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# Does Comorbid Obesity Impact Quality of Life Outcomes in Patients Undergoing Endoscopic Sinus Surgery?

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## Abstract

**Background—**Both obesity and chronic rhinosinusitis (CRS) are characterized by inflammation. Furthermore, both disease processes are independently associated with decreases in quality-of-life (QOL). We sought to investigate the role of comorbid obesity in QOL outcomes in CRS patients undergoing endoscopic sinus surgery (ESS).

**Methods—**Adult patients with medically refractory CRS (n=241) were prospectively enrolled into a multi-institutional treatment outcomes investigation. Body mass index (BMI) calculations were used to differentiate patient weight groups (normal weight: 18.5–24.9, overweight: 25.0–29.9; and obese: ≥30.0). Preoperative and postoperative QOL (Rhinosinusitis Disability Index (RSDI) and the 22-item Sinonasal Outcome Test (SNOT-22)) were evaluated compared across BMI groups and obesity subclasses.

**Results—**The prevalence of comorbid obesity was 41% (n=99). Higher prevalence of comorbid disease was found across increasing BMI groups including diabetes mellitus, asthma, and depression. No significant differences were found in mean preoperative QOL measures between any BMI groups. Significant improvement between preoperative and postoperative QOL mean scores ($p \leq 0.050$) was found for all BMI groups. Despite no significant difference in mean QOL improvement between BMI groups ($p \geq 0.142$), overweight and obese patients reported reduced relative mean percentage (%) improvement compared to normal weight participants on the RSDI

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total score (33% and 37% vs. 55%, respectively) and SNOT-22 total score (29% and 40% vs. 48%, respectively).

**Conclusions—**Patients with comorbid obesity experience significant improvement in average QOL gains following ESS though the percentage of relative improvement in QOL may be decreased in patients with comorbid obesity and CRS as compared to those without.

### MeSH Key Words

Sinusitis; endoscopy; chronic disease; quality of life; obesity; overweight; body mass index

## INTRODUCTION

The World Health Organization defines obesity as an abnormal or excessive accumulation of fat that leads to negative health consequences.[1] Regardless of age, race, sex, and socioeconomic status, the prevalence of obesity is increasing in the United States.[2] Over 30% of Americans are obese and more than two-thirds are overweight.[3] While the numbers in the United States may be staggering, the prevalence of obesity is increasing in nearly every country with reported data.[4] Well-documented health risks directly related to obesity include chronic kidney disease, osteoarthritis, diabetes, sleep apnea, nonalcoholic fatty liver disease, hypertension and cardiovascular disease. Obesity also leads to a greater degree of functional impairment, reduced quality of life[5,6] and increased mortality.[7]

Recent evidence suggests adipose tissue acts as an endocrine organ capable of contributing to and maintaining metabolic and inflammatory pathways.[8] Obesity is characterized by a low-grade systemic inflammation induced by different inflammatory mediators such as IL-6, TNF-alpha, IL-1, and adipokines.[8,9] The association between chronic rhinosinusitis (CRS) and obesity has garnered recent attention. Bhattacharyya demonstrated that increasing body mass index (BMI) was significantly associated with the presence of both allergic rhinitis and CRS.[10] Chung et al. established obesity as one of the most common comorbidities for subjects with CRS, surpassing other common CRS comorbidities such as migraine and depression.[11] Although it is unclear whether a true causal relationship exists between obesity and CRS, both share a predisposition to chronic inflammation.

Based on evidence that implicates obesity as a hyper-inflammatory state, we hypothesized that patients with increasing BMI would demonstrate increased disease severity measures at baseline. Furthermore, we hypothesized that patients in the overweight and obese groups would demonstrate less postoperative improvement in disease specific and general quality of life measures following endoscopic sinus surgery (ESS).

## MATERIALS and METHODS

### Inclusion criteria and study population

Adult patients (≥18 years) were recruited from Oregon Health & Science University (OHSU, Portland, OR) and the Medical University of South Carolina (MUSC, Charleston, SC) as part of a multi-site, observational, prospective investigation to evaluate treatment outcomes following ESS. All patients were diagnosed with CRS following criteria currently

endorsed by both The European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS2012) and the American Academy of Otolaryngology[12,13] and self-selected ESS as the next treatment option. All patients had previously taken medical therapies including at least one course (≥14-days) of broad spectrum or culture-directed antibiotics and at least one trial of topical corticosteroids (≥21-days) or a 5-day course of oral corticosteroids.

Enrolled study participants provided informed consent in English and agreed to complete all study-related evaluations. Participants were asked to provide medical history, social history, and personal demographic information. Study involvement was completely voluntary and standard of care was not altered during the study duration. The Institutional Review Boards(IRB) at OHSU (eIRB #7198) and MUSC (IRB #12409) granted study approval and annual review of safety protocols and enrollment progression. Consenting participants were followed for a total of 18-months postoperatively with follow-up assessments 6-month intervals either during routine, physician-directed clinical appointments or via follow-up mailings. Concurrent follow-up clinical examinations were also collected at 6-month intervals when feasible. Previous results from this investigation have been published.[14–18]

## Clinical measures of disease severity

Clinical measures of disease severity, collected during preoperative evaluations, were used simultaneously for investigational purposes. The paranasal sinuses were evaluated bilaterally using fiberoptic endoscopes (SCB Xenon 175, Karl Storz, Tuttlingen, Germany) and endosopic exams were staged by the enrolling physician at each site (RJS, ZMS, TLS) using the bilateral Lund-Kennedy scoring system (score range: 0–20) which quantifies pathologic states within the paranasal sinuses using a Likert scale.[19] Endoscopic examinations were collected during concurrent 6-month intervals during standard clinic follow-up visitations.

High resolution computed tomography (CT) with bone and tissue windows was utilized to evaluate preoperative sinonasal disease severity using 1.0*mm* contiguous images. Images were staged by the enrolling physician in accordance with the Lund-Mackay bilateral scoring system (score range: 0–24) which quantifies the severity of image opacification using a Likert scale.[20] Postoperative CT evaluations were not collected due to risks associated with elevated radiation exposure and divergence from the standard of care. Higher scores on both staging systems reflect worse disease severity.

Olfactory function was evaluated using the Brief Smell Identification Test (BSIT) screening tool during QOL survey evaluations. The BSIT is a validated 12-item, non-invasive test of olfactory function that uses microencapsulated odorant strips in a ‘scratch ‘n sniff’ format.[21] Participants are instructed to identify each odorant using a method of ‘forced choice’ (score range: 0–12). Higher total scores represent better olfactory status whereas both male and females can be categorized as having “normal” (score ≥9) or “abnormal” olfactory function.

