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Original article

Changes in weight and co-morbidities among adolescents undergoing bariatric surgery: 1-year results from the Bariatric Outcomes Longitudinal Database

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Abstract

Background: Bariatric surgery is 1 of the few effective treatments of morbid obesity. However, the weight loss and other health-related outcomes for this procedure in large, diverse adolescent patient populations have not been well characterized. Our objective was to analyze the prospective Bariatric Outcomes Longitudinal Database (BOLD) to determine the weight loss and health related outcomes in adolescents. The BOLD data are collected from 423 surgeons at 360 facilities in the United States.

Methods: The main outcome measures included the anthropometric and co-morbidity status at baseline (n = 890) and at 3 (n = 786), 6 (n = 541), and 12 (n = 259) months after surgery. Adolescents (75% female; 68% non-Hispanic white, 14% Hispanic, 11% non-Hispanic black, and 6% other) aged 11 to 19 years were included in the present analyses.

Results: The overall 1-year mean weight loss for those who underwent gastric bypass surgery was more than twice that of those who underwent adjustable gastric band surgery (48.6 versus 20 kg, $P < .001$). Similar results were found for all other anthropometric changes and comparisons within 1 year between surgery types ($P < .001$). In general, the gastric bypass patients reported more improvement than the adjustable gastric band patients in co-morbidities at 1 year after surgery. A total of 45 readmissions occurred among gastric bypass patients and 10 among adjustable gastric band patients, with 29 and 8 reoperations required, respectively.

Conclusions: The weight loss at 3, 6, and 12 months after surgery is approximately double in adolescent males and females who underwent gastric bypass surgery versus those who underwent adjustable gastric band surgery. Bariatric surgery can safely and substantially reduce weight and related co-morbidities in morbidly obese adolescents for ≥1 year. (Surg Obes Relat Dis 2013;9: 503–513.) © 2013 American Society for Metabolic and Bariatric Surgery. All rights reserved.

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The global epidemic of obesity is a worldwide public and clinical health issue [1]. According to the World Health Organization, obesity is increasing by 30 million cases annually [1]. In the United States, the life expectancy is projected to decrease as a consequence of obesity alone, prompting the investigation of more treatment options [2]. Moreover, the distribution of the body mass index (BMI) has become skewed so that the heaviest have become even heavier [3].

Specifically, the U.S. Centers for Disease Control and Prevention recently began estimating the proportion of morbidly obese (BMI ≥97th percentile for age and gender) children and adolescents [3]. In 2007 to 2008, an estimated 12% of all U.S. children aged 2 to 19 years old were morbidly obese. Among 12- to 19-year-old adolescents, the estimates were 11% for non-Hispanic whites, 15% for Mexican Americans and other Hispanics, and 19% for non-Hispanic blacks [3].

Childhood-onset obesity has several health-related consequences that, until recently, were documented only in adulthood, including hypertension, insulin resistance, glucose intolerance, and dyslipidemia [4,5]. In turn, these conditions are risk factors for type 2 diabetes and cardiovascular disease in both childhood and adulthood [6,7]. Additionally, childhood obesity has also been associated with orthopedic problems [8], polycystic ovarian syndrome [9], nonalcoholic fatty liver disease [10], anxiety [11], and depression [11]. Most of these health issues also track consistently into adulthood [4].

Weight loss surgery among both adults and adolescents has become increasingly recognized as effective treatment of these co-morbidities, and it is considered to be a reasonable option when nonoperative methods of weight loss fail [11,12]. Current studies have suggested that neither pharmacologic nor dietary treatment can maintain weight loss in obese adolescents as effectively as can weight loss surgery [12–14].

Although bariatric surgery is accepted as the treatment of choice for recalcitrant morbid obesity among adults, the acceptance of the surgery for adolescents has not been universal. Adolescents account for a small percentage of the cases performed; however, this percentage is expected to increase [15]. The long-term safety and efficacy of bariatric surgery in adolescents have not yet been determined, particularly in large geographically and ethnically diverse samples [15,16]. The specific concerns include the ability to obtain appropriate consent, risks of major surgery, long-term adherence to dietary recommendations, unknown long-term effects, and the probabilities of long-term weight maintenance and resolution of related co-morbidities [16–18]. Although the published data on bariatric outcomes in adolescents has increased exponentially, most studies have been small and usually from individual surgical practices [17].

Accordingly, we analyzed the data from the Bariatric Outcomes Longitudinal Database (BOLD), a large database that tracks the outcomes of patients from a wide geographic area who have undergone bariatric surgery. We report the effects of bariatric surgery on weight loss, co-morbidities, and complications in a large multiethnic cohort of morbidly obese adolescents 1 year after surgery.

Methods

The BOLD database

The data for the BOLD database are collected prospectively from participants in the Bariatric Surgery Center of Excellence (BSCOE) program sponsored by the American Society for Metabolic and Bariatric Surgery (ASMBS) [19]. The participating centers enter data collected for all bariatric surgery patients during preoperative visits, hospital stay, and all postoperative visits. These data are used to monitor adherence to the requirements of the BSCOE program and to support quality improvement for the surgical treatment of obesity and its associated conditions.

Data quality assurance procedures

All BSCOE programs undergo a site inspection before approval and recertification every 3 years. During the site inspection, the accuracy of BOLD data are verified in an impartially selected sample of 10% of medical records. All data on complications and readmissions are also reviewed for accuracy. Specifically, all surgeries reported in BOLD are compared with a hospital-generated surgery list, and all complications and readmissions occurring within 30 days of surgery are verified. In addition, a 10% random chart review is performed. Any unreported reoperations, readmissions, deaths, transfers, or revisions found during chart review trigger a 100% chart review. Inconsistencies noted during the site inspections are reported to the Bariatric Surgery Review Committee, who recommends whether the applicant should receive or maintain BSCOE designation status.

