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Impact of Socioeconomic Status on Adolescent Bariatric Surgery Outcomes in a Quaternary Pediatric Hospital

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ABSTRACT

Background: Research on the impact of socioeconomic characteristics on bariatric surgical outcomes in adolescents and young adults is limited.

Objectives: To determine whether race, household income, or insurance type impacted body mass index (BMI) at time of surgery and weight loss at 1 year post-surgery.

Methods: Adolescents and young adults who underwent bariatric surgery at a single center (Boston Children's Hospital) between 2011 and 2019 were retrospectively reviewed. The primary outcome was BMI percentile at time of surgery and one and 2 years post-surgery.

Results: Among 54 subjects, 83% were female. Racially, 56% were White, 33% were Hispanic, 9% were Black, and 2% were Chinese (cumulatively referred to as people of color [POC]). 22% were publicly insured. There was no statistical difference in BMI at time of neither surgery, nor weight loss at 1 year for subjects on public vs. private insurance, nor by household income. BMI for POC subjects was 8.5% higher than for White subjects' at time of surgery and 1 year post-op (P=0.02).

Conclusion: Relative to the pool of adolescents and young adults with obesity, our patients were disproportionately female, White, and privately insured, suggesting disparities in surgical access. POC subjects demonstrated less post-surgery weight loss than White subjects, but other socioeconomic variables did not impact weight loss.

Keywords: Adulthood; Weight loss; BMI; Surgery

INTRODUCTION

The prevalence of severe pediatric obesity, defined as a BMI 120% or more than the 95th BMI percentile continues to rise, affecting nearly 6% of children and teens in the United States. Obesity related conditions, including type 2 diabetes mellitus, hypertension, obstructive sleep apnea, and non-alcoholic fatty liver disease are likewise increasing in prevalence. Because 88% of adolescents with BMI>99th percentile remain obese in adulthood, there is an urgent need to develop effective, accessible treatments for pediatric obesity. Adolescents with severe obesity demonstrate minimal change in BMI with lifestyle interventions and there are few FDA-approved pharmacologic options for adolescents. Bariatric surgery in adolescents results in durable weight loss of nearly 30% of pre-surgical BMI, along with resolution of comorbidities such as hypertension and type 2 diabetes mellitus [1-4].

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Although pediatric bariatric surgeries are becoming more common, with the rate of such surgeries increasing 1.8 fold from 2012 to 2016, less than 0.4% of pediatric patients eligible for the surgery undergo it (similar to the 0.5% utilization rate among eligible adults) and pediatric weight loss surgery makes up <1% of total weight loss surgeries in the US each year. However, there is a growing evidence base that bariatric surgery is effective in the management of severe pediatric obesity and obesity related conditions [4-9].

Disparities in access are key drivers of the discrepancy between those eligible for weight loss surgery and those who receive it. It is well documented that the prevalence of pediatric obesity is disproportionately higher among those on public insurance (39.6% of publically insured children have obesity vs. 26.7% of privately insured). However, public insurance plans of 44 states cover bariatric surgery among adults, and all states are required to cover all "medically necessary" services for comprehensive obesity services through the Early and Periodic Screening, Diagnostic, and Treatment (EPSDT) program. Despite this apparent accessibility to surgical weight management, a recent survey of the National Inpatient Sample, representing nearly 20% of all hospital discharges, found that 72.8% of adult patients undergoing bariatric surgery were privately insured. In the pediatric population, similarly, approximately 80% of patients undergoing bariatric surgery are privately insured. Furthermore, independent of insurance type, adolescents seeking bariatric surgery appear to face additional barriers to care, with one study reporting that fewer than half of adolescents who met clinical criteria for surgery received insurance approval on their first request, as opposed to over 80% of adults [8,10-13].

In addition to socioeconomic barriers, there are also racial and sex disparities in access to bariatric surgery, with White adolescents undergoing bariatric surgeries 2.5 times more frequently than Black and Hispanic patients, despite severe obesity being more prevalent in these populations. Finally, among both adults and adolescents, male patients are less likely to be referred for bariatric surgery than female patients [14-16].