## Disease-specific quality of life measures

Study participants completed two QOL surveys during both preoperative evaluation and at all subsequent follow-up time points. The Rhinosinusitis Disability Index (RSDI) is a 30-

item survey instrument comprised of 3 subdomains to assess the impacts of CRS on a participants physical, functional, and emotional status.[22] Higher subdomain and total RSDI scores (score range: 0–120) represent worse QOL and greater impact of CRS on patients' daily function. The 22-item Sinonasal Outcome Test (SNOT-22) is a validated survey developed to evaluate symptom severity in rhinosinusitis (©2006, Washington University, St. Louis, MO).[23,24] Previous exploratory factor analysis of SNOT-22 scores using this cohort identified 5 distinct subdomains.[18] Subdomains include rhinologic symptoms, extra-nasal rhinologic symptoms, ear and/or facial symptoms, psychological dysfunction, and sleep dysfunction. Higher subdomain and SNOT-22 scores (score range: 0–110) represent worse QOL and symptom severity. Enrolling physicians were blinded to all survey responses during the study duration.

## Surgical intervention

Surgery consisted of either unilateral or bilateral maxillary antrostomy, partial or total ethmoidectomy, sphenoidotomy, middle turbinate resection or inferior turbinate reduction, septoplasty, or frontal sinusotomy (*Draf* I, IIa, IIb, or III) and involved judicious use of image guidance. Study participants were either primary or revision surgery cases. The approach to endoscopic sinus surgery was contingent upon and directed by intraoperative physician's discretion on a case-by-case basis.

## Body Mass Index

Study participants undergoing surgical management of chronic sinusitis were considered for cohort inclusions if they had height (inches (in.)) and weight (pounds (lb.)) measurements on the day of surgery as part of the peri-operative standard of care. Body Mass Index (BMI) was calculated for each patient using the standard formula: BMI = (weight (lb.) × 703) / (height (in.)$^2$). Participants were then categorized into conventionally defined adult groups using the International Classification of Diseases (9$^{th}$ edition; ICD-9) including: normal weight (BMI: 18.5–24.9), overweight (BMI: 25.0–29.9; ICD-9: 278.02), and obese (BMI: ≥ 30.0). Participants categorized as obese were further divided into *Class I* (BMI: 30.0–34.9; ICD-9: 278.0), *Class II* (BMI: 35.0–39.9; ICD-9: 278.0), and *Class III* (BMI: ≥ 40.0; ICD-9: 278.01) and evaluated for subclass differences.[1]

## Exclusion Criteria

Patients with exacerbations of recurrent acute rhinosinusitis and either comorbid sarcoidosis[25] or ciliary dyskinesia[26] / cystic fibrosis were excluded due to possible variations in treatment and potential associations with BMI measures. Additional subjects were excluded if they had not yet entered the initial follow-up period (≤6-months) or were categorized as underweight with a BMI less than 18.5. Any participants who failed to provide any study-related evaluations within the 18-months after ESS were considered lost to follow-up.

## Data management and statistical analyses

Statistical analyses were completed using SPSS v.22 software (IBM Corp., Armonk, NY). All data was de-identified and manually entered into a relational database (Microsoft

Access; Microsoft Corp., Redmond, WA). Baseline study population characteristics, clinical measures of disease severity, disease-specific quality of life scores, and measures of surgical extent were descriptively evaluated across BMI categories and obese subclasses. Primary outcomes of interest included mean postoperative improvements in endoscopy, BSIT, RSDI, and SNOT-22 scores operationalized by subtracting last available score from preoperative scores. Last available RSDI and SNOT-22 scores were used due to historical consistency between 6, 12, and 18 month follow-up.[27,28] Significant improvement over time was evaluated using either matched pairing t-tests or Wilcoxon signed rank testing. Two-sided Pearson's chi-square ($\chi^2$) and Fishers exact testing were used to compare all prevalence measures across BMI categories and obese subclasses using either 2×2 or 2 × 3 omnibus contingency tables when appropriate. Pearson's correlation coefficients ($R_p$) were used to evaluate linear associations between BMI and all QOL measures. Differences between BMI categories were evaluated using Kruskall-Wallis or analysis of variance (ANOVA) omnibus test statistics with adjustments for multiple comparisons. All comparisons were reported with Type I error probability determined at the 0.050 level for significant differences. Potential variation in baseline QOL status was considered further when evaluating postoperative improvements by calculating the mean percentages (%) of absolute relative improvement in QOL outcomes determined for each participant using the algorithm: [(mean preoperative score − mean postoperative score) / mean preoperative score] × 100.

## RESULTS

### Preoperative characteristics

A total of 290 study participants were enrolled between March, 2011 and July, 2014. 241 participants were selected for final analyses, after exclusion of patients without peri-operative height and weight measurements (n=9), sarcoidosis (n=2), ciliary dyskinesia / cystic fibrosis (n=9), recurrent acute rhinosinusitis (n=27), and a BMI of less than 18.5 (n=2). The final study cohort consisted of 66 participants with normal weight (27%), 76 participants categorized as overweight (32%), and 99 participants defined as obese (41%). Normal weight, overweight, and obese subgroups were found to have statistically similar frequencies ($\chi^2$=1.89, p=0.389) of postoperative follow-up (80%, 80%, and 73%). Comparisons of participant characteristics and preoperative clinical measures of disease severity across BMI subgroups are described in Table 1.

Compared to either overweight or obese participants, patients with normal weight were found to be significantly younger in average age (p≤0.001) after adjustments for multiple comparisons while obese participants were found to provide fewer mean postoperative months of follow-up (p=0.042) compared to normal and overweight patients. A significantly higher proportion of obese participants were found to be male compared to normal weight participants ($\chi^2$=6.17; p=0.013). Likewise, a higher prevalence of African Americans were categorized as obese compared to both normal weight ($\chi^2$=5.24; p=0.022) and overweight ($\chi^2$=6.63; p=0.010) patients. No significant differences in mean CT score or BSIT olfactory function scores were noted, however average endoscopy scores were significantly higher in obese (p=0.007) and overweight (p=0.019) subgroups as compared to normal weight participants.

