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Influence of Body Weight on Surgical Treatment for Neurogenic Thoracic Outlet Syndrome

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Background: Body weight affects outcomes of surgical treatment for various conditions, but its effects on the treatment of neurogenic thoracic outlet syndrome (NTOS) are unknown. The purpose of this study was to evaluate the influence of body weight on technical and functional outcomes of surgical treatment for NTOS.

Methods: A retrospective review of prospectively collected data was conducted for 265 patients who underwent supraclavicular decompression for NTOS between January 1, 2014 and March 31, 2016. Patients were grouped according to 6 standard body mass index (BMI) categories. The influence of BMI on measures of surgical outcome was analyzed using Pearson correlation statistics, analysis of variance (ANOVA), and multivariate logistic regression.

Results: Mean patient age was 33.3 ± 0.7 years (range, 12−70), and 208 (78%) patients were women. Mean BMI was 27.2 ± 0.4 (range 16.8−49.9), with 7 underweight (3%), 95 normal (36%), 84 overweight (32%), 47 obese-I (18%), 15 obese-II (6%), and 17 obese-III (6%). There was a slight but significant association between BMI and age (Pearson $P < 0.0001$, $r = 0.264$; ANOVA $P = 0.0002$), but no correlations between BMI and other preoperative variables. There were no differences between BMI groups for intraoperative, immediate postoperative, or 3-month outcomes. Multivariate logistic regression demonstrated that BMI had no significant effect on functional outcome as measured by the extent of improvement in Disability of the Arm, Shoulder, and Hand score at 3 months ($P = 0.429$).

Conclusions: There was no substantive influence of BMI on preoperative characteristics or intraoperative, postoperative, or 3-month outcomes for patients with NTOS, and no indication of an "obesity paradox" for this condition. Supraclavicular decompression for NTOS achieves similar outcomes across the BMI spectrum.

INTRODUCTION

The worldwide prevalence of obesity has increased over the past several decades. In the United States, current data indicate that 69% of adults are overweight, with 35% meeting criteria for obesity.[1] These findings have broad implications for medical care given strong associations between obesity and diabetes, hypertension, hyperlipidemia, and other conditions. Increased body weight may also affect the incidence and outcomes of treatment for surgical diseases, by increasing the technical difficulty of abdominal and pelvic operations, elevating the risk of postoperative complications (such as wound infection and dehiscence, pneumonia, obstructive

sleep apnea, and deep vein thrombosis), and prolonging hospital stay, recovery from operation, and functional rehabilitation.[2-12]

The effect of body weight on the conduct and outcomes of surgical treatment has been widely studied, with increased cardiovascular risk observed at higher body mass index (BMI) categories and an increased incidence of cardiovascular complications regardless of other risk factors.[2,13,14] Prospective cohort studies in general surgery have also shown surgical site infections, and postoperative mortality are positively associated with obesity.[3,7-10,12] However, when stratified by body weight category, the lowest risk for postoperative mortality has been among those overweight and in obesity class I, giving rise to the concept of an ''obesity paradox'' in which mild elevations in BMI seem to be protective.[5,11,12]

Neurogenic thoracic outlet syndrome (NTOS) is an uncommon condition caused by dynamic brachial plexus nerve compression within the supraclavicular scalene triangle and/or the subcoracoid (pectoralis minor) space, resulting in positional upper extremity pain, numbness, and paresthesia.[15] NTOS can be particularly disabling because this condition often affects young, active, individuals in the prime working years. The outcomes of surgical treatment for NTOS have been examined with increasing rigor over the past decade, in part to help better identify factors that influence treatment results, but to date, there have been no studies addressing the potential effects of body weight on outcomes of surgical treatment for NTOS.[16-26] The purpose of this study was to evaluate the effect of body weight on intraoperative, technical, postoperative, and functional outcomes following supraclavicular decompression for NTOS at a high-volume academic medical center.

METHODS

Study Population

All subjects in this study gave informed consent for the publication of their medical data, through a protocol approved by the Human Research Protection Office at Washington University, St. Louis, Missouri. The study population consisted of all patients undergoing surgical treatment for NTOS at the Washington University Center for Thoracic Outlet Syndrome at Barnes-Jewish Hospital (St. Louis, MO) from January 1, 2014 to March 31, 2016. Each patient met predefined clinical diagnostic criteria for NTOS.[24,27-29] Indications for surgical treatment included a sound clinical diagnosis,

significantly disabling symptoms, and absence of satisfactory improvement following conservative management with NTOS-specific physical therapy.[15,20-23] All patients underwent supraclavicular scalenectomy, first rib resection, and brachial plexus neurolysis, with concomitant pectoralis minor tenotomy through an additional deltopectoral groove incision, when indicated by physical examination findings, as previously described.[15,20-23] Patients undergoing isolated pectoralis minor tenotomy as surgical treatment for NTOS were excluded from analysis. Data were collected from office notes, hospital records, imaging studies, and records from treating physicians and therapists, including Disability of the Arm, Shoulder, and Hand (DASH) scores to assess functional disability and entered into a prospectively maintained database.

