class III obese patients) ($P < 0.0001$). Smoking and alcohol use rates did not increase proportionally with increasing obesity class [Table 4].

Multivariable analysis of postoperative outcomes was performed for those preoperative and intraoperative variables with $n > 10$ events, and $P < 0.05$ on bivariate screen [Tables 5 and 6]. After controlling for preoperative and interoperative differences by multivariable analysis, a significant increase was noted in any complication in class III obese patients (12.2%), when compared to underweight/normal (4.4%), overweight (5.7%), class I (6.1%) and class II (6.4%) patients ($P < 0.0001$). Surgical complications were significantly greater when comparing class III (3.3%) with underweight/normal (1.5%), overweight (1.6%) and class I patients (1.2%) ($P < 0.0214$). Regarding wound complications, class III patients had significantly increased rates (9.3%) compared to all other categories. However, they were also found to be greater in class I (4.7%) and class II patients (4.8%) when compared to underweight and normal weight patients (2.8%) ($P < 0.0001$). An unexpected return to the operating room occurred more frequently in class III patients (1.6%) relative to underweight/normal, overweight and class I patients ($P < 0.0156$). Superficial SSI and wound dehiscence also occurred significantly more in class III

Table 7: Using propensity scores, obese patients were matched to non-obese patients on the variables listed

	Full cohort			Matched cohort		
	% of patients		*P*-value	% of patients		*P*-value
	Non-obese *n* = 2,962	Obese *n* = 3,054		Non-obese *n* = 1,464	Obese *n* = 1,464	
Age, years			0.0399			0.1067
< 45	50.9	49.1		54.1	52.9	
45-65	42.8	45.6		41.1	43.7	
> 65	6.2	5.2		4.8	3.3	
Diabetes	2.0	7.2	< 0.0001	1.8	2.0	0.8774
Hypertension	13.5	29.7	< 0.0001	15.2	16.9	0.1344
Respiratory disease	1.0	4.5	< 0.0001	1.5	1.2	0.5708
ASA class			< 0.0001			0.3593
1 or 2	94.2	82.7		93.0	93.8	
3 or 4	5.7	17.3		7.0	6.2	
Total comorbidities			< 0.0001			0.4571
0	71.6	52.4		69.1	68.2	
1	23.7	33.5		25.1	26.8	
2 or more	4.7	14.0		5.7	50.0	
Inpatient status	11.6	17.5	< 0.0001	11.8	13.9	0.0831
Total RVU, median (range)	16.0 (16.6-54.7)	16.0 (15.6-52.0)	< 0.0001	16.0 (15.6-49.2)	16.0 (15.6-51.9)	0.7769
Operating time, min, median (range)	133 (13-739)	163 (14-636)	< 0.0001	146 (14-543)	146 (14-488)	0.3134

Prior to matching, obese patients were found to be significantly different from non-obese patients on all of the characteristics. After matching, none of these characteristics were found to differ between the two groups. ASA: American Society of Anesthesiologists; RVU: relative value units

patients (7.2% and 2.7%, respectively) compared to all other categories; wound dehiscence occurred more in class I obese patients compared to the underweight and normal ($P < 0.0001$) [Table 5].

Unmatched multivariable analysis

Again on multivariable analysis, obese patients (BMI 30 or more) were compared to the non-obese (BMI < 30) in an unmatched analysis. Rates of overall complications (7.2% *vs.* 5.3%, $P = 0.0024$), wound complications (5.5% *vs.* 3.6%, $P = 0.0004$), superficial SSI (4.1% *vs.* 2.8%, $P = 0.0050$), and wound dehiscence (0.3% *vs.* 1.1%, $P = 0.0005$) were found to be statistically different. Total hospital length of stay was found to change with obesity status ($P < 0.0001$) [Table 6].

Propensity score matched analysis

Using propensity scores, obese patients were then matched to non-obese patients according to preoperative and operative variables, totaling 1,464 patients in each group. After matching, none of these variables were found to differ between the two groups. When comparing the matched obese *vs.* non-obese patients, only wound complications (4.6% *vs.* 3.1%, $P = 0.0334$) and hospital length of stay ($P < 0.0001$) were significantly increased in the obese cohort.

DISCUSSION

Obesity continues to be an epidemic not only in North America, but globally as well. Thirty-six percent of the population is considered obese, with a greater proportion of women than men.[19,20] Symptomatic macromastia is a common condition which afflicts many women, particularly the obese population. Although obesity has been correlated with increased complication rates,[9-13] this population also has a propensity towards having greater medical comorbidities. With literature demonstrating improved longevity in overweight patients compared to normal weight patients,[21] BMI and obesity must therefore be assessed independent of these confounding comorbidities.