Comparing overweight and obese patients (n=175) with normal weight patients (n=66) found patients within the overweight/obese group to be significantly older on average (54.2[14.3] vs 47.0[17.2] years, respectively; p=0.001), were more predominantly male (47% vs. 65.2%; p=0.014), had a higher prevalence of both revision ESS (53% vs. 39%; p=0.068) and nasal polyposis (39% vs 27%; p=0.080). Overweight and obese patients reported a lower prevalence of alcohol consumption compared to normal weight participants (46% vs 61%; p=0.047) and significantly worse average endoscopy scores (6.8[3.6] vs 5.1[3.7]; p=0.001).

Obese study participants were further categorized into subclasses and evaluated across all cohort characteristics and preoperative clinical measures of disease severity. Participants with *Class I* (n=58), *Class II* (n=24), and *Class III* (n=17) obesity were found to have mean BMI measures of 32.1[1.5], 37.4[1.4], and 45.8[5.5], respectively. There was a significantly higher prevalence of males in the *Class I* obese subgroup compared to *Class II* (67% vs. 42%, respectively, $\chi^2$=4.62; p=0.032) and *Class III* subgroup (67% vs. 29%, respectively, $\chi^2$=7.76; p=0.005). Participants in the *Class III* obese subgroup were found to have a higher prevalence of a history of allergies (n=7; 41%) compared to both *Class I* (n=8; 14%; $\chi^2$=6.16; p=0.013) and *Class II* (n=3, 13%; p=0.063). Participants in the *Class I* obese subgroup also reported a higher prevalence of alcohol use (n=31; 53%) compared to the *Class II* (n=5; 21%; $\chi^2$=7.33; p=0.007) subgroup. Participants in the *Class I* obese subgroup were found to have significantly worse preoperative endoscopy scores (7.8[3.9]) compared to the *Class II* (6.0[2.8]; p=0.046) and *Class III* (4.8[2.6]; p=0.004). Similarly, participants in the *Class I* obese subgroups had worse preoperative CT scores (13.5[6.7]) compared to both *Class II* (10.8[5.1]; p=0.059) and *Class III* (9.7[4.3]; p=0.021).

## Preoperative quality of life measures

No significant differences were found in average preoperative QOL measures between any BMI subgroups as measured by the RSDI or SNOT-22 survey total scores or subdomains scores (p≥0.067; Table 2). Comparing overweight and obese patients (n=175) with normal weight patients (n=66) found patients in the overweight and obese group to report significantly worse SNOT-22 rhinologic domain scores (16.8[6.5] vs. 14.6[6.6] p=0.020). All other mean preoperative QOL scores were similar between weight groups.

Study participants in the *Class II* obese subclasses were found to have significantly worse preoperative QOL compared to the Class I subgroup as measured by the RSDI total mean score (57.5[28.3] vs. 42.9[21.2]; p=0.023), RSDI functional subdomain (18.8[9.4] vs. 13.4[8.0]; p=0.014) scores, and RSDI emotional subdomain (17.4[11.2] vs. 11.5[7.3]; p=0.022) scores. No further difference between any obese subclass was found for any of the preoperative SNOT-22 total or subdomain scores.

## Endoscopic sinus surgery procedures

The frequency of endoscopic sinus surgery procedures was found to be similar between BMI subgroups for most procedural categories (Table 3). Exceptions were found for the use of image guidance with a significantly higher percentage of obese ($\chi^2$=6.51; p=0.011) and overweight ($\chi^2$=6.60; p=0.010) participants having image guidance used during ESS

compared to normal weight patients. Participants categorized as obese ($\chi^2$=6.47; p=0.011) and overweight ($\chi^2$=5.63; p=0.018) had significantly less overall sides undergoing partial ethmoidectomy compared to normal weight participants. Similarly, overweight participants were found to have a significantly higher percentage of overall sides requiring both total ethmoidectomy ($\chi^2$=8.17; p=0.004) and sphenoidotomy ($\chi^2$=4.93; p=0.026) compared to normal participants. The frequency of bilateral procedures was found to be similar between obese subclasses.

## Postoperative quality of life improvements

A total of 186 participants (77%) completed at least 6-month follow-up QOL evaluations with similar prevalence (p=0.389) of follow-up between BMI subgroups categorized as normal weight (n=53; 80%), overweight (n=61; 80%), and obese (n=72; 73%). Significant improvement over time between preoperative mean scores and postoperative mean scores (p≤0.050) was found for all weight groups for all quality of life measures (Table 4). Obese participants improved, on average, to a slightly lesser magnitude compared to normal weight or overweight participants, however the magnitude of average improvement was statistically similar between all three BMI subgroups (p≥0.142). Comparing patients in overweight and obese subgroups (n=133) with normal weight patients (n=53) with follow-up found no additional significant differences between groups for any mean QOL scores improvements (p≥0.256).

The 72 participants (73%) categorized as obese completed at least 6-month follow-up QOL evaluations with similar prevalence (p=0.718) of follow-up between *Class I* (n=41; 71%), *Class II* (n=19; 79%), and *Class III* (n=12; 71%). Trends similar to Table 4 were found across obese subgroups with no statistical differences in the magnitude of average improvements between *Class I*, *Class II*, and *Class III* participants (p≥0.125) for any QOL measure. Likely due to insufficient sample size, statistically significant postoperative improvement over time was not identified for *Class II* obese patients (n=19) for the RSDI emotional subdomain (−3.2[8.1]; p=0.081). Likewise, significant improvement was not reported by *Class III* obese patients (n=12) for the RSDI emotional subdomain (−7.8[8.2]; p=0.054) and the sleep dysfunction domain (−3.7[6.0]; p=0.056) of the SNOT-22.

The prevalence of relative postoperative improvement for each BMI subgroup is delineated in Table 5A–B. Participants classified as obese were found to have a lesser magnitude of overall mean relative improvement across most QOL measures, compared to normal weight and overweight participants, however those differences were not statistically significant. Interestingly, the group of study participants with follow-up who were categorized as obese *Class III* (n=12) reported the greatest percentage of relative improvement on all RSDI total and subdomain scores after ESS of any BMI group or obese subclass. Similar trends were found when comparing normal weight participants (n=53) to overweight and obese subjects (n=133) as denoted in Table 6.

## Postoperative improvement in disease severity measures

All three BMI subgroups were found to have significant improvement (p≤0.001) in postoperative endoscopy scores over time and with similar average magnitudes (Table 7).

Mean BSIT scores were not found to improve significantly over time for any BMI subgroup ($p \geq 0.187$). Relative improvements in endoscopy scores were greater for obese participants (53%) compared to overweight (43%) and normal weight (38%) participants. Relative improvements in BSIT scores were minimal for all BMI subgroups (range: −1% to 4%).