The BOLD software has built in numerous data validation and verification rules that are intended to prevent the entry of invalid, out-of-range, and inconsistent data. The software will not accept out-of-range values (e.g., out-of-range values for height, weight, and age), and data entry personnel are asked to confirm the entries that lie within suspect ranges. Within BOLD is a data validation report that lists patients with questionable data that must be addressed. The sites are generally given 14 days to correct their data in BOLD. For those sites that do not use an electronic medical record to transfer data to BOLD, the Surgical Review Corporation (SRC) encourages centers to use patient encounter forms to collect BOLD data during the patient encounter using the same format as in the software.

The SRC

The SRC was established in 2003 as an independent, nonprofit organization dedicated to advancing the safety, efficacy, and efficiency of bariatric and metabolic surgical care worldwide. With the ASMBS, the SRC developed the BSCOE program and administers it on behalf of the ASMBS. The primary function of the BSCOE program is to collect and analyze data to improve bariatric surgical care. Surgeons and hospitals qualify for BSCOE designation by passing a rigorous evaluation process verifying that they have a comprehensive, multidisciplinary bariatric program that meets or exceeds the approved clinical practice guidelines for bariatric surgery [19].

Research data

The Copernicus Group Independent Review Board approved the use of BOLD data for research with a waiver of informed consent. The BOLD study has been registered with the National Institutes of Health (NCT01002352). The Copernicus Group Independent Review Board determined that the BOLD study poses minimal risk to patients and that the SRC has adequate safeguards in place to ensure confidentiality of the protected health information described in the study protocol. Patients (or their guardians if <18 years old) are presented with a Copernicus Group Independent Review Board-approved Patient Information Sheet or local institutional review board-approved document during their initial visit. Patients or their guardians inform the bariatric surgeon or staff if they do not wish to participate in the study before their surgery. All consent process data are included in the BOLD database.

About 65% (169,000) of the patients treated by surgeons participating in the BSCOE program have allowed their data to be analyzed for research purposes. Analyses (data not presented) showed that the demographic, preoperative characteristics (BMI, prevalence of co-morbidities), and 30-day safety outcomes (rates of mortality, serious complications, readmissions, and reoperations) across all procedures do not differ substantially between those who are and are not included in the database. Data are currently entered into the database by >1000 surgeons from >600 facilities in the United States (all states are represented, with the exception of Vermont and New Mexico), representing approximately 85% of all facilities nationwide performing ≥10 bariatric procedures annually.

Patient selection

We analyzed data from all patients aged 11 to 19 years who had undergone bariatric surgery from April 2004 to October 2010 and who allowed their data to be used for research purposes. The data analyzed for the present study were from 423 surgeons and 360 facilities participating in the BSCOE program.

Data collection

At BSCOE, primary BOLD data are generally collected using medical charts (paper or electronic) by a healthcare provider. The SRC encourages the use of BOLD patient encounter forms to streamline this effort. Several third-party electronic medical record systems interface with BOLD to prevent duplicate data entry. Each surgical practice must appoint a BOLD administrator who manages the administrative aspects of BOLD and is responsible for ensuring high-quality BOLD data entry by the practice. The assignment of BOLD data entry responsibility varies across bariatric programs. Each BSCOE participant practice determines who within their program is most appropriate to enter the data and is responsible for their participation in the training opportunities offered by the SRC. BOLD data entry can be managed entirely by the surgical practice or can be shared with the hospital. The training and support provided to all data entry personnel by the SRC includes on-demand BOLD data entry webinars, data entry guidelines, weekly ASK SRC teleconferences, and general support through the SRC's Helpdesk.

Variables used for analysis

We collected data on age, gender, race, weight, BMI, weight loss (difference between baseline weight in kilograms and weight at each respective measurement point), surgery type, and the status of several cardiometabolic, psychosocial, and general co-morbidities, including diabetes, hypertension, hyperlipidemia, asthma, gastroesophageal reflux disease, and depression.

Co-morbidity severity was scored using a system based on the Assessment of Obesity-Related Co-morbidities Scoring System [20], the National Institutes of Health Longitudinal

Table 1
Demographic characteristics of 890 adolescents who underwent bariatric surgery from 2004 to 2010

Characteristic	Value	Baseline BMI Z score	P
Age at surgery (yr)	18.5 ± .1		
Gender			<.001
Male	225 (25.3)	3.14 ± .2	
Female	665 (74.7)	2.41 ± .2	
Surgery type			<.001
Gastric bypass	454 (51.0)	2.67 ± .4	
Adjustable gastric band	436 (49.0)	2.53 ± .4	
Race			
Non-Hispanic white	606 (68.1)	2.57 ± .4*,†	
Hispanic	129 (14.5)	2.68 ± .4*	
Non-Hispanic black	98 (11.0)	2.67 ± .3†	
Other	57 (6.4)	2.60 ± .4	

BMI = body mass index.

Data presented as mean ± standard deviation or numbers, with percentages in parentheses.

* Non-Hispanic white versus Hispanic, $P = .004$.

† Non-Hispanic white versus non-Hispanic black, $P = .02$.

Assessment of Bariatric Surgery protocol (LABS)[21], and an extensive review of the published data and was developed by BSCOE to report uniform outcomes. Severity was scored from 0 to 5, with 0 indicating no symptoms or evidence of disease; 1, symptomatic but requiring no medication; 2, having a diagnosis but not requiring medication; 3, having a diagnosis and requiring medication; 4, requiring >1 medication because of severe medical complications; and 5, having the most severe form of the co-morbidity (e.g., poorly controlled by medications, organ damage, and dysfunction). For example, depression was scored as follows: 0, no symptoms of depression; 1, mild and episodic depression not requiring treatment; 2, moderate depression accompanied by some impairment, might require treatment; 3, moderate depression with significant impairment, treatment indicated; 4, severe depression definitely requiring intensive treatment; and 5, severe depression requiring hospitalization. Severity was assessed for each co-morbidity at each postoperative visit by the surgeon.