Body Weight Groups

Patients were grouped into 6 categories according to BMI at the time of surgical treatment: (1) underweight, BMI < 18.5; (2) normal, BMI 18.6-25.0; (3) overweight, BMI 25.1-30.0; (4) obese-I, BMI 30.1-35.0; (5) obese-II, BMI 35.1-40.0; or (6) obese-III, BMI > 40.0.

Statistical Analysis

Descriptive data are presented as the incidence and proportions for categorical data and as the mean ± SEM for continuous measures. For analysis of BMI as a continuous variable, Pearson correlation tests were performed with calculation of P, r, and R^2 values. For analysis of BMI as a categorical variable, multiple-group comparisons were conducted with analysis of variance (ANOVA) and Tukey's multiple comparisons test, where appropriate. Multivariate logistic regression was used to analyze associations between preoperative patient characteristics and functional outcome. All statistical tests were performed using either Prism, version 6.0 h (GraphPad Software, Inc., San Diego, CA) or SAS, version 9.3 (SAS Institute, Inc., Cary, NC), with *P* values < 0.05 considered significant.

RESULTS

Patient Characteristics

Two-hundred sixty-five patients underwent surgical treatment for NTOS between January 1, 2014 and March 31, 2016. The mean age of the study population was 33.3 ± 0.7 years (range, 12 to 70 years). There were 208 (77%) women, 150 (57%) with

Table I. Presenting characteristics and operative outcomes of patients with NTOS by body mass index group

Group (BMI)	Underweight (<18.5)	Normal (18.6−25)	Overweight (25.1−30)	Obese-I (30.1−35)	Obese-II (35.1−40)	Obese-III (>40)
No. of patients (%)	7 (3%)	95 (36%)	84 (32%)	47 (18%)	15 (6%)	17 (6%)
Age (years)*	24 ± 4	30 ± 1	33 ± 1	39 ± 2	38 ± 3	37 ± 2
Female (%)[‡]	7 (100%)	77 (81%)	63 (75%)	36 (77%)	12 (80%)	13 (76%)
Right side (%)[‡]	5 (71%)	60 (63%)	46 (55%)	22 (47%)	8 (53%)	9 (53%)
Rib anomaly[‡]	1 (14%)	16 (17%)	4 (5%)	4 (8%)	2 (13%)	1 (6%)
Height (in)[†]	65 ± 0.5	67 ± 0.4	67 ± 0.5	66 ± 0.5	66 ± 1.0	66 ± 1.3
Weight (kg)[†]	48 ± 1	64 ± 1	78 ± 1	89 ± 1	104 ± 3	120 ± 5
BMI[†]	17 ± 0.2	22 ± 0.2	27 ± 0.2	31 ± 0.2	36 ± 0.3	42 ± 0.7
Preop DASH[†]	62 ± 9.4	59 ± 2.0	55 ± 2.1	61 ± 2.7	69 ± 3.9	64 ± 5.3
OR time (min)[†]	181 ± 6	181 ± 2	182 ± 3	186 ± 4	189 ± 7	197 ± 11
EBL (mL)[†]	36 ± 9	56 ± 9	60 ± 8	54 ± 10	67 ± 37	60 ± 16
Fluid (L)[†]	2.6 ± 0.4	3.0 ± 0.1	3.0 ± 0.1	3.2 ± 0.1	3.3 ± 0.3	3.0 ± 0.2
ASM (g)[†]	6.7 ± 0.4	7.5 ± 0.2	7.9 ± 0.2	7.8 ± 0.3	7.4 ± 0.5	7.8 ± 0.5
MSM (g)[†]	4.9 ± 0.6	5.7 ± 0.2	6.1 ± 0.3	5.5 ± 0.3	7.7 ± 1.1	5.5 ± 0.4
LOS (days)[†]	4.7 ± 0.9	4.3 ± 0.1	4.6 ± 0.2	4.6 ± 0.4	4.4 ± 0.4	4.2 ± 0.3
Drain (L)[†]	0.7 ± 0.1	1.1 ± 0.9	1.2 ± 0.1	1.1 ± 0.2	0.8 ± 0.2	0.6 ± 0.9
Drain (days)[†]	5.9 ± 0.5	5.8 ± 0.1	5.9 ± 0.2	5.9 ± 0.4	5.7 ± 0.5	5.5 ± 0.3
Lymph Leak[‡]	0 (0%)	1 (1%)	2 (2%)	2 (4%)	0 (0%)	1 (6%)
Readmit[‡]	0 (0%)	3 (3%)	4 (5%)	2 (4%)	0 (0%)	2 (12%)
Postop DASH[†]	41 ± 13.5	41 ± 2.7	37 ± 2.6	47 ± 3.8	46 ± 5.0	54 ± 6.1
Δ DASH[†]	12 ± 7.9	23 ± 5.9	20 ± 2.8	14 ± 3.1	23 ± 5.9	12 ± 7.9
Δ DASH %[†]	44 ± 16.3	25 ± 5.5	30 ± 5.0	24 ± 6.2	31 ± 7.1	5 ± 15.3
Improved %[‡]	86%	70%	75%	81%	86%	60%

Data shown represent the number and percentage of patients or the mean ± SEM for each BMI group.