Similar trends were found between obese sub-classifications. *Class I* participants were found to have significant improvement in endoscopy exam scores (−4.4[4.3]; $p<0.001$; 50.4%) compared to *Class II* (−5.7[3.7]; p=0.017; 71.0%) and *Class III* (−1.9[1.8]; p=0.041; 58.6%), though no significant differences in mean endoscopy score improvement were found between subclasses (p=0.119). The difference in magnitude in endoscopy score improvements between obese subclasses were statistically similar ($p \geq 0.272$). Mean BSIT scores were not found to improve significantly over time for any of the three obese subclasses ($p \geq 0.165$).

## DISCUSSION

Obesity is associated with an increased risk of a variety of comorbidities including cardiovascular disease, diabetes, and asthma.[7] BMI is inversely correlated with QOL with increasing BMI associated with reductions in both the quality and quantity of life.[7] Similar comorbidities have been associated with chronic rhinosinusitis, and patients with CRS have higher levels of comorbid asthma, GERD, migraine, and mental illness.[11,17,29,30] We sought to describe baseline characteristics of patients with CRS and comorbid obesity and examine the influence of obesity on QOL outcomes in patients with CRS electing to undergo ESS.

Clinical measures of disease status including Lund-McKay CT score and BSIT were not significantly different between normal weight, overweight, and obese groups either pre-operatively or postoperatively. Interestingly, olfactory sensitivity may be affected by BMI[31], though no difference was seen between groups in the current study. Baseline endoscopy scores were found to be significantly higher in obese and overweight subgroups as compared to normal weight patients and may be a reflection of differential rates of revision and nasal polyposis. Patients with and without comorbid obesity exhibited significant improvements in endoscopy scores over time, though there was no difference between the two groups in the degree of improvement. Postoperatively, each treatment group exhibited significant improvement in each QOL construct; however, on average overweight and obese participants reported less relative percent improvement compared to normal weight participants on the RSDI total score (33% and 37% vs. 55%, respectively) and SNOT-22 total scores (29% and 40% vs. 48%, respectively) though these differences were not statistically significant nor were subgroup analyses within obese participants. Relative percentage of improvement was chosen as a supplemental measure as it may best describe the true reflection of postoperative improvement relative to preoperative symptom severity.[32,33]

Patients with CRS and comorbid obesity were found to have a higher prevalence of comorbid diabetes, asthma, and depression, though these differences did not all reach statistical significance at the 0.050 alpha level. These associations were anticipated, as there is substantial data linking obesity to these chronic diseases. The long-term risk of type II

diabetes increases significantly with increasing weight,[34] and weight loss is associated with a reduction in the risk of diabetes and improved diabetes control.[35,36] Literature also supports the association between obesity and depression, though the link between the two is more complex. Several authors have reported that depression is more likely to increase the risk of subsequent obesity rather than the contrary.[37–39] Increasing epidemiological data identify a link between obesity and asthma incidence, severity, and response to treatment.[40,41] Obese asthmatics have been shown to utilize greater healthcare resources including more frequent emergency room visits and more prescribed asthma medications.[42,43] The pathophysiologic mechanism by which asthma severity is increased is still under investigation; however authors have proposed that increased levels of pro-inflammatory adipokines may modulate airway reactivity.[44]

Recent advances in understanding of allergic rhinitis, CRS, and asthma suggest that the upper and lower airways function as one system[45,46]. Given the link between asthma and CRS, the mechanisms by which obesity increases prevalence, severity, and response to treatment in asthmatic patients could produce similar affects in the CRS population. In the current study, over 41% of patients with CRS were found to have comorbid obesity which surpasses both statewide and national obesity rates (Oregon-26%, South Carolina-31%, United States-34%).[3,47] This is consistent with previously reported data in which obesity has been significantly associated with CRS.[10] Contrary to our initial hypothesis, preoperative disease-specific QOL measures were not significantly different between BMI groups. However, relative improvement was diminished in obese patients when compared to normal weight patients, although this difference did not reach statistical significance. Given the large effect size of ESS on QOL, the influence of this comorbidity may be difficult to detect. One possible consideration of diminished improvement could be secondary to higher rates of comorbid disease (e.g., diabetes mellitus, obstructive sleep apnea). Subset analysis, however, demonstrates that all of the domains of the SNOT-22 are impacted to a similar degree including a greater severity of rhinologic symptoms within the overweight and obese group, suggesting that there may be some validity to an increased systemic pro-inflammatory milieu. From a clinical standpoint, these differences may not influence treatment decision-making, however from an epidemiology stand point, it should not be surprising that the differences would be small, considering all patients were required to have CRS by definition with sufficient disease severity to warrant surgery. Whether or not the low grade inflammation associated with obesity contributes to increased inflammation in the sinonasal passages is unclear, but the data presented above suggest that increasing weight/BMI may play a role in disease-specific outcomes following ESS. Additional study, using much larger sample sizes, will be necessary to understand whether a true association is present and if so, its ramifications.

There are several limitations to consider when interpreting results of the current study. BMI, as a viable measure of obesity, has several inherent confines. BMI cannot account for the potential wide variation in the nature of obesity between individuals and critics of BMI suggest that it fails to accurately quantify body composition.[48] We have used BMI within this study as a general mechanism to identify individuals within a specific population who are at risk of increasing morbidity. It may be possible that increased sample size would increase power to detect significant differences between BMI subgroups and QOL

improvement scores. However, selecting a meaningful clinical difference for a power calculation would be unusually arbitrary as there is no historical standard or comparison for QOL in patients with CRS and comorbid obesity across BMI subgroups. This first publication of these data will inform future investigations and sample size/power calculations. Additionally, the current study population was limited to patients with refractory CRS recruited from tertiary rhinology centers and may not be generalizable to those who have less severe disease. Due to the lack of consistent and robust significant associations between BMI measures and primary QOL outcome measures, we opted not to further identify and control for potential confounding factors, such as extent of surgery, using multivariate analysis. This is another potential limitation of the current study and should be considered in future analysis if a true association between BMI and QOL can be clearly identified.

## CONCLUSION

Both obesity and CRS are characterized in part by chronic inflammation and are associated with concurrent conditions marked by chronic inflammation such as allergic rhinitis and asthma. Regardless, patients with CRS and comorbid obesity experience significant QOL gains following ESS; however, relative improvement across QOL domains decreases with increasing BMI levels. Further investigation into the impact of BMI on sinonasal inflammation in CRS and QOL is warranted.