Guidelines, including definitions [19], were provided to all BSCOEs to document an adverse event/complication as (1) death; (2) a complication that prolonged hospitalization (>18-hr beyond the expected discharge date), required readmission to the emergency room or hospital (i.e., any hospital or facility stay that lasted for ≥24-h), or requires treatment outside of standard postoperative care (e.g., a therapeutic surgical, endoscopic, or radiologic intervention, regardless of where the intervention is performed or a pharmacologic treatment with the exception of over-the-counter drugs); (3) within 30 days of surgery (all adverse events/complications, readmissions, and reoperations are entered into BOLD, regardless of whether they appeared to be related to the surgery); and (4) >30 days after surgery (all adverse events/complications that appeared on the list of complications in BOLD must be entered).

All hospital readmissions and/or reoperations occurring as a result of a complication listed in BOLD must also be entered. Adverse events/complications unrelated to the surgery not on the list of complications in BOLD are entered. BSCOE participants are expected to report all complications in their patients that meet the outlined criteria, even if these complications were managed by another healthcare provider. At routine postdischarge visits, the BSCOE participants are instructed to review with patients any complications they might have had that were managed by another program. The SRC site inspectors note the inclusion of documents from other healthcare providers within the patient charts.

Table 2
Mean anthropometric measures after bariatric surgery (2004–2010) stratified by surgery type*

Variable	Preoperative	Postoperatively (mo)†,‡,§		
		3	6	12
Gastric bypass	454	402	258	108
BMI (kg/m^2)	50.69 (.39)	45.42 (.37)	38.00 (.39)	33.62 (.43)
BMI percentile	99.42 (.03)	99.07 (.04)	96.38 (.29)	91.48 (.92)
BMI *Z* score	2.67 (.01)	2.50 (.01)	2.08 (.03)	1.71 (.05)
BMI change (%)		−.36 (.05)	−3.04 (.28)	−7.85 (.88)
Weight (kg)	145.23 (1.19)	130.11 (1.15)	109.03 (1.15)	96.51 (1.29)
Weight percentile	99.67 (.03)	99.35 (.05)	96.58 (.36)	91.90 (1.06)
Weight *Z* score	2.95 (.01)	2.73 (.02)	2.25 (.03)	1.86 (.05)
WL (kg)		15.05 (.41)	36.09 (.64)	48.60 (1.02)
WL (%)		10.35 (.28)	25.38 (.45)	33.69 (.61)
Adjustable gastric banding	436	384	283	151†
BMI (kg/m^2)	46.01 (.32)	43.38 (.31)	41.03 (.33)	39.09 (.41)
BMI percentile	99.20 (.03)	98.91 (.04)	98.17 (.20)	97.24 (.33)
BMI *Z* score	2.54 (.01)	2.43 (.01)	2.29 (.02)	2.14 (.03)
BMI change (%)		−.28 (.02)	−1.02 (.2)	−1.95 (.32)
Weight (kg)	130.43 (.96)	122.97 (.94)	116.35 (.97)	110.66 (1.18)
Weight percentile	99.48 (.02)	99.25 (.04)	98.78 (.09)	97.72 (.35)
Weight *Z* score	2.77 (.01)	2.64 (.02)	2.51 (.02)	2.36 (.03)
WL (kg)		7.46 (.23)	14.13 (.47)	19.81 (.91)
WL (%)		5.70 (.16)	10.73 (.34)	14.89 (.67)

BMI = body mass index; BMI change = difference between baseline BMI percentile and BMI percentile at each measurement point; WL = estimated weight loss or difference between baseline weight in kilograms and weight at each measurement point; although the percentage of excess weight loss (calculated using the middle of the 1983 Metropolitan Life Insurance tables for a median frame + percentage of weight lost + percentage of excess BMI lost with excess >25 kg/m^2) is the standard measure used in the adult population, it is not appropriate for adolescents because the Metropolitan Life Insurance tables were designed for adults aged 25–59 years only.

Data presented as estimate ± standard error.

* Model adjusted by age, gender, and race.

† $P < .001$ for change across all points, for all anthropometric measures, for both surgery types.

‡ $P < .01$ for changes between each point, for all anthropometric measures, for both surgery types.

§ $P < .001$ for change across all time points, for all anthropometric measures between surgery types.

The intraoperative data used in the present study consisted of the procedure (gastric bypass or adjustable gastric band) and the date of surgery. The primary outcomes were weight loss, change in co-morbidity severity, and surgical complications. Data were assessed before surgery and at 3, 6, and 12 months after surgery. Because not all patients had their follow-up appointments exactly at these times, the 3-month data collection point included data collected from 0 to 3 months after surgery, the 6-month point included data collected from 3 to 9 months after surgery, and the 12-month point included data collected 9 to 15 months after surgery.

Statistical analysis

The baseline differences in BMI *Z* scores [22] for all demographic variables were evaluated using analysis of variance. To assess the changes over time for individual surgery types and between surgery types in weight and BMI, separate repeated measures, linear mixed models were fit using the MIXED procedure in SAS, version 9.2 (SAS Institute, Cary, NC). A compound symmetry variance-covariance matrix was selected for each model to account for the correlation of within-patient repeated observations. Age at surgery, gender, ethnicity, surgery type (gastric bypass or adjustable gastric band), and point of data collection were the fixed covariates considered for potential inclusion in each model. The patients were considered to be random. In a mixed model, the particular levels of fixed effects are of interest, and inferences are made for those specific levels. The random effects are considered to be random samples from the population, and inferences are not made to a specific sample but to the entire population. The interaction between time and gender was also assessed. Contrasts were used to test for differences between groups at each point for the mean values of weight and BMI and the presence of co-morbidities. The same mixed-model approach was also used to test for any selection bias between the whole sample (n = 890) and a subsample (n = 226) of patients for whom data from all 4 points were available by including an indicator variable for complete or incomplete data [23]. The Fisher exact test was applied to assess the difference in co-morbidities between the 2 types of surgery. Alpha was set at .05.