ASM, anterior scalene muscle specimen weight; Δ (delta), numerical decrease in DASH score from preoperative to 3-month postoperative follow-up; Drain, output from closed-suction drain after operative procedure, expressed for total volume (liters) and time until drain removal (days); Improved, percentage of patients exhibiting a decrease in DASH score at 30-day follow-up; Fluid, intraoperative fluid administered; LOS, length of hospital stay after operative procedure; Lymph leak, number and percentage of patients requiring early reoperation to control a persistent lymph leak; MSM, middle scalene muscle specimen weight; Postop, postoperative follow-up 3 months after surgical treatment; OR time, duration of operative procedure; Readmit, hospital readmission within 30 days of discharge.

*$P < 0.05$, ANOVA for differences between BMI groups.
[†]$P > 0.05$, ANOVA for differences between BMI groups.
[‡]$P > 0.05$, Chi-square for differences between BMI groups.

right-sided symptoms and 28 (10%) with a bony abnormality (complete cervical rib, $n = 9$; partial cervical rib, $n = 14$; first rib hypoplasia, $n = 1$; first rib fracture, $n = 3$; clavicle fracture, $n = 1$) (Table I). Mean BMI was 27.2 ± 0.4 (range 16.8−49.9), with 7 underweight (3%), 95 normal (36%), 84 overweight (32%), 47 obese-I (18%), 15 obese-II (6%), and 17 obese-III (6%) (Table I and Fig. 1A, B). There was a slight but significant association between BMI and age (Pearson $P < 0.0001$, $r = 0.264$; ANOVA $P = 0.0002$), but no correlations were observed between BMI and gender, side affected, or the presence of a bony abnormality. (Table I and Fig. 1C, D).

Clinical Presentation

Approximately half of the patients had a history of a co-existing medical condition other than NTOS, the most frequent being anxiety disorder or depression ($n = 59$, 22%) and degenerative lumbar spine disease ($n = 41$, 15%). Cardiac and pulmonary diseases were infrequent, and diabetes was present in only 6 (2%). There was a history of previous injury in 168 patients (63%), with a relatively even distribution between recreational, accidental, and occupational injuries, as well as a smaller number with unclassified repetitive strain injury (Fig. 2A, B). Over half of the patients had symptoms for 2 or more years before referral, consistent with our previous experience (Fig. 2C, D).[20,24,29] Forty-eight patients (18%) had undergone a previous operation for the presenting symptoms without improvement, including peripheral nerve decompression, cervical spine operations, or shoulder procedures, with 11 (4%) having had combined or multiple previous operations (Fig. 2E, F). While 64% of patients were taking
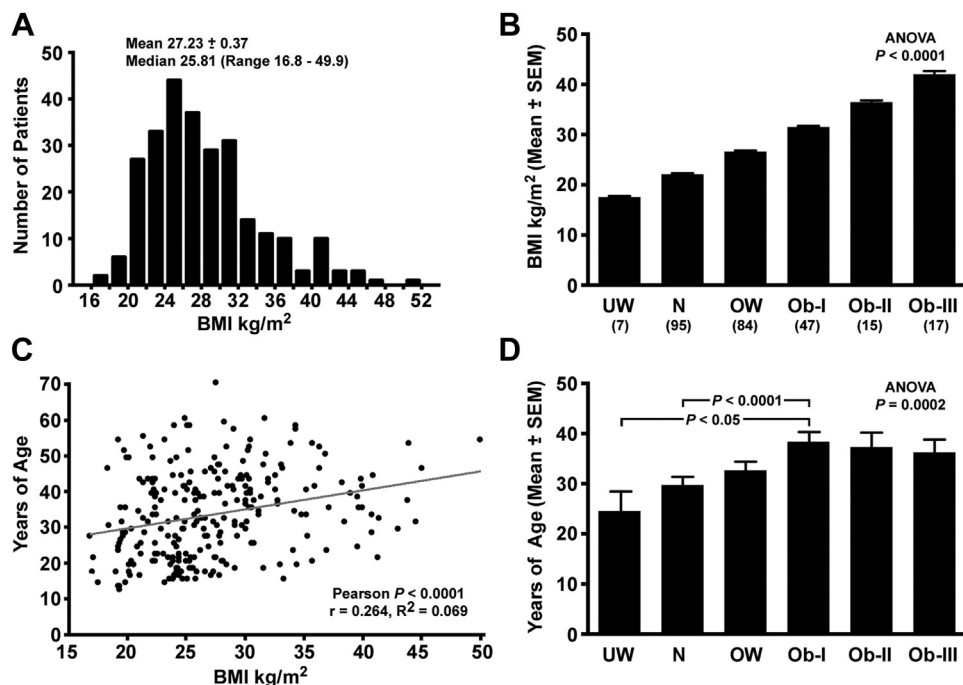
Fig. 1. Body mass index in patients undergoing surgical treatment for neurogenic thoracic outlet syndrome. **(A)** Histogram illustrating the distribution of BMI in 265 patients. **(B)** Bar graph demonstrating the mean (±SEM) BMI for patients in each of the 6 BMI groups, with a significant difference between groups (ANOVA). The number of patients in each group is indicated in parentheses.