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## REFERENCES

1. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization technical report series. 2000; 894:i–xii. 1–253. [PubMed: 11234459]
2. McAllister EJ, Dhurandhar NV, Keith SW, et al. Ten putative contributors to the obesity epidemic. Crit Rev Food Sci Nutr. 2009; 49(10):868–913. [PubMed: 19960394]
3. Ogden CL, Carroll MD, Flegal KM. Prevalence of obesity in the United States. Jama. 2014; 312(2): 189–190. [PubMed: 25005661]
4. Caballero B. The global epidemic of obesity: an overview. Epidemiol Rev. 2007; 29:1–5. [PubMed: 17569676]
5. Kushner RF, Foster GD. Obesity and quality of life. Nutrition. 2000; 16(10):947–952. [PubMed: 11054600]
6. Mannucci E, Petroni ML, Villanova N, Rotella CM, Apolone G, Marchesini G. Clinical and psychological correlates of health-related quality of life in obese patients. Health Qual Life Outcomes. 2010; 8:90. [PubMed: 20731871]

7. Allison DB, Downey M, Atkinson RL, et al. Obesity as a disease: a white paper on evidence and arguments commissioned by the Council of the Obesity Society. Obesity. 2008; 16(6):1161–1177. [PubMed: 18464753]
8. Balistreri CR, Caruso C, Candore G. The role of adipose tissue and adipokines in obesity-related inflammatory diseases. Mediators Inflamm. 2010; 2010:802078. [PubMed: 20671929]
9. Hotamisligil GS, Shargill NS, Spiegelman BM. Adipose expression of tumor necrosis factor-alpha: direct role in obesity-linked insulin resistance. Science. 1993; 259(5091):87–91. [PubMed: 7678183]
10. Bhattacharyya N. Associations between obesity and inflammatory sinonasal disorders. Laryngoscope. 2013; 123(8):1840–1844. [PubMed: 23401212]
11. Chung SD, Chen PY, Lin HC, Hung SH. Comorbidity profile of chronic rhinosinusitis: a population-based study. Laryngoscope. 2014; 124(7):1536–1541. [PubMed: 24395611]
12. Fokkens WJ, Lund VJ, Mullol J, et al. European Position Paper on Rhinosinusitis and Nasal Polyps 2012. Rhinol Suppl. 2012; (23):1–298.
13. Rosenfeld RM, Andes D, Bhattacharyya N, et al. Clinical practice guideline: adult sinusitis. Otolaryngol Head Neck Surg. 2007; 137(3 Suppl):S1–S31. [PubMed: 17761281]
14. Alt JA, Smith TL, Mace JC, Soler ZM. Sleep quality and disease severity in patients with chronic rhinosinusitis. Laryngoscope. 2013; 123(10):2364–2370. [PubMed: 23918740]
15. Alt JA, Smith TL, Schlosser RJ, Mace JC, Soler ZM. Sleep and quality of life improvements after endoscopic sinus surgery in patients with chronic rhinosinusitis. Int Forum Allergy Rhinol. 2014; 4(9):693–701. [PubMed: 25079334]
16. DeConde AS, Mace JC, Alt JA, Schlosser RJ, Smith TL, Soler ZM. Comparative effectiveness of medical and surgical therapy on olfaction in chronic rhinosinusitis: a prospective, multi-institutional study. Int Forum Allergy Rhinol. 2014; 4(9):725–733. [PubMed: 25044658]
17. DeConde AS, Mace JC, Smith TL. The impact of comorbid gastroesophageal reflux disease on endoscopic sinus surgery quality-of-life outcomes. Int Forum Allergy Rhinol. 2014; 4(8):663–669. [PubMed: 24723428]
18. DeConde AS, Bodner TE, Mace JC, Smith TL. Response shift in quality of life after endoscopic sinus surgery for chronic rhinosinusitis. JAMA Otolaryngol Head Neck Surg. 2014; 140(8):712–719. [PubMed: 25074504]
19. Lund VJ, Kennedy DW. Staging for rhinosinusitis. Otolaryngol Head Neck Surg. 1997; 117(3 Pt 2):S35–S40. [PubMed: 9334786]
20. Lund VJ, Mackay IS. Staging in rhinosinusitus. Rhinology. 1993; 31(4):183–184. [PubMed: 8140385]
21. Doty RL, Mishra A. Olfaction and its alteration by nasal obstruction, rhinitis, and rhinosinusitis. Laryngoscope. 2001; 111(3):409–423. [PubMed: 11224769]
22. Benninger MS, Senior BA. The development of the Rhinosinusitis Disability Index. Arch Otolaryngol Head Neck Surg. 1997; 123(11):1175–1179. [PubMed: 9366696]
23. Hopkins C, Gillett S, Slack R, Lund VJ, Browne JP. Psychometric validity of the 22-item Sinonasal Outcome Test. Clin Otolaryngol. 2009; 34(5):447–454. [PubMed: 19793277]
24. Piccirillo JF, Merritt MG Jr, Richards ML. Psychometric and clinimetric validity of the 20-Item Sino-Nasal Outcome Test (SNOT-20). Otolaryngol Head Neck Surg. 2002; 126(1):41–47. [PubMed: 11821764]
25. Gvozdenovic BS, Mihailovic-Vucinic V, Vukovic M, et al. Effect of obesity on patient-reported outcomes in sarcoidosis. Int J Tuberc Lung Dis. 2013; 17(4):559–564. [PubMed: 23485390]
26. Mok CA, Heon E, Zhen M. Ciliary dysfunction and obesity. Clin Genet. 2010; 77(1):18–27. [PubMed: 19968672]
27. DeConde AS, Mace JC, Alt JA, Rudmik L, Soler ZM, Smith TL. Longitudinal improvement and stability of the SNOT-22 survey in the evaluation of surgical management for chronic rhinosinusitis. Int Forum Allergy Rhinol. 2015; 5(3):233–239. [PubMed: 25511442]
28. Soler ZM, Smith TL. Quality-of-life outcomes after endoscopic sinus surgery: how long is long enough? Otolaryngol Head Neck Surg. 2010; 143(5):621–625. [PubMed: 20974329]