Table 3
Mean anthropometric measures from morbidly obese adolescent boys 1 year after bariatric surgery performed from 2004 to 2010, by surgery type*

Variable	Preoperative	Postoperatively (mo)		
		3	6	$12^{\dagger,\ddagger}$
Gastric bypass	125	110	68	23
BMI (kg/m^2)	53.60 ± .79	47.46 ± .75	40.40 ± .78	35.30 ± .95
BMI percentile	99.92 ± .02	99.80 ± .03	98.61 ± .37	96.85 ± .89
BMI *Z* score	3.21 ± .02	2.99 ± .03	2.58 ± .06	2.18 ± .11
BMI change (%)		−.10 ± .05	−1.34 ± .37	−3.10 ± .87
Weight (kg)	167.58 ± 2.36	148.32 ± 2.30	126.39 ± 2.39	110.14 ± 3.02
Weight percentile	99.96 ± .02	99.79 ± .06	98.68 ± .38	96.76 ± .99
Weight *Z* score	3.61 ± .04	3.27 ± .05	2.74 ± .07	2.26 ± .12
WL (kg)		19.40 ± .97	41.42 ± 1.32	57.97 ± 2.31
WL (%)		11.47 ± .53	24.49 ± .78	33.66 ± 1.35
Adjustable gastric banding	100	92	67	38
BMI (kg/m^2)	49.14 ± .77	46.18 ± .78	43.40 ± .82	41.31 ± .85
BMI percentile	99.86 ± .01	99.74 ± .03	99.39 ± .10	98.37 ± .82
BMI *Z* score	3.07 ± .03	2.94 ± .03	2.75 ± .05	2.57 ± .07
BMI change (%)		−.12 ± .02	−.50 ± .10	−1.48 ± .80
Weight (kg)	155.66 ± 2.34	146.25 ± 2.38	137.31 ± 2.45	130.54 ± 2.58
Weight percentile	99.93 ± .01	99.85 ± .02	99.54 ± .11	98.63 ± .65
Weight *Z* score	3.41 ± .04	3.22 ± .04	3.00 ± .06	2.82 ± .08
WL (kg)		9.46 ± .59	18.41 ± 1.15	25.18 ± 1.84
WL (%)		6.16 ± .37	11.93 ± .75	16.07 ± 1.20

BMI = body mass index; BMI change = difference between baseline BMI percentile and BMI percentile at each measurement point; WL = estimated weight loss or difference between baseline weight in kilograms and weight at each measurement point; although the percentage of excess weight loss (calculated using the middle of the 1983 Metropolitan Life Insurance tables for a median frame + percentage of weight lost + percentage of excess BMI lost with excess >25 kg/m^2) is the standard measure used in the adult population, it is not appropriate for adolescents because the Metropolitan Life Insurance tables were designed for adults aged 25–59 years only.

Data presented as estimate ± standard error.

* Model adjusted by age, and race.

† $P < .05$ for change across all points, for all anthropometric measures, for both surgery types, with the exception of BMI percentile for adjustable gastric banding; $P < .01$ for changes between each point, with the exception of BMI and weight percentile for adjustable gastric banding between 6 and 12 months after surgery.

‡ $P < .001$ for change across all points, for all anthropometric measures between surgery types.

Results

Of the 890 eligible adolescents, about 75% were girls (mean age 18.5 yr), 68% were non-Hispanic white, 14% were Hispanic, 11% were non-Hispanic black, and 6% were "other" (Table 1). A total of 51% of the sample underwent gastric bypass surgery (99% laparoscopic) and 49% underwent adjustable gastric band surgery. At baseline, the boys were significantly heavier than the girls. Those undergoing gastric bypass surgery were significantly heavier than those undergoing adjustable gastric band surgery. Non-Hispanic whites were significantly lighter than their ethnic group counterparts (Table 1). Because of these significant baseline differences in gender and ethnic group, all subsequent analyses were adjusted for these 2 variables, in addition to age.

The patients were not eligible for follow-up analysis if they had undergone surgery shortly before our analysis. At 3 months, 88% of eligible patients were seen in follow-up (786 of 890), at 6 months, 66% of eligible patients were seen (541 of 821), and at 12 months, 37% were seen (259 of 692).

When comparing surgery types, the overall 1-year mean weight loss for those who had undergone gastric bypass surgery was more than twice that of those who had undergone adjustable gastric band surgery (48.6 versus 20 kg, $P < .001$; Table 2). Similar results were found for all other anthropometric changes and comparisons at 1 year between surgery types ($P < .001$; Table 2).

Specifically, the mean weight loss at 1 year for those who had undergone gastric bypass surgery was 48.6 kg ($P < .001$; Table 2). Similarly, the mean BMI significantly decreased by 17.1 kg/m^2 during the same period ($P < .001$). The mean weight loss at 1 year for those who underwent adjustable gastric band surgery was 19.8 kg ($P < .001$; Table 2). Similarly, the mean BMI had significantly decreased by 6.9 kg/m^2 during the same period ($P < .001$). The weight decreased the most between 3 and 6 months after surgery for those who had undergone gastric bypass surgery (21 kg) and in the first 3 months among those who had undergone adjustable band surgery (6.67 kg). Decreases in weight and BMI *Z* scores showed similar patterns (Table 2). For those undergoing gastric bypass surgery, the overall mean BMI percentile decreased from the 99.4th percentile (obese) to the 91.5th percentile (overweight) 1 year after surgery. Gastric bypass surgery resulted in a BMI percentile decrease approximately 4 times that of adjustable gastric band surgery.