(C) Scatter plot illustrating correlation analysis between BMI and patient age. **(D)** Bar graph showing the mean (±SEM) age for each BMI group, with a significant difference between groups (ANOVA). UW, underweight; N, normal; OW, overweight; Ob-I, obese-I; Ob-II, obese-II; Ob-III, obese-III.

no pain medications or only nonsteroidal anti-inflammatory drugs to manage symptoms of NTOS before surgical treatment, over one-quarter were taking opiates (10% strong opiates and 18% weak opiates) (Fig. 2G, H). Three-quarters of the patients were working (44% full time and 8% part time) or students (23%) at the time of surgery, with the remainder either unemployed (9%) or disabled (16%) (Fig. 3A, B). The mean preoperative DASH score was 59.1 ± 1.2, reflecting a substantial level of functional disability (Fig. 3C, D). Although there were significant associations between previous injury and BMI, and between work status and BMI, no correlations were observed between BMI and co-existing medical conditions, incidence or type of injury, duration of symptoms, pain medication use, previous operations, or preoperative DASH scores (Figs. 2 and 3).

Surgical Treatment

All patients underwent supraclavicular thoracic outlet decompression, with 243 (92%) having concomitant ipsilateral pectoralis minor tenotomy.

As shown in Table I, the overall mean duration of operation (incision to wound closure) was 184 ± 2 minutes (range, 72–306 minutes). The mean estimated blood loss (EBL) was 57 ± 5 mL (range, 0–700 mL), and the amount of fluid administered was 3.0 ± 0.1 liters (range, 0.5–6.5 liters), with no patients requiring blood transfusion. The specimen weights of the resected anterior and middle scalene muscles were 7.7 ± 0.1 and 5.8 ± 0.2 grams, respectively, with a total scalene muscle weight of 13.5 ± 0.2 grams. Mean hospital length of stay was 4.5 ± 0.1 days (range, 2.7–21.9 days). Mean total postoperative drain volume was 1053 ± 72 mL, and drain duration was 5.8 ± 0.1 days. Six patients (2%) underwent early reoperation for control of a persistent lymph leak that had not responded to conservative measures (clear liquid diet, parenteral nutrition, and octreotide). There were 11 (4%) readmissions within 30 days of operation, all for unsatisfactory outpatient control of postoperative pain. There was a significant correlation between BMI and duration of operation, but no significant differences between BMI groups for duration of operation, EBL, amount