Obesity is an often assumed risk factor for postoperative complications following breast reduction surgery. However, its effect on risk outcomes remains incompletely understood. Our study hopes to better define obesity as a preoperative risk factor for breast reduction. Multivariate analysis both before propensity score matching [Tables 5 and 6] and after matching [Tables 7 and 8] was utilized to isolate the effects of obesity alone on postoperative outcomes. Propensity score matching produces estimates that are less biased, more robust, more precise, and with greater empirical power than logistic regression when

Table 8: Complications and obesity status - matched analysis

	Obese		Non-obese		*P*-value
	n	%	*n*	%	
Overall	1,464		1,464		
Any complication	91	6.2	72	4.9	0.1456
Surgical complication	22	1.5	24	1.6	0.8828
Wound complication	68	4.6	45	3.1	0.0334
Medical complication	9	0.6	5	0.3	0.4227
Return to operating room	22	1.5	24	1.6	0.8828
Superficial SSI	55	3.8	36	2.5	0.0536
Deep SSI	8	0.5	5	0.3	0.5465
Organ/space SSI	3	0.2	0	0.0	0.2482
Wound dehiscence	4	0.3	4	0.3	1.0000
Venous thromboembolism	2	0.1	3	0.2	1.0000
Unplanned reintubation	0	0.0	0	0.0	NR
Urinary tract infection	1	0.2	2	0.1	1.0000
Other bleeding	3	0.2	0	0.0	0.2482
Hospital length of stay, median and range	0	0-32	0	0-234	< 0.0001

A total of 2,928 patients (1,464 per group) were matched using propensity scores. The unmatched patients were discarded from the analysis. McNemar's test and the Wilcoxon signed rank test test were used to compare the two matched groups. The rate of wound complication ($P = 0.0334$) and the distribution of length of stay ($P < 0.0001$) was found to differ between the matched groups. SSI: surgical site infection; NR: not reported

the number of events are low and there are multiple confounders.[22]

Many authors have tried to definitively determine the correlation between obesity and adverse events after surgery. Although many studies consistently demonstrate the deleterious effect of obesity, nearly all analyses are confounded by the effects of associated medical conditions on outcomes. One such study did not find a statistical difference in obese versus non-obese patients in relation to complication and hospital length of stay.[23] Another did not find significant differences in complications attributable to age, BMI, size of resection, smoking status, comorbidities, or surgical technique, even in the morbidly obese.[16] Other studies similarly found no statistically significant difference in complication rates among the obese.[14,15,17]

However, contradictory findings exist in the literature as well, supporting obesity as a risk factor.[6,9-13] Chun *et al*.[13] identified a threshold of BMI 35.6 at which postoperative complications were increased two-fold, the most common complication being infection. The pioneering study using NSQIP data to analyze BMI and breast reduction complications by Nelson *et al*.[6] included 4,545 patients between 2005 and 2011. This study used logistic regression to account for demographics and comorbidities. They found an increased rate in overall complications, wound complications in all obesity classes, and major surgical complications in class III obesity.

Multivariate analysis among the non-obese, overweight, and three classes of obesity showed statistically significant differences in demographics, comorbidities, and complication rates [Tables 4-6]. In our unmatched analysis [Table 6], overall complications, wound complications, superficial SSI, and wound dehiscence were significantly increased in the obese population compared to the non-obese cohort after multivariable analysis controlling for significantly different variables between obese and non-obese cohorts. Comorbidities may confound the isolated risk of obesity on complication rates. The distinguishing feature of our study was matching obese patients to non-obese patients with similar preoperative and operative variables, thus eliminating the confounding effect of associated comorbidities on outcomes. While multivariable analysis attempts to control for comorbidities via advanced statistical techniques, 1:1 matching is a dramatically more powerful technique that matches each study patient with a near-identical "control" patient, in spite of detractors of this technique.[24] After analysis of matched cohorts, only wound complications were increased in the obese population [Table 8]. On further analysis, the difference was mainly attributed to a risk of increased surgical site infection in the obese cohort. Of note, length of hospital stay was found to be significantly increased in the normal-weight cohort. On close examination, this was due to a statistical aberrancy (in that the range of values for length of stay for non-obese patients was greater than for obese patients).

In previous studies, dissatisfied patients had frequently