Table 4
Mean anthropometric measures from morbidly obese adolescent girls 1 year after bariatric surgery performed from 2004 to 2010, by surgery type*

Variable	Preoperative	Postoperatively (mo)		
		3	6	12[†,‡]
Gastric bypass	329	292	190	85
BMI (kg/m^2)	49.63 ± .44	44.68 ± .43	37.11 ± .44	32.93 ± .47
BMI percentile	99.25 ± .03	98.81 ± .05	95.59 ± .37	89.96 ± 1.12
BMI *Z* score	2.47 ± .01	2.32 ± .01	1.90 ± .03	1.53 ± .05
BMI change (%)		−.43 ± .05	−3.64 ± .35	−9.18 ± 1.07
Weight (kg)	137.03 ± 1.37	123.47 ± 1.32	102.65 ± 1.31	90.96 ± 1.38
Weight percentile	99.57 ± .04	99.20 ± .06	95.84 ± .47	90.52 ± 1.30
Weight *Z* score	2.71 ± .01	2.54 ± .02	2.07 ± .04	1.70 ± .06
WL (kg)		13.53 ± .43	32.22 ± .73	45.66 ± 1.10
WL (%)		9.94 ± .33	25.67 ± .54	33.65 ± .67
Adjustable gastric banding	336	292	216	113
BMI (kg/m^2)	45.04 ± .34	42.51 ± .32	40.30 ± .35	38.42 ± .47
BMI percentile	98.99 ± .03	98.65 ± .05	97.81 ± .26	96.88 ± .35
BMI *Z* score	2.37 ± .01	2.27 ± .01	2.14 ± .02	2.01 ± .03
BMI change (%)		−.32 ± .02	−1.19 (.25)	−2.10 ± .33
Weight (kg)	122.57 ± 1.03	115.71 ± .98	109.83 ± 1.01	104.57 ± 1.31
Weight percentile	99.34 ± .03	99.06 ± .05	98.55 ± .12	97.43 ± .41
Weight *Z* score	2.57 ± .01	2.47 ± .02	2.35 ± .02	2.22 ± .04
WL (kg)		6.83 ± .23	12.76 ± .50	18.08 ± 1.04
WL (%)		5.56 ± .18	10.36 ± .39	14.52 ± .79

BMI = body mass index; BMI change = difference between baseline BMI percentile and BMI percentile at each measurement point; WL = estimated weight loss or difference between baseline weight in kilograms and weight at each measurement point; although the percentage of excess weight loss (calculated using the middle of the 1983 Metropolitan Life Insurance tables for a median frame + percentage of weight lost + percentage of excess BMI lost with excess >25 kg/m^2) is the standard measure used in the adult population, it is not appropriate for adolescents because the Metropolitan Life Insurance tables were designed for adults aged 25–59 years only.

Data presented as estimate ± standard error.

* Model adjusted by age, and race.

† $P < .05$ for change across all points, for all anthropometric measures, for both surgery types, with the exception of BMI percentile for adjustable gastric banding; $P < .01$ for changes between each point, with the exception of BMI and weight percentile for adjustable gastric banding between 6 and 12 months after surgery.

‡ $P < .001$ for change across all points, for all anthropometric measures between surgery types.

All anthropometric measurements significantly decreased during the study period for both boys and girls (Tables 3 and 4). Adolescent boys undergoing gastric bypass surgery lost an average of approximately 58 kg, and adolescent girls undergoing gastric bypass surgery lost an average of 45.7 kg. Adolescent boys undergoing adjustable gastric band surgery lost an average of 25.2 kg, and adolescent girls lost an average of 18.1 kg. Gastric bypass surgery resulted in a BMI percentile decrease approximately twice that of adjustable gastric band surgery among boys and >4 times that of adjustable gastric band surgery in girls.

The most prevalent preoperative co-morbidities for both gastric bypass and adjustable gastric band groups were back pain (36% and 26%, respectively) and gastroesophageal reflux disease (28% and 25%, respectively). Among the gastric bypass patients, these 2 most prevalent co-morbidities were followed by hypertension and obstructive sleep apnea (both 26%) and depression (25%). Among the adjustable gastric band patients, they were followed by depression (21%), musculoskeletal disorder (21%), and asthma (19%; Table 5). Before surgery, the gastric bypass patients were significantly more likely to have hypertension, liver disease, stress urinary incontinence, back pain, musculoskeletal disorders, psychosocial impairment, obstructive sleep apnea, and menstrual irregularities compared with adjustable gastric band patients ($P < .05$). At 1 year after surgery, the gastric bypass patients were significantly more likely to have improved lipid levels compared with the adjustable gastric band patients ($P < .05$). In general, gastric bypass patients reported more improvement than the adjustable gastric band patients in co-morbidities 1 year after surgery.

Because of the low baseline prevalence rates, the following co-morbidities were not included (and not analyzed further at follow-up): abdominal hernia (n = 11), angina (n = 12), congestive heart failure (n = 2), ischemic heart disease (n = 8), peripheral vascular disease (n = 2), gout (n = 7), decreased ambulatory functional status (n = 2), fibromyalgia (n = 4), pseudotumor cerebri (n = 23), substance abuse (n = 3), and obesity hypoventilation syndrome (n = 11).