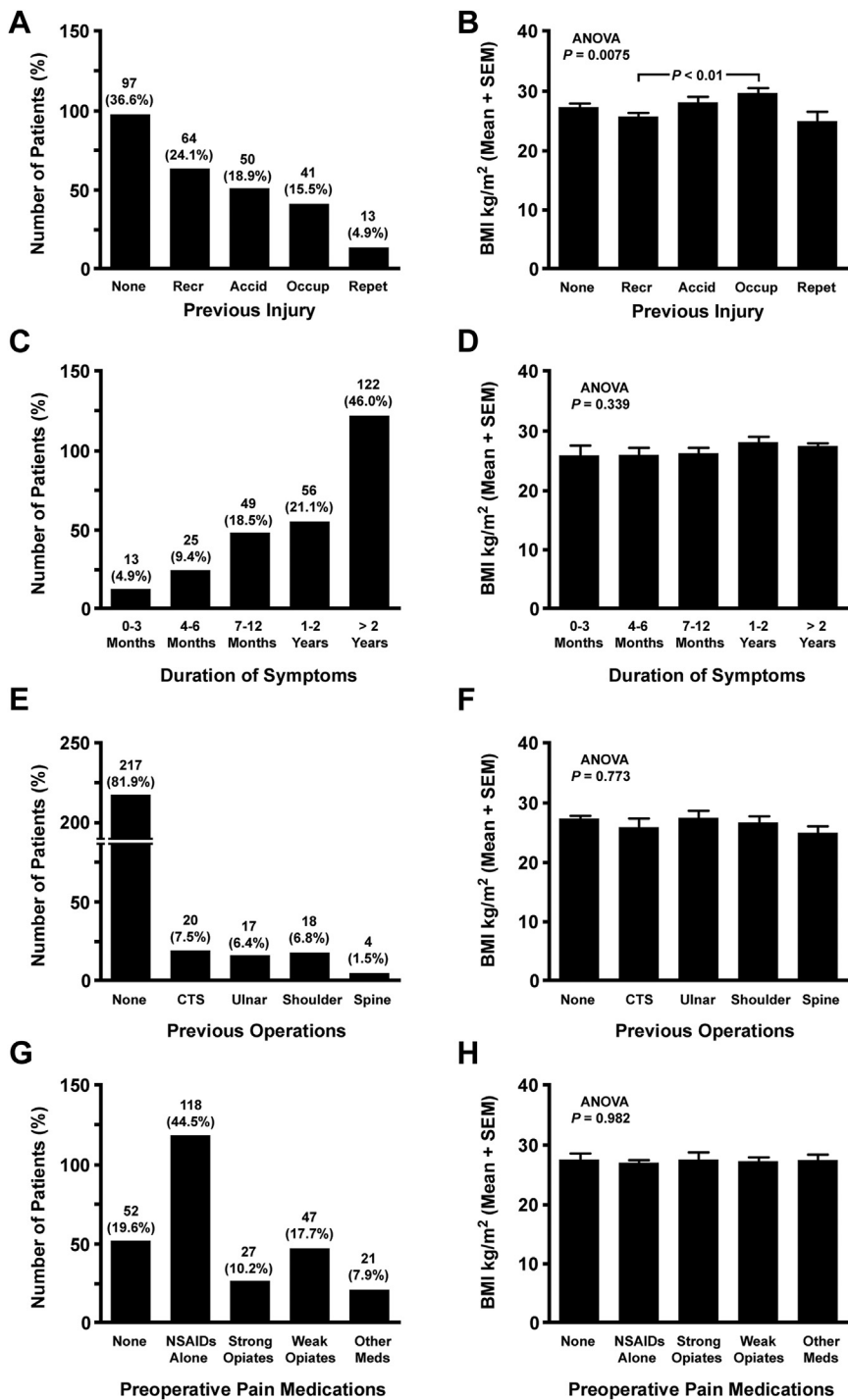
Fig. 2. Presenting characteristics of patients with NTOS in relation to BMI. **(A** and **B)** Frequency of previous injury in patients with NTOS **(A)** and relationship between BMI and previous injury **(B)**, with a significant difference between groups (ANOVA). **(C** and **D)** Frequency of different duration of symptoms in patients with NTOS **(C)** and relationship between BMI and duration of symptoms **(D)**, with no significant difference between groups (ANOVA). **(E** and **F)** Frequency of previous operations in patients with NTOS **(E)** and relationship between BMI and previous operations **(F)**, with no significant difference between groups (ANOVA). **(G** and **H)** Frequency of preoperative pain medication use in patients with NTOS **(G)** and relationship between BMI and pain medication use **(H)**, with no significant difference between groups (ANOVA). NSAIDs, nonsteroidal anti-inflammatory drugs; Recr, recreational; Accid, accidental; Occup, occupational; Repet, repetitive strain; CTS, carpal tunnel syndrome.
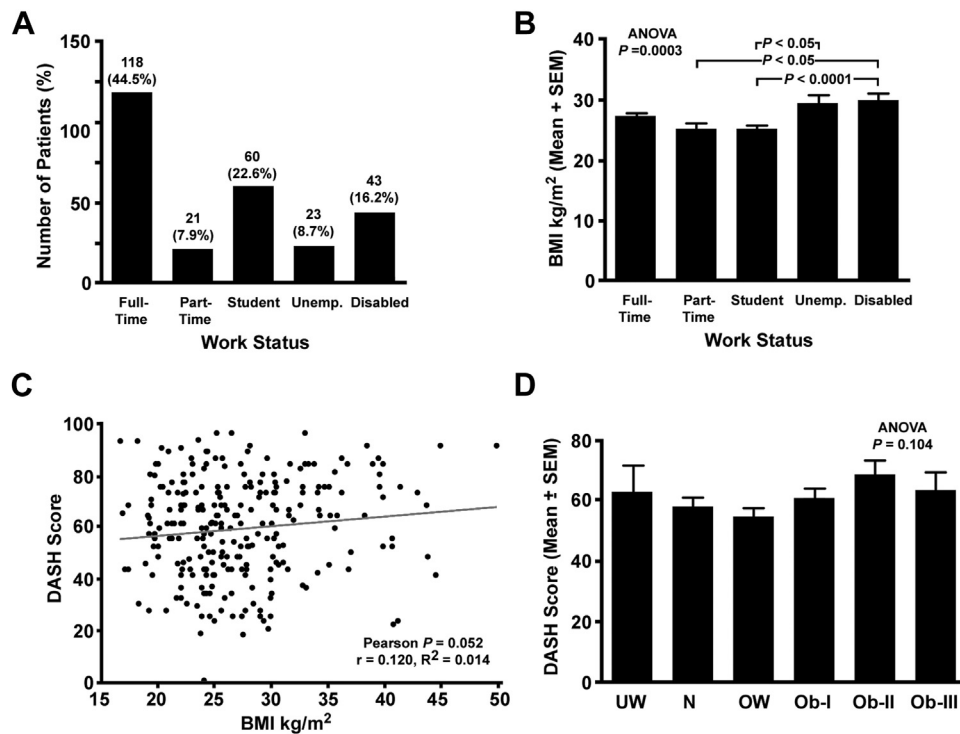
Fig. 3. Preoperative functional status of patients with NTOS in relation to BMI. **(A** and **B)** Frequency of work status in patients with NTOS **(A)** and relationship between BMI and work status **(B)**, with a significant difference between groups (ANOVA). **(C)** Scatter plot illustrating correlation analysis between BMI and preoperative DASH score. **(D)** Bar graph showing the mean (±SEM) preoperative DASH score for each BMI group, with no significant difference between groups (ANOVA). Unemp, unemployed.

of fluid administered, scalene muscle weight, hospital length of stay, total drain volume, drain duration, incidence of lymph leaks requiring reoperation, or incidence of readmissions (Table I and Fig. 4).