Alongside inequities in access, there are well-documented disparities in surgical outcomes by socioeconomic status among adults undergoing bariatric surgery. For example, a large national case control study of adult patients undergoing bariatric surgery demonstrated that publicly insured patients have an increased risk of complications compared to privately insured patients, an effect that is not mediated solely by access to care. In adults, studies suggest that Black patients have lower weight loss at one year than White patients, independent of income or payer type, although this finding was not consistent among adolescents [14,17,18].

Given that the majority of the literature in adolescent bariatric surgery relies on administrative databases, there is a paucity of evidence regarding granular, patient level outcomes by socioeconomic status. This study aimed to characterize the population of adolescents undergoing bariatric surgery at a single, large, quaternary pediatric hospital between 2011 and 2019. We investigated whether BMI at time of referral for surgery and at one year post-surgery varied based on race, sex, household income, and insurance type (public vs. private).

METHODS

This was a retrospective, single-arm cohort study of all adolescents who underwent bariatric surgery at Boston Children's Hospital between October 2011 and January 2019. Demographic and clinical data was abstracted from the electronic medical record. Median household income, census tract minority percentage, and census tract poverty percentage were determined using the Federal Financial Institutions Examination Council geocoding system based on the census tract and the patient's address. Race was determined by self-report during registration. Insurance type (private vs. public) was determined by the patient's primary insurance at time of surgery. The decision to use the insurance on record at time of surgery was due to the high frequency of patients who reported different insurance payers from the time of initial visit to time of surgery. The primary outcome assessed was BMI as a percent of the 95th percentile of BMI for age at time of surgery and one year post-surgery, based on the Centers for Disease Control growth charts.

Statistical Methods

Categorical variables are summarized by frequency count and percentage and compared across dichotomous groups by Fisher exact test. Continuous variables are summarized as mean ± standard deviation (SD) and compared across dichotomous groups by Student's t-test. The primary outcome, % of the 95th percentile of BMI for age, was calculated using CDC growth charts and the SAS program provided at www.cdc.gov. Height and weight measurements were obtained at clinic visits from the time of the initial visit until up to 2 years post-surgery; however, due to the sparsity of data, the analysis was limited to anthropometry measurements obtained between 30 months pre-surgery and 12 months post-surgery. Beyond these limits, the number of observations available for subjects with public insurance is <5 within any 6 month interval.

The primary outcome was modelled over time with a repeated measures random intercept generalized linear model with cubic B-splines and knots at 6 months prior to surgery, the time of surgery, and 6 months post-surgery. The shape of the model and placement of knots was informed by a nonparametric locally weighted scatterplot smoothing (LOESS) regression. Changes over time were adjusted for outcome at the initial clinic visit and were evaluated for the main effect of insurance type as well as an interaction effect for insurance type by time. Comparison of more than two groups was adjusted for multiplicity by Holm's step down Bonferroni surgery. All point estimates are presented with 95% confidence interval (95% CI), with P<0.05 considered statistically significant. Statistical analysis was performed with SAS version 9.4 (Cary, NC).

RESULTS

Demographics

A total of 55 patients underwent bariatric surgery at our centre from 10/31/2011 to 01/04/2019. One subject who underwent an experimental endoscopic sleeve gastrectomy surgery was excluded from analysis. Patient characteristics are reported in **Table 1**. The majority (n=45, 83%) were female. 24 patients (44%) were

Black, Latino/a, and Asian people of color (POC). The age at initial visit ranged from 13.7-22.9 years (mean 17.2 ± 1.8). The majority were privately insured at time of surgery (n=42, 78%) with a mean census tract household income of $ 88,337 ± 38,390.

Table 1: Subject, family, and surgical characteristics (n=54).