The 120 total medical complications within 1 year after surgery included 1 death from cardiac failure 5 months after

Table 5
Percentage of change in co-morbidities among morbidly obese adolescents after treatment with bariatric surgery, by surgery type, 2004–2010

Morbidity	Before surgery (n)		12 mo after surgery (%)					
			Unchanged		Improved		Worsened	
	GB	AGB	GB	AGB	GB	AGB	GB	AGB
Cardiovascular disease								
Swelling in the legs	53 (11.67)	37 (8.49)	46.2	50.0	46.2	44.4	7.7	5.6
Hypertension	118 (25.99)*	80 (18.35)*	32.1	42.9	60.7	54.3	7.1	2.9
Gastrointestinal system								
GERD	127 (27.97)	109 (25.00)	32.4	47.6	61.8	45.2	5.9	7.1
Liver disease	25 (5.51)*	11 (2.52)*	33.3	50.0	55.6	33.3	11.1	16.7
General								
Abdominal skin irritation	17 (3.74)	22 (5.05)	37.5	80.0	37.5	20.0	25.0	.0
SUI	31 (6.83)*	12 (2.75)*	22.2	50.0	66.7	50.0	11.1	.0
Metabolic-related								
Diabetes	67 (14.76)	65 (14.91)	14.3	40.9	78.6	59.1	7.1	.0
Hyperlipidemia	65 (14.32)	61 (13.99)	29.4*	76.7*	58.8*	23.3*	11.8	.0
Musculoskeletal system								
Back pain	162 (35.68)*	113 (25.92)*	48.8	45.0	51.2	50.0	.0	5.0
Musculoskeletal disorder	127 (27.97)*	90 (20.64)*	29.2	55.9	70.8	44.1	.0	.0
Psychosocial/behavioral								
Alcohol use	43 (9.47)	37 (8.49)	58.3	77.8	25.0	11.1	16.7	11.1
Depression	115 (25.33)	93 (21.33)	60.9	47.2	34.8	41.7	4.3	11.1
Psychosocial impairment	52 (11.45)*	32 (7.34)*	66.7	81.8	25.0	.0	8.3	18.2
Tobacco use	25 (5.51)	20 (4.59)	50.0	100.0	37.5	.0	12.5	.0
Pulmonary system								
Asthma	94 (20.70)	84 (19.27)	60.0	71.0	40.0	22.6	.0	6.5
OSA	117 (25.77)*	80 (18.35)*	43.3	46.2	56.7	46.2	.0	7.7
Pulmonary hypertension	17 (3.74)	8 (1.83)	16.7	60.0	66.7	40.0	16.7	.0
Reproductive system								
Menstrual irregularity	85 (18.72)*	50 (11.47)*	53.6	62.5	32.1	37.5	14.3	.0
Polycystic ovarian syndrome	41 (9.03)	45 (10.32)	58.3	68.8	33.3	31.3	8.3	.0

GB = gastric bypass; AGB = adjustable gastric banding; GERD = gastroesophageal reflux disease; SUI = stress urinary incontinence; OSA = obstructive sleep apnea.

Data in parentheses are percentages.

* $P < .05$.

gastric bypass surgery. The most common complication for both surgery types was gastrointestinal (n = 29 for gastric bypass patients, n = 9 for adjustable gastric band patients) followed by nutritional deficiencies among those undergoing gastric bypass (n = 24) and device-related issues among those undergoing adjustable gastric banding (n = 5; Table 6). A total of 45 readmissions occurred among gastric bypass patients and 10 among adjustable gastric band patients, with 29 and 8 reoperations required, respectively.

Table 6
Complications within 1 year after surgery, by surgery type among 890 morbidly obese adolescents undergoing bariatric surgery from 2002 to 2010

Variable	GB (n = 454)	AGB (n = 436)
Complication		
Gastrointestinal system*	29 (29.6)	9 (41)
Nutritional deficiency†	24 (24.5)	2 (9.1)
Surgical (bleeding/hemorrhage, intra-abdominal)	3 (3.1)	1 (4.5)
General (obstruction, abscess, internal hernia)	16 (16.3)	2 (9.1)
Band (port revision, removal, replacement)‡	0 (0.0)	3 (13.6)
Pulmonary system (pneumonia, pulmonary embolism)	7 (7.1)	0 (0.0)
Device-related	8 (8.2)	5 (22.7)
Skin or soft tissue	3 (3.1)	0 (0.0)
Death (from cardiac failure 6 mo after surgery)	1 (1)	0 (0.0)
Endocrine/metabolic system	3 (3.1)	0 (0.0)
Infection (at surgical site)	1 (1)	0 (0.0)
Renal or genitourinary system	1 (1)	0 (0.0)
Arrhythmia	2 (2)	0 (0.0)
Total§	98 (21.6)	22 (5)
Readmissions required	45 (9.9)	10 (2.3)
Reoperation required	29 (6.4)	8 (1.8)
Reason for reoperation		
Cholecystectomy	6 (20.8)	2 (25)
Other‖	7 (24.1)	0 (0.0)
EGD with dilation	6 (20.8)	0 (0.0)
Hernia repair, internal	5 (17.2)	0 (0.0)
Band replacement	0 (0.0)	2 (25)
Band, port revision	0 (0.0)	2 (25)
Band, removal	0 (0.0)	2 (25)
Small bowel obstruction, repair	2 (6.9)	0 (0.0)
Gastric tube, placement	1 (3.4)	0 (0.0)
Hernia repair, umbilical	1 (3.4)	0 (0.0)
Wound, debridement	1 (3.4)	0 (0.0)
Total	29 (6.4)	8 (1.8)

GB = gastric bypass; AGB = adjustable gastric banding; EGD = esophagogastroduodenoscopy; LOA = lysis of adhesions.

Data presented as numbers, with percentages in parentheses.

* Nausea or vomiting, intestinal bleeding, diarrhea, gallstones.

† Vitamins A, B_{12}, D, folate, iron, magnesium, zinc, electrolytes.

‡ Slippage (n = 10,7.1%), stricture (n = 6, 4.3%; categories not mutually exclusive).

§ Adverse event rate significantly different between gastric bypass and adjustable gastric band groups (20.33% versus 5.10%, respectively).