Functional Outcomes

DASH scores were obtained at 3 months after surgery as an indicator of early functional response to surgical treatment, with 245 patients (92%) providing satisfactory follow-up data (Table I). The mean follow-up DASH score was 41.6 ± 1.6, which compared favorably with the mean preoperative DASH score of 59.1 ± 1.2 ($P < 0.0001$, Mann−Whitney test). The mean numerical change in DASH score was 17.6 ± 1.6, and the mean percentage change in DASH score was 26.3 ± 3.0%, with an improvement in DASH score exhibited by 196 (74%) of patients. There were no correlations with BMI or differences between BMI groups for changes in DASH score, the percentage changes in DASH score, or the proportion of patients with measureable functional improvement (Table I and Fig. 5).

Multivariate logistic regression was used to further analyze associations between various preoperative patient characteristics and postoperative functional outcome, as measured by the percent improvement in DASH score at 3-month follow-up. As shown in Table II, none of the BMI groups exhibited a significant association with functional improvement. Of the variables assessed, only an unemployment work status before surgery was significantly (negatively) associated with functional outcome (odds ratio 0.236, 95% confidence interval 0.086−0.610, $P = 0.004$).

DISCUSSION

In this study, we examined the potential effects of body weight on various aspects of surgical treatment for NTOS. The average BMI in the study cohort (27.2 kg/m^2) was in the overweight range, but there was a wide and even distribution of body weights indicating a sufficiently representative sample of patients across the entire body weight spectrum. We also evaluated a relatively large number of patients undergoing surgical treatment for NTOS, thereby providing an ample basis for analysis. Because all patients who met the predefined diagnostic criteria
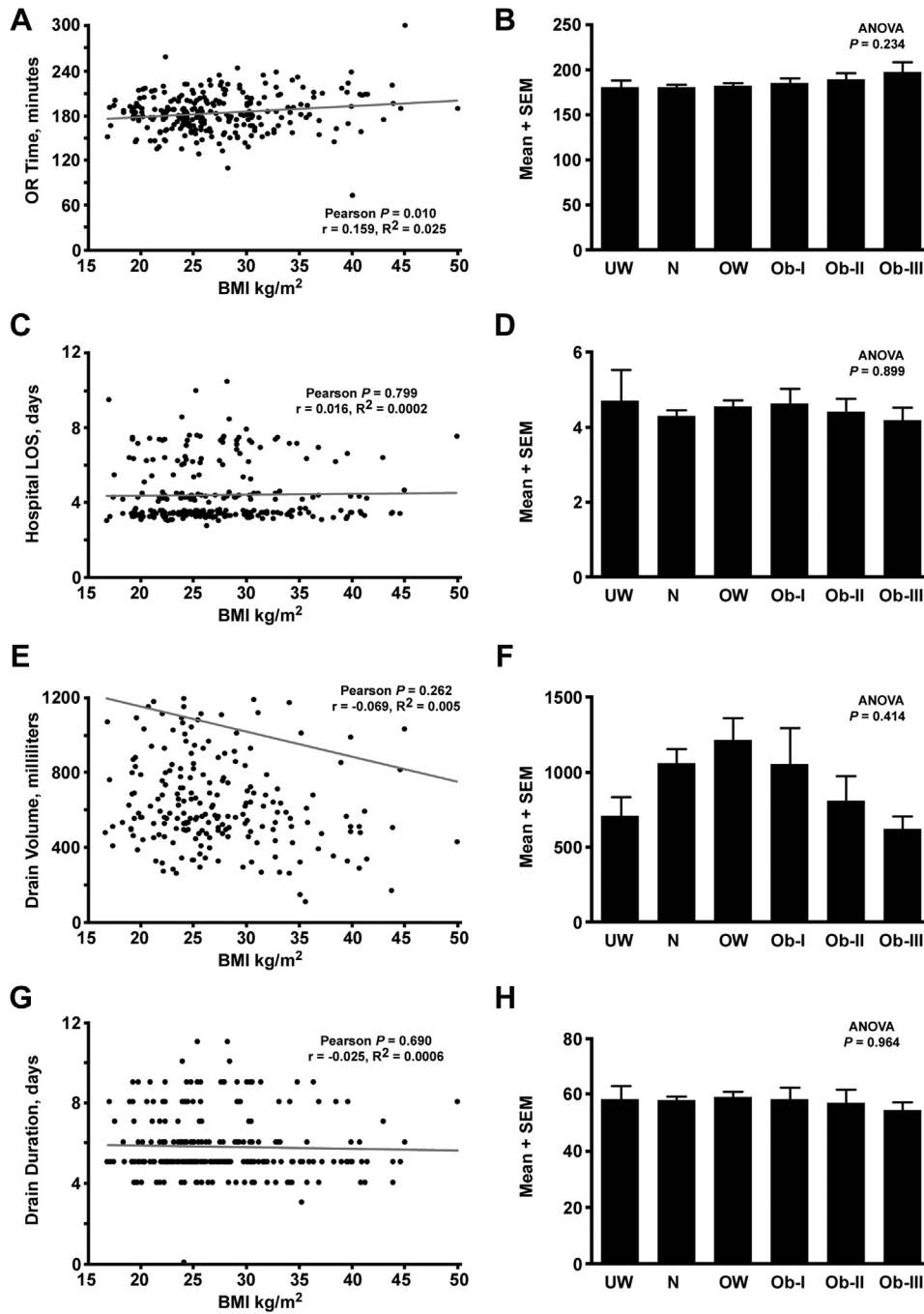