Characteristics	Overall (n=54)	Public (n=12)	Private (n=42)	P
	Subject			
Female sex	45 (83%)	10 (83%)	35 (83%)	1
People of Color1	24 (44%)	5 (42%)	19 (45%)	1
Age at initial visit (y), (range 13.7-22.9)	17.2 ± 1.8	17.3 ± 1.0	17.2 ± 1.9	0.81
	Family			
Household income ($) (range $ 14,634-172,941)	88,337 ± 38,390	72,454 ± 42,497	93,390 ± 36,344	0.23
<$ 75,000	14 (26%)	5 (42%)	9 (21%)	
$ 75,000-$ 100,000	21 (39%)	5 (42%)	16 (38%)	
$ 100,000 +	19 (35%)	2 (17%)	17 (40%)	
Number of insurance plans on the date of initial visit (n=1 unknown)				0.25
1	24 (45%)	7 (64%)	17 (40%)	
2	21 (40%)	4 (36%)	17 (40%)	
3	8 (15%)	0 (0%)	8 (19%)	
Number of insurance plans on the date of surgery (n=2 unknown)				0.002
1	30 (58%)	12 (100%)	18 (45%)	
2	18 (35%)	0 (0%)	18 (45%)	
3	4 (8%)	0 (0%)	4 (10%)	
	Surgery			
Months from initial visit until surgery (range 3.9-34.9)	11.7 ± 7.0	12.1 ± 5.5	11.5 ± 7.4	0.82
Age at surgery (y), (range 14.4-24.0)	18.2 ± 1.9	18.3 ± 1.1	18.2 ± 2.0	0.75
Type of surgery				0.74
Sleeve	31 (57%)	6 (50%)	25 (60%)	
Bypass	23 (43%)	6 (50%)	17 (40%)	
No. of overnights, n=1 unknown	2.8 ± 0.7	3.0 ± 0.9	2.8 ± 0.7	0.32
1	1 (2%)	0 (0%)	1 (2%)	
2	17 (32%)	4 (33%)	13 (32%)	
3	26 (49%)	4 (33%)	22 (54%)	
4	9 (17%)	4 (33%)	5 (12%)	

[1]Includes Black (n=5), Hispanic (n=18), and Chinese (n=1).

Pre-Surgical Process and Surgical Length of Stay

The average number of months from initial visit to surgery was 11.7 ± 7.0 and did not vary significantly between publicly and privately insured patients. However, as reported in **Table 2**, younger patients had fewer months from initial visit until surgery (9.4 ± 4.5 months for patients aged 14-17 y vs. 14.5 ± 8.4 months for patients aged 18-24 y, P=0.01). The type of surgery did not vary by payer type. The type of surgery, RYGB vs. sleeve gastrectomy was similar across the cohort with a small majority undergoing sleeve gastrectomy (n=31, 57%). The average length of stay following surgery was 2.8 ± 0.7 nights and did not vary by payer type.

Table 2: Subject, family, and surgical characteristics by age at the time of surgery (n=54).

Characteristics	14-17y (n=30)	18-24 y (n=24)	P
	Subject		
Female sex	24 (80%)	21 (88%)	0.7
POC	12 (40%)	12 (50%)	0.6
	Family		
Household income ($), mean ± SD	91,210 ± 43,279	85,647 ± 31,884	0.6
<$ 75,000	9 (30%)	5 (21%)	
$ 75,000-$ 100,000	9 (30%)	12 (50%)	

$ 100,000 or more	12 (40%)	7 (29%)	
Number of insurance plans on the date of surgery (n=2 unknown)			0.7
1	16 (57%)	14 (58%)	
2	9 (32%)	9 (38%)	
3	3 (11%)	1 (4%)	
Public insurance (vs. private)	6 (20%)	6 (25%)	0.8
Surgery			
Months from initial visit until surgery, mean ± SD	9.4 ± 4.5	14.5 ± 8.4	0
Sleeve (vs. Bypass) Surgery	17 (57%)	14 (58%)	1
No. of overnights, n=1 unknown			0.6
1	1 (3%)	0 (0%)	
2	11 (38%)	6 (25%)	
3	13 (45%)	13 (54%)	
4	4 (14%)	5 (21%)	