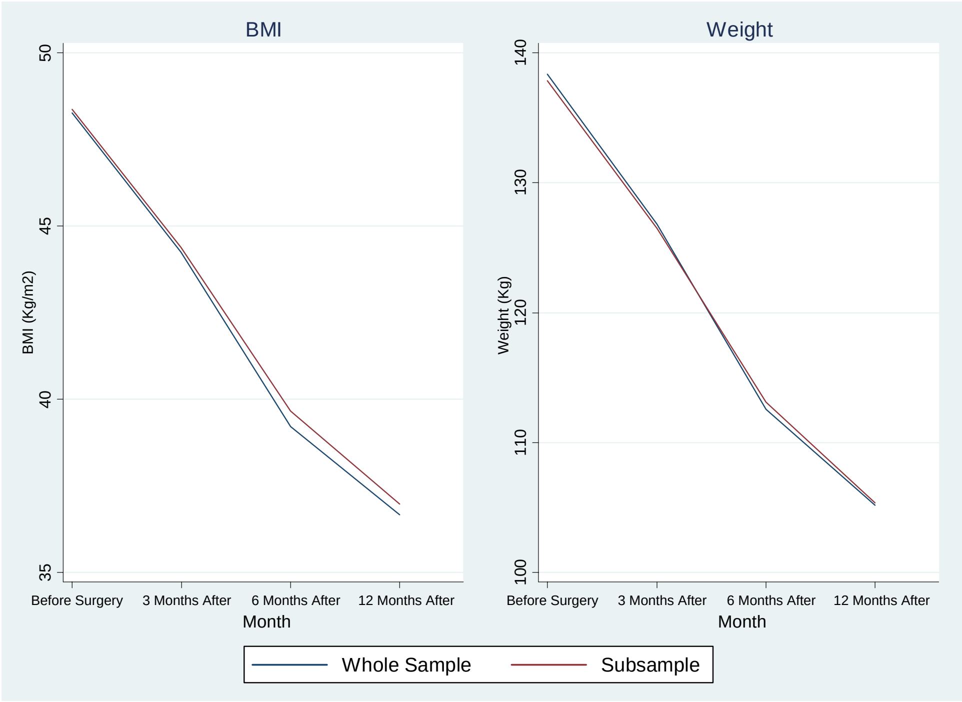
‖ Abdominal pain, internal hernia, repair of lapband tubing, diagnostic laparoscopy, LOA, parenteral hernia repair, gastroparesis internal hernia, repair of lapband tubing.

Analysis using the mixed-model approach to test for any selection bias between the whole sample (n = 890) and a subsample (n = 226) of patients for whom data from all 4 points were available, including an indicator variable for complete or incomplete data [23], showed that the 2 samples did not differ in BMI or weight outcomes or between the proportion of boys and girls (Figs. 1 and 2).

Discussion

In a large and diverse sample of multiethnic, morbidly obese adolescents, we found substantial decreases in weight and co-morbidities 1 year after bariatric surgery. Surgery resulted in an average weight loss of >30 kg per person, a loss far exceeding those reported in nonsurgical weight-management programs [24–26]. The overall 1-year mean weight loss for those who underwent gastric bypass surgery was more than twice that of those who underwent adjustable gastric band surgery (48.6 versus 20 kg). Similar results were found for all other anthropometric changes and comparisons at 1 year between surgery types. Surgery also reduced the weight and BMI among both males and females. Additionally, several physical and mental health co-morbidities resolved or had improved substantially 1 year after surgery, suggesting an improvement in quality of life. This substantial improvement in co-morbidities 1 year after bariatric surgery has not been documented for other treatment options nor with this number of adolescent patients [27,28]. Approximately 10% of gastric bypass patients and 2% of adjustable gastric band patients required readmission for a variety of causes. Of these readmissions, 6% of those who underwent gastric bypass and <2% of those who underwent adjustable gastric banding required reoperation (also for a variety of reasons). Our findings indicate that bariatric surgery can be a safe and effective treatment option for morbid obesity and its ensuing co-morbidities in adolescents [29].

Although the childhood obesity epidemic continues unabated in most developed countries, nonsurgical approaches to the long-term (≥1 yr) management and decrease of overweight in childhood have had limited success [23]. Despite standardized criteria for qualifying adolescents for bariatric surgery [29], obese children are not simply younger versions of obese adults; they are still developing and growing, both physically and psychologically. Extreme obesity should be treated sooner rather than later [30], in particular, in adolescents who may have not yet developed full-blown, obesity-related co-morbidities, such as diabetes or heart disease. However, the optimal point in adolescence for bariatric surgery is as yet unknown [31]. Our findings support those of others [32,33] reporting that bariatric surgery before adulthood can result in substantial weight loss and resolution of co-morbidities [34] and thus improve overall quality of life. Moreover, earlier treatment of obesity could prevent later costs. For example, children and adoles-



***The difference between the two groups was not statistically significant for either BMI or weight.**

Fig. 1. Change in mean BMI and weight for entire sample (n = 890) and subsample with complete data (n = 226) for morbidly obese adolescents after bariatric surgery performed from 2004 to 2010.