Fig. 4. Operative outcomes of patients with NTOS in relation to BMI. **(A** and **B)** OR time. Scatter plot illustrating correlation analysis between BMI and operating room time **(A)**, showing a significant association, and bar graph showing the mean (±SEM) operating room time for each BMI group, with no significant difference between groups (ANOVA). **(C** and **D)** Hospital length of stay (LOS). Scatter plot illustrating correlation analysis between BMI and LOS **(A)**, showing no significant association, and bar graph showing the mean (±SEM) LOS for each BMI group, with no significant difference between groups (ANOVA). **(E** and **F)** Total drain volume. Scatter plot illustrating correlation analysis between BMI and drain volume **(A)**, showing no significant association, and bar graph showing the mean (±SEM) drain volume for each BMI group, with no significant difference between groups (ANOVA). **(G** and **H)** Drain duration. Scatter plot illustrating correlation analysis between BMI and drain duration **(A)**, showing no significant association, and bar graph showing the mean (±SEM) drain duration for each BMI group, with no significant difference between groups (ANOVA).
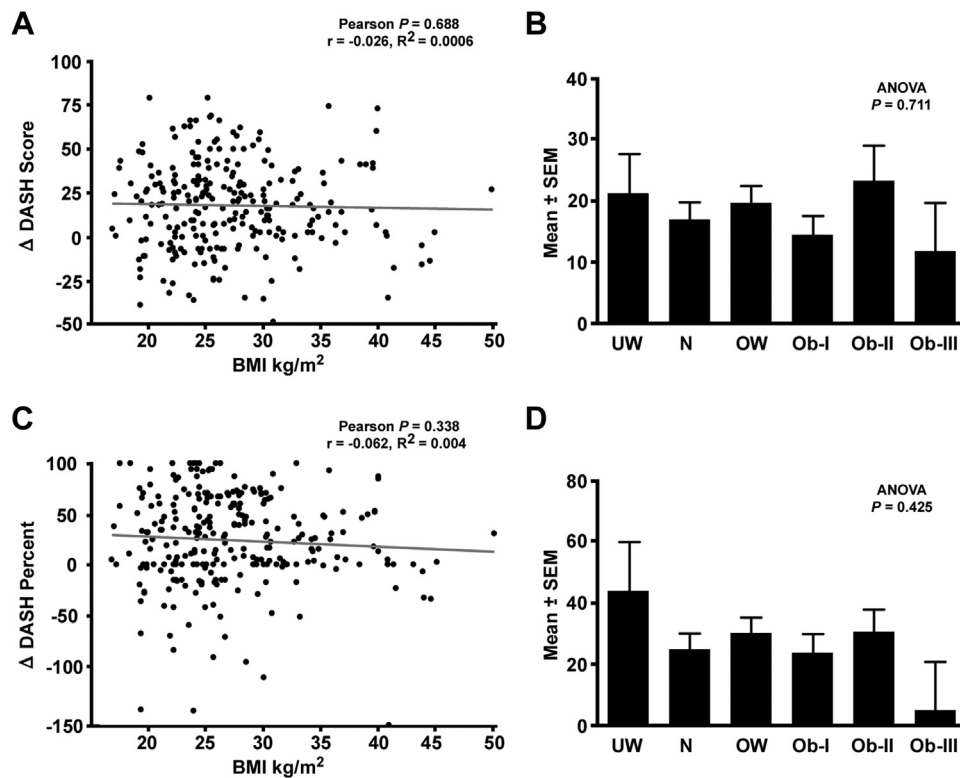
Fig. 5. Functional outcomes of patients with NTOS in relation to BMI. **(A** and **B)** Follow-up change (delta) in DASH score. Scatter plot illustrating correlation analysis between BMI and 3-month follow-up change in DASH score **(A)**, showing no significant association, and bar graph showing the mean (±SEM) follow-up change in DASH score for each BMI group, with no significant difference between groups (ANOVA). **(C** and **D)** Follow-up percentage change (delta percent) in DASH score. Scatter plot illustrating correlation analysis between BMI and 3-month follow-up percentage change in DASH score **(A)**, showing no significant association, and bar graph showing the mean (±SEM) follow-up percentage change in DASH score for each BMI group, with no significant difference between groups (ANOVA).