29. DeConde AS, Mace JC, Smith TL. The impact of comorbid migraine on quality-of-life outcomes after endoscopic sinus surgery. Laryngoscope. 2014; 124(8):1750–1755. [PubMed: 24431279]
30. Mace J, Michael YL, Carlson NE, Litvack JR, Smith TL. Effects of depression on quality of life improvement after endoscopic sinus surgery. Laryngoscope. 2008; 118(3):528–534. [PubMed: 18043488]
31. Skrandies W, Zschieschang R. Olfactory and gustatory functions and its relation to body weight. Physiol Behav. 2015; 142:1–4. [PubMed: 25619950]
32. Rudmik L, Soler ZM, Mace JC, DeConde AS, Schlosser RJ, Smith TL. Using preoperative SNOT-22 score to inform patient decision for endoscopic sinus surgery. Laryngoscope. 2015 [Epub ahead of print].
33. Stewart MG, Donovan DT, Parke RB Jr, Bautista MH. Does the severity of sinus computed tomography findings predict outcome in chronic sinusitis? Otolaryngol Head Neck Surg. 2000; 123(1 Pt 1):81–84. [PubMed: 10889486]
34. Pi-Sunyer X. The Medical Risks of Obesity. Postgrad Med. 2009; 121(6):21–33. [PubMed: 19940414]
35. Pi-Sunyer X. The Look AHEAD Trial: A Review and Discussion Of Its Outcomes. Curr Nutr Rep. 2014; 3(4):387–391. [PubMed: 25729633]
36. Wannamethee S, Shaper A, Walker M. Overweight and obesity and weight change in middle aged men: impact on cardiovascular disease and diabetes. J Epidemiol Community Health. 2005; 59(2): 134–139. [PubMed: 15650145]
37. Hasler G, Lissek S, Ajdacic V, et al. Major depression predicts an increase in long-term body weight variability in young adults. Obes Res. 2005; 13(11):1991–1998. [PubMed: 16339131]
38. Blane D, Netuveli G, Montgomery SM. Quality of life, health and physiological status and change at older ages. Soc Sci. Med. 2008; 66(7):1579–1587. [PubMed: 18241966]
39. Merikangas AK, Mendola P, Pastor PN, Reuben CA, Cleary SD. The association between major depressive disorder and obesity in US adolescents: results from the 2001–2004 National Health and Nutrition Examination Survey. J Behav Med. 2012; 35(2):149–154. [PubMed: 21479835]
40. Kim SH, Sutherland ER, Gelfand EW. Is there a link between obesity and asthma? Allergy Asthma Immunol Res. 2014; 6(3):189–195. [PubMed: 24843792]
41. Shore SA, Johnston RA. Obesity and asthma. Pharmacol Ther. 2006; 110(1):83–102. [PubMed: 16297979]
42. Luder E, Melnik TA, DiMaio M. Association of being overweight with greater asthma symptoms in inner city black and Hispanic children. J Pediatr. 1998; 132(4):699–703. [PubMed: 9580773]
43. von Mutius E, Schwartz J, Neas LM, Dockery D, Weiss ST. Relation of body mass index to asthma and atopy in children: the National Health and Nutrition Examination Study III. Thorax. 2001; 56(11):835–838. [PubMed: 11641506]
44. Sideleva O, Suratt BT, Black KE, et al. Obesity and asthma: an inflammatory disease of adipose tissue not the airway. Am J Respir Crit Care Med. 2012; 186(7):598–605. [PubMed: 22837379]
45. Krouse JH. The unified airway--conceptual framework. Otolaryngol Clin North Am. 2008; 41(2): 257–266. [PubMed: 18328366]
46. Marple BF. Allergic rhinitis and inflammatory airway disease: interactions within the unified airspace. Am J Rhinol Allergy. 2010; 24(4):249–254. [PubMed: 20819460]
47. Prevalence of Self-Reported Obesity Among U.S. [Accessed March 22, 2015] Adults by State and Territory, BRFSS. 2013. Available at: www.cdc.gov/obesity/data/table-adults.html.
48. Nevill AM, Stewart AD, Olds T, Holder R. Relationship between adiposity and body size reveals limitations of BMI. Am J Phys Anthropol. 2006; 129(1):151–156. [PubMed: 16270304]

**Table 1**

Comparison of cohort characteristics and preoperative clinical measures of disease severity across BMI subgroups

| | Normal weight (BMI: 18.5 – 24.9) | | Overweight (BMI: 25.0 – 29.9) | | Obese (BMI: ≥ 30.0) | | |
|---|---|---|---|---|---|---|---|
| **Characteristics:** | **Mean[SD]** | **N (%)** | **Mean[SD]** | **N (%)** | **Mean[SD]** | **N (%)** | **p-value** |
| Body Mass Index (BMI) | 22.9 [1.5] | | 27.4 [1.5] | | 35.7 [5.7] | | <0.001 |
| Age (years) | 47.0 [17.2] | | 57.0 [14.3] | | 52.0 [14.0] | | 0.001 |
| Follow-up duration (months) | 16.2 [4.3] | | 15.9 [5.1] | | 14.0 [4.9] | | 0.023 |
| White / Caucasian | | 61 (92%) | | 68 (90%) | | 82 (83%) | 0.156 |
| African American | | 3 (5%) | | 3 (4%) | | 16 (16%) | 0.007 |
| Hispanic / Latino | | 3 (5%) | | 1 (1%) | | 1 (1%) | 0.253 |
| Male | | 23 (35%) | | 38 (50%) | | 54 (55%) | ---- |
| Female | | 43 (65%) | | 38 (50%) | | 45 (46%) | 0.041 |
| Previous sinus surgery | | 26 (39%) | | 41 (54%) | | 51 (52%) | 0.180 |
| Nasal polyposis | | 18 (27%) | | 30 (40%) | | 39 (39%) | 0.215 |
| Septal deviation | | 25 (38%) | | 23 (30%) | | 37 (37%) | 0.542 |
| Turbinate hypertrophy | | 8 (12%) | | 11 (15%) | | 10 (10%) | 0.678 |
| Diabetes Mellitus (Type I or II) | | 2 (3%) | | 7 (9%) | | 11 (11%) | 0.172 |
| Asthma | | 18 (27%) | | 26 (34%) | | 36 (36%) | 0.466 |
| Aspirin intolerance | | 2 (3%) | | 7 (9%) | | 9 (9%) | 0.274 |
| Allergies (history) | | 12 (18%) | | 15 (20%) | | 18 (18%) | 0.956 |
| Allergies (mRAST confirmed) | | 26 (39%) | | 31 (41%) | | 41 (41%) | 0.967 |
| Depression | | 8 (12%) | | 13 (17%) | | 18 (18%) | 0.565 |
| Current tobacco use | | 6 (9%) | | 2 (3%) | | 11 (11%) | 0.109 |
| Alcohol use | | 40 (61%) | | 40 (53%) | | 41 (41%) | 0.047 |
| **Clinical measures of disease severity:** | | | | | | | |
| Endoscopy score | 5.1 [3.7] | | 6.8 [3.5] | | 6.9 [3.6] | | 0.005 |
| Computed tomography (CT) score | 11.4 [6.0] | | 13.2 [5.8] | | 12.2 [6.1] | | 0.240 |
| BSIT Olfactory function score | 9.1 [3.0] | | 8.6[3.1] | | 9.0[2.9] | | 0.540 |