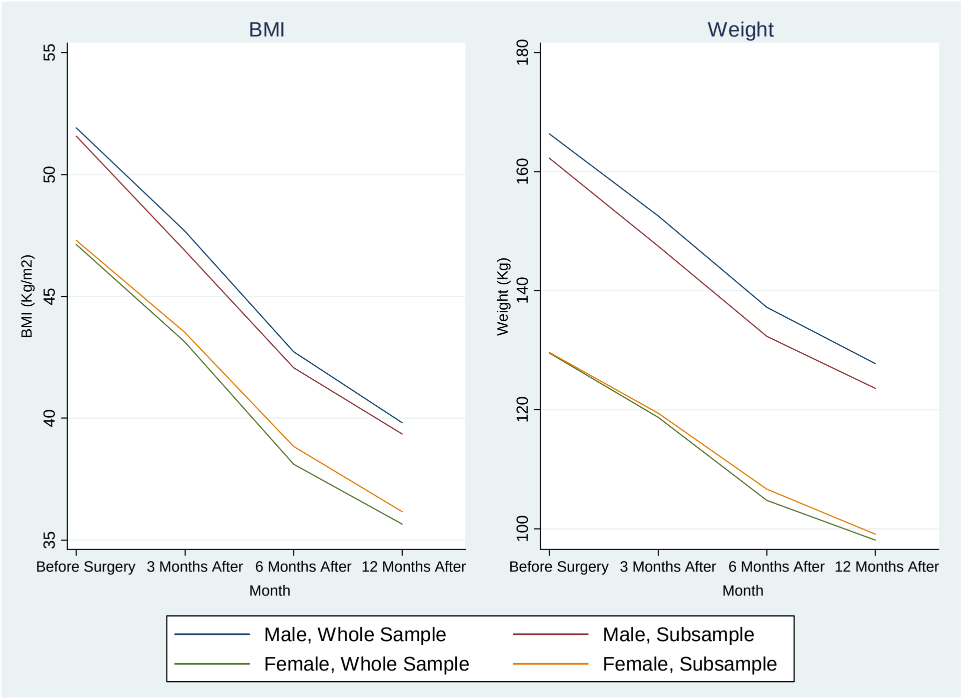
cents with a primary or secondary diagnosis of overweight, obesity, or morbid obesity require longer hospital stays than do children without these diagnoses [35].

Even as the emerging data on bariatric surgery, including those from randomized controlled trials [32], continue to show important long-term weight loss and improvement in most obesity-related co-morbidities, many pediatric specialists are hesitant to refer patients for surgery. A survey of pediatricians in the United States showed that although they believed pediatric obesity to be a major problem, fewer than one half would be somewhat or very likely to refer an adolescent for surgery [30]. The medical community must strive to provide additional data on the long-term results after bariatric surgery, in both adults and adolescents.

Our study had some limitations. The data entered into BOLD by BSCOE participants are reported by participating surgeons and surgical practices on all postdischarge complications, even if another healthcare provider manages these complications. Thus, complications are potentially underrepresented in the database. Variations in practice management among BSCOE participants might delay data entry, potentially resulting in incomplete follow-up data.

Another limitation was the lack of sensitivity of the Assessment of Obesity Related Co-Morbidities Severity Scoring System, which most likely reduced the accuracy of assessing the severity of co-morbidities in our analysis. Specifically, the current scoring system indicates improvement in some co-morbidities only when there is a major change in the treatment type. For example, patients with diabetes might decrease the number of oral medications they take from 2 to 1, with a marked improvement in hemoglobin A1c, without improving their stratification score. Additionally, preoperative information on nutritional deficiencies is not available to determine whether surgery was the cause of the deficiency or whether deficiencies existed before surgery.

Additionally, our findings and conclusions are limited by missing follow-up data, a common problem reported in the bariatric data. Because of potential selection bias caused by losses to follow-up, we tested the differences between the entire sample and the subsample with follow-up data at all points and found no differences. This finding supports the external validity of our overall conclusions. Also, unless the surgeon obtained follow-up data from the patient's pediatrician and included these data in medical charts at the surgeon's practice, the SRC does not independently verify additional follow-up occurring outside the office. Moreover, older adolescents, in particular, are difficult to monitor because they might leave the geographic area for education or employment. More age-relevant tracking procedures, such as those using social media or handheld or cellular telephone devices, might be able to decrease the losses to follow-up. Recognizing this challenge, the ASMBS Pediat-



*All pairwise group differences were not significant.

Fig. 2. Change in mean BMI and weight for entire sample (n = 890) and subsample with complete data (n = 226) for morbidly obese adolescents 1 year after bariatric surgery performed from 2004 to 2010 by gender.

ric Committee has formed a subcommittee to explore the development of a Pediatric/Adolescent Center of Excellence program that will include a pediatrician component and a more flexible mechanism for collecting long-term data on adolescent patients. Nevertheless, the present initial observational study of adolescents treated at BSCOEs has provided a valuable snapshot of the adolescent bariatric surgery outcomes in a diverse population.

Additionally, it should be noted that of the 10% of charts that were audited at each BSCOE site every 3 years, it is possible that adolescents were not represented, because not all sites perform surgery on adolescent patients. Patients identified from the hospital surgery list who were outside the National Institutes of Health criteria or who were high risk were given greater consideration for inclusion in the 10% of charts identified for review, but it is possible that not all adolescent charts were audited.

Finally, BOLD does not include dietary, exercise, and/or lifestyle behavior modification, which were or were not implemented as a part of the patient's treatment during the pre- or postoperative period; thus, it was not possible to analyze how these factors contributed to the outcomes.

Conclusions

The weight loss at 3, 6, and 12 months after surgery was approximately double in adolescent boys and girls who underwent gastric bypass surgery than in those who underwent adjustable gastric band surgery. Our results support the conclusion that bariatric surgery can safely and substantially reduce the weight and related co-morbidities in morbidly obese, multiethnic adolescents for ≥1 year. The BOLD database and those like it are important in studying the long-term effects of bariatric surgery in this population. Multi-institutional, prospective data and studies are necessary to determine the outcomes of surgical responses to the obesity epidemic. With this longitudinal data, the questions of which patient groups, which surgical procedures, and when surgery should be performed can be answered.

Disclosures

Dr. de la Cruz-Munoz is a consultant and proctor for Ethicon EndoSurgery, which manufactures equipment for performing bariatric surgery. No conflicts of interest to report for all other authors. The National Institutes of Health had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all data and had final responsibility to submit this report for publication after it had been approved by the Surgical Review Corporation and co-authors.

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