and surgical indications for NTOS during the study period underwent surgical treatment, and there was no inherent patient-selection bias on the basis of body weight.

NTOS is a relatively uncommon condition caused by predisposing variations in anatomy combined with hypertrophy, injury, and persistent spasm of the scalene and/or pectoralis minor muscles.[15,27] There was an association between BMI and underlying mechanism of injury because the average BMI for occupational-associated injuries was somewhat higher than those with recreation-associated injuries. In addition, those identified as disabled or unemployed had a higher mean BMI relative to part-time workers or students, but this variation was not seen between disabled/unemployed and those employed full time. In examining other preoperative characteristics of patients with NTOS, there was a mild association between BMI and increasing age, but BMI was independent of gender,

side effects, and the presence of an underlying bony abnormality. Although half of the patients had underlying co-existing medical conditions in addition to NTOS, most were psychological in nature and not influenced by body weight. Indeed, the incidence of diabetes in the study population was only 2.3%, allowing us to examine any potential influence of obesity in relative isolation. We therefore found no evidence to suggest that body weight had a significant causal relationship to the development or clinical presentation of NTOS.

Patients with NTOS have often had symptoms for long periods of time before clinical diagnosis, as well as confounding previous surgical procedures and chronic use of opioid pain medications. Consistent with previous studies, 67% of the study cohort had exhibited symptoms for more than 1 year and 46% for more than 2 years, 18% had undergone previous surgical procedures involving the ipsilateral neck and/or extremity, and 28% were taking

Table II. Logistic regression analysis of operative outcomes for patients with NTOS

Variable	OR	95% CI	P Value
Age	0.975	0.949–1.000	0.055
Male gender	0.567	0.292–1.109	0.095
BMI group: normal	Reference		
BMI group: underweight	2.760	0.408–55.810	0.374
BMI group: overweight	1.479	0.760–2.917	0.253
BMI group: obese-I	2.080	0.903–5.037	0.093
BMI group: obese-II	1.913	0.470–9.980	0.393
BMI group: obese-III	0.669	0.206–2.226	0.503
Symptom duration >2 years	Reference		
Symptom duration 1–2 years	1.401	0.660–2.973	0.380
Symptom duration 7–12 months	1.478	0.668–3.269	0.335
Symptom duration 4–6 months	1.539	0.535–4.432	0.424
Symptom duration 0–3 months	0.315	0.088–1.128	0.076
Diagnosis: anxiety/ depression	1.315	0.684–2.600	0.597
Preoperative opiate use	1.208	0.608–2.487	0.419
Work status: employed	Reference		
Work status: unemployed	0.236	0.086–0.610	0.004

Multivariate logistic regression was used to analyze associations between various preoperative patient characteristics and postoperative functional outcome, as measured by a decrease (improvement) in DASH score at 3-month follow-up.
CI, confidence interval; OR, odds ratio.

opioid medications; however, there were no significant associations found between BMI and the time interval to clinical presentation, type of interval surgery, or pain medication use. The characteristics of the patients in this study were therefore generally comparable with those of others with NTOS, both in our earlier studies and in those from others, across the body weight spectrum.[29]

Given that supraclavicular decompression for NTOS involves mobilization of the scalene fat pad and requires careful dissection deep within the anterior neck, we suspected that obesity might have had an adverse influence on the technical conduct of surgery or on early postoperative complications, such as wound infection and persistent lymph drainage. However, there were no significant differences between the 6 BMI categories in the length of operation, intraoperative blood loss, amount of fluid administered, scalene muscle weight, or hospital

length of stay and no differences in the amount of lymphatic fluid production or drain duration. Hospital readmission rate was also not associated with BMI, suggesting that those patients at the higher end of the BMI spectrum did not impose greater risks for operation or elevated health-care costs in the setting of treatment for NTOS.

We assessed DASH scores with regard to the extent of disability at initial presentation and functional outcomes of surgical treatment, a validated measure of upper extremity disability that has been used in previous studies on NTOS.[17–21,24,29] The high level of pretreatment functional disability exhibited by patients in this study is reflected by the mean preoperative DASH score of 59.1 ± 1.2, similar to that observed in previous studies on NTOS from our center and others.[17–21,24,29] Most importantly, the changes in DASH scores after surgical treatment were not significantly different between BMI groups, either as evaluated by the change in absolute DASH scores or by the percentage change from preoperative baseline levels. This finding suggests that the benefit of supraclavicular decompression for disabling NTOS is maintained across the body weight spectrum, with those who are obese gaining the same benefits from operation as those at "normal" weight, and at similar levels of surgical risk. Thus, obesity alone should not be used to disqualify patients from being considered for surgical decompression.

One limitation of this study is that the patient population described here may not be representative of all patients with NTOS but reflects that of a specialty practice focused on this relatively uncommon condition. The results described here are also specific to NTOS and do not necessarily translate to surgical treatment of venous or arterial forms of TOS. Moreover, the high volume of operative experience in our center may be associated with technical approaches and perioperative care processes that are not necessarily used in other settings.[22,23] It is therefore not clear whether the results of this study can be generalized to other vascular surgery or thoracic surgery practice environments where NTOS may be treated on a far less frequent basis.

A second limitation is that the results of this study are applicable only to supraclavicular thoracic outlet decompression, as opposed to other surgical approaches used for NTOS, such as transaxillary first rib resection. This concern may be particularly relevant given that these 2 operative approaches involve significant differences in patient positioning, surgical exposure, and the extent of decompression that can be accomplished (e.g., partial versus complete scalenectomy and feasibility of

brachial plexus neurolysis). It is therefore not yet clear if the results described here can also be extended to any potential influence of body weight on outcomes of transaxillary first rib resection in the treatment of NTOS.

CONCLUSIONS

This study demonstrated no substantive influence of BMI on preoperative characteristics, intraoperative findings, technical results, or early postoperative outcomes for patients undergoing supraclavicular decompression for NTOS and no indication of an ''obesity paradox'' for this condition. Supraclavicular decompression for NTOS can therefore be safely and effectively performed and achieve similar outcomes, across the body weight spectrum. It is not known if these findings can be extrapolated to other operative approaches for NTOS.

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