BMI, Body mass index; SD, standard deviation; mRAST, modified radioallergosorbent testing; BSIT, Brief smell identification test. Reported p-values represent preliminary omnibus comparison test results using either ANOVA for continuous variables or $\chi^2$ omnibus test statistics for prevalence measures. Bivariate comparisons are further described throughout manuscript.

**Table 2**

Comparison of average preoperative quality of life measures across BMI subgroups

| | Normal weight (BMI: 18.5 – 24.9) | Overweight (BMI: 25.0 – 29.9) | Obese (BMI: > 30.0) | | |
|---|---|---|---|---|---|
| **Quality of life measures:** | **Mean [SD]** | **Mean [SD]** | **Mean [SD]** | **F-test** | **p-value** |
| RSDI total score | 45.6 [25.8] | 51.9 [23.5] | 47.6 [25.2] | 1.22 | 0.298 |
| Physical subdomain | 18.3 [9.6] | 21.5 [8.4] | 19.1 [9.1] | 2.41 | 0.092 |
| Functional subdomain | 14.4 [9.1] | 16.7 [8.5] | 15.2 [8.8] | 1.26 | 0.284 |
| Emotional subdomain | 12.9 [9.3] | 13.8 [8.9] | 13.3 [9.6] | 0.15 | 0.861 |
| SNOT-22 total score | 50.6 [20.6] | 57.3 [21.0] | 54.9 [21.2] | 1.84 | 0.161 |
| Rhinologic symptoms | 14.6 [6.6] | 16.8 [6.4] | 16.8 [6.6] | 2.74 | 0.067 |
| Extra-nasal rhinologic symptoms | 8.1 [3.8] | 8.6 [3.8] | 8.4 [3.3] | 0.24 | 0.790 |
| Ear and/or facial symptoms | 8.8 [5.3] | 9.8 [5.5] | 10.0 [5.5] | 1.00 | 0.369 |
| Psychological dysfunction | 15.5 [8.7] | 17.8 [8.2] | 16.6 [8.6] | 0.24 | 0.290 |
| Sleep dysfunction | 13.9 [6.7] | 15.9 [6.7] | 14.1 [7.2] | 2.04 | 0.133 |

BMI, Body mass index; SD, standard deviation; RSDI, Rhinosinusitis Disability Index; SNOT-22, 22-item Sinonasal Outcome Test. Reported p-values for mean value comparisons represent omnibus comparison test results using ANOVA for continuous variables.

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**Table 3**

The prevalence of surgical procedures between BMI subgroups

| | Normal weight (BMI: 18.5 – 24.9) | | Overweight (BMI: 25.0 – 29.9) | | Obese (BMI: > 30.0) | | |
|---|---|---|---|---|---|---|---|
| **Surgical procedures:** | **Left side N (%)** | **Right side N (%)** | **Left side N (%)** | **Right side N (%)** | **Left side N (%)** | **Right side N (%)** | **p-value** |
| Maxillary antrostomy | 56 (85%) | 56 (85%) | 72 (95%) | 67 (88%) | 87 (88%) | 80 (81%) | 0.115 |
| Partial ethmoidectomy | 17 (26%) | 18 (27%) | 11 (15%) | 12 (16%) | 18 (18%) | 12 (12%) | 0.016 |
| Total ethmoidectomy | 42 (64%) | 41 (62%) | 61 (80%) | 58 (76%) | 71 (72%) | 70 (71%) | 0.017 |
| Sphenoidotomy | 42 (6%) | 39 (59%) | 58 (77%) | 54 (71%) | 69 (70%) | 68 (69%) | 0.080 |
| Middle turbinate resection | 10 (15%) | 14 (21%) | 10 (13%) | 12 (16%) | 12 (12%) | 15 (15%) | 0.509 |
| Inferior turbinate reduction | 9 (14%) | 9 (14%) | 14 (18%) | 14 (18%) | 14 (14%) | 12 (12%) | 0.344 |
| Septoplasty | 22 (33%) | | 19 (25%) | | 34 (34%) | | 0.376 |
| Frontal sinusotomy *Draf* I | 8 (12%) | 8 (12%) | 9 (12%) | 9 (12%) | 14 (14%) | 11 (11%) | 0.975 |
| Frontal sinusotomy *Draf* IIa | 20 (30%) | 20 (30%) | 30 (40%) | 27 (36%) | 36 (36%) | 36 (36%) | 0.395 |
| Frontal sinusotomy *Draf* IIb | 7 (11%) | 8 (12%) | 7 (9%) | 10 (13%) | 13 (13%) | 13 (13%) | 0.825 |
| Frontal sinusotomy *Draf* III* | 4 (6%) | | 5 (7%) | | 2 (2%) | | 0.284 |
| Image guidance | 33 (50%) | | 54 (71%) | | 69 (70%) | | 0.013 |

BMI, Body mass index; p-values reflect differences between summarized total (right and left) sides when appropriate.

* indicates bilateral sinusotomy. Reported p-values represent omnibus test results using the $\chi^2$ test for differences in prevalence measures using 2×3 contingency tables.

**Table 4**

Comparison of average postoperative change in quality of life measures across BMI subgroups

| | Normal weight (BMI: 18.5 – 24.9) | Overweight (BMI: 25.0 – 29.9) | Obese (BMI: > 30.0) | | |
|---|---|---|---|---|---|
| **Quality of life measures:** | **Mean [SD]** | **Mean [SD]** | **Mean [SD]** | **F-test** | **p-value** |
| RSDI total score | −23.8 [24.3]* | −25.6 [27.8]* | −18.0 [22.1]* | 1.74 | 0.179 |
| Physical subdomain | −10.1 [9.1]* | −10.7 [11.2]* | −8.4 [8.9]* | 0.99 | 0.373 |
| Functional subdomain | −8.0 [8.9]* | −8.6 [10.2]* | −6.0 [8.2]* | 1.42 | 0.245 |
| Emotional subdomain | −5.7 [9.0]* | −6.3 [8.6]* | −3.5 [8.1]* | 1.98 | 0.142 |
| SNOT-22 total score | −24.2 [20.6]* | −24.5 [26.9]* | −22.1 [20.5]* | 0.23 | 0.792 |
| Rhinologic symptoms | −7.4 [6.6]* | −7.8 [8.0]* | −7.1 [7.8]* | 0.14 | 0.872 |
| Extra-nasal rhinologic symptoms | −4.4 [3.5]* | −3.8 [4.3]* | −3.6 [3.8]* | 0.72 | 0.488 |
| Ear and/or facial symptoms | −4.5 [5.0]* | −4.7 [6.0]* | −4.4 [5.2]* | 0.06 | 0.941 |
| Psychological dysfunction | −6.5 [8.5]* | −6.8 [10.3]* | −6.2 [7.8]* | 0.08 | 0.921 |
| Sleep dysfunction | −6.3 [7.1]* | −6.3 [7.9]* | −5.1 [6.1]* | 0.61 | 0.546 |

BMI, Body mass index; SD, standard deviation; RSDI, Rhinosinusitis Disability Index; SNOT-22, 22-item Sinonasal Outcome Test,

* indicates significant postoperative improvement over time for matched pairings ($p<0.001$) Negative mean scores indicates postoperative improvement over time.

Reported p-values for mean value comparisons represent ANOVA omnibus comparison test results for continuous variables.

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**Table 5**

Comparison of mean percentages of relative improvement in quality of life scores between BMI subgroups and obese subclasses

| A: Quality of life measures: | Normal weight (BMI: 18.5 – 24.9) | Overweight (BMI: 25.0 – 29.9) | Obese (BMI: > 30.0) | F-test | p-value |
|---|---|---|---|---|---|
| RSDI total score | 55% | 33% | 37% | 0.74 | 0.480 |
| Physical subdomain | 59% | 48% | 33% | 1.43 | 0.243 |
| Functional subdomain | 56% | 23% | 19% | 0.59 | 0.555 |
| Emotional subdomain | 35% | 36% | 24% | 0.24 | 0.785 |
| SNOT-22 total score | 48% | 29% | 40% | 1.79 | 0.171 |
| Rhinologic symptoms | 46% | 39% | 32% | 0.86 | 0.424 |
| Extra-nasal rhinologic symptoms | 54% | 38% | 33% | 2.06 | 0.131 |
| Ear and/or facial symptoms | 49% | 31% | 41% | 1.11 | 0.331 |
| Psychological dysfunction | 39% | −17% | 38% | 1.28 | 0.279 |
| Sleep dysfunction | 42% | 14% | 27% | 0.85 | 0.428 |

| B: Quality of life measures: | Obese class I (BMI: 30.3–34.9) | Obese class II (BMI: 35.0–39.9) | Obese class III (BMI: 40.0–49.9) | | |
|---|---|---|---|---|---|
| RSDI total score | 41% | 10% | 67% | 1.84 | 0.167 |
| Physical subdomain | 27% | 29% | 63% | 0.44 | 0.649 |
| Functional subdomain | 44% | −59% | 66% | 1.32 | 0.273 |
| Emotional subdomain | 25% | −1% | 67% | 1.05 | 0.358 |
| SNOT-22 total score | 39% | 42% | 41% | 0.08 | 0.925 |
| Rhinologic symptoms | 35% | 41% | 9% | 1.05 | 0.355 |
| Extra-nasal rhinologic symptoms | 41% | 32% | 11% | 0.74 | 0.483 |
| Ear and/or facial symptoms | 43% | 42% | 33% | 0.21 | 0.812 |
| Psychological dysfunction | 33% | 43% | 45% | 0.32 | 0.731 |
| Sleep dysfunction | 30% | 33% | −3% | 0.89 | 0.416 |

BMI, body mass index; RSDI, Rhinosinusitis Disability Index; SNOT-22, 22-item Sinonasal Outcome Test. Reported p-values for mean value comparisons represent ANOVA omnibus comparison test results. Negative mean percentages indicate worse quality of life scores over time.

## Table 6

Comparison of mean percentages of absolute relative improvement in quality of life scores between normal BMI and overweight and obese subgroups

| A: Quality of life measures: | Normal weight (BMI: 18.5 – 24.9) | Overweight-Obese (BMI: 25.0+) | T-test | p-value |
|---|---|---|---|---|
| RSDI total score | 54% | 35% | 1.20 | 0.233 |
| Physical subdomain | 59% | 40% | 1.36 | 0.175 |
| Functional subdomain | 56% | 21% | 1.08 | 0.280 |
| Emotional subdomain | 35% | 30% | 0.32 | 0.750 |
| SNOT-22 total score | 48% | 35% | 1.48 | 0.141 |
| Rhinologic symptoms | 46% | 35% | 1.13 | 0.262 |
| Extra-nasal rhinologic symptoms | 54% | 35% | 1.99 | 0.048 |
| Ear and/or facial symptoms | 49% | 36% | 1.20 | 0.232 |
| Psychological dysfunction | 39% | 12% | 0.75 | 0.454 |
| Sleep dysfunction | 42% | 21% | 1.14 | 0.257 |

BMI, body mass index; RSDI, Rhinosinusitis Disability Index; SNOT-22, 22-item Sinonasal Outcome Test

## Table 7

Comparison of average postoperative change in clinical measures of disease severity across BMI subgroups

| | **Normal weight (BMI: 18.5 – 24.9)** | **Overweight (BMI: 25.0 – 29.9)** | **Obese (BMI: > 30.0)** | |
|---|---|---|---|---|
| **Clinical measures of disease severity:** | **Mean [SD]** | **Mean [SD]** | **Mean [SD]** | **p-value** |
| Endoscopy score | −2.6 [3.2]* | −3.0 [3.9]* | −4.2 [4.0]* | 0.284 |
| BSIT Olfactory function score | 0.3 [2.3] | 0.5 [2.7] | −0.1 [2.5] | 0.589 |

* indicates significant postoperative improvement over time for matched pairings ($p<0.001$) BMI, Body mass index; SD, standard deviation; BSIT, Brief smell identification test. Negative mean scores indicates postoperative improvement over time. Reported p-values for mean score improvement comparisons represent omnibus comparison test results using Kruskall-Wallis test for nonparametric distributions.