Post-Surgery BMI Outcomes

Based on the repeated measures model, the mean (95% confidence interval) among all patients combined for percentage of 95th percentile for BMI was 159% (155%-163%) at 3 months prior to surgery (a time point which for which all patients were enrolled for medically supervised weight loss, and thus had data available) and 149% (145%-153%) at the time of surgery. This fell to 108% (104%-113%) at 6 months post-surgery (Figure 1).

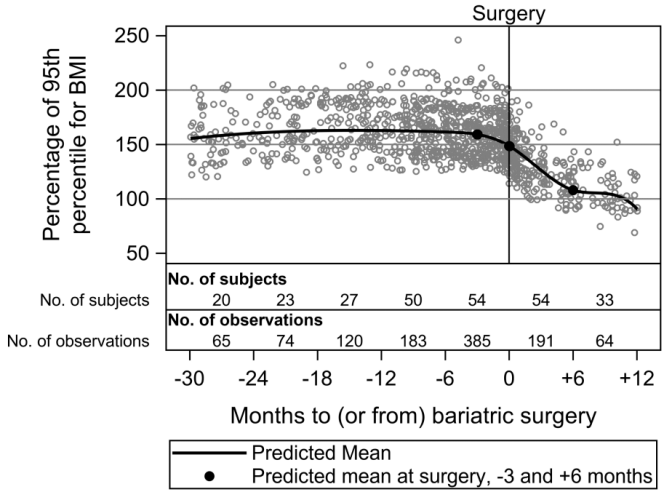

Figure 1: Change in percent of 95th percentile for BMI for all patients.

The change in BMI did not vary for: publicly insured vs. privately insured patients (P=0.93) (Figure 2), census tract household income (P=0.81) (Figure 3), sex, age, type of surgery, or length of stay (Table 3). As compared to White patients, POC patients demonstrated a mean % of 95th percentile for BMI change that was 8.5% lower (95% confidence interval 1.4%-15.5%), P=0.02 (Figure 4 and Table 2). Similarly, patients from a census tract with a racial minority percentage ≥ 40% had a mean percentage of 95th percentile for BMI change that was 8.3% lower than those from a census tract with a minority percentage <40% (95% confidence interval 0.7% to 15.8%), P=0.03 (Table 2). Patients older than 18 years old had a mean percentage of 95th percentile for BMI change that was 7.0% lower than those under 18 years (95% confidence interval 0.1% to 14.0%), P=0.05 (Table 2), although there was not a monotonically increasing effect when looking at the age by tertiles and the evidence of an effect by age is thus weak.

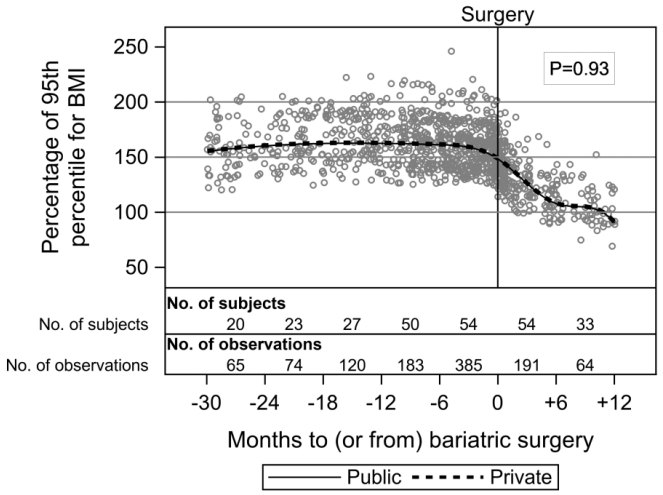

Figure 2: Change in percent of 95th percentile for BMI over time for publicly insured vs. privately insured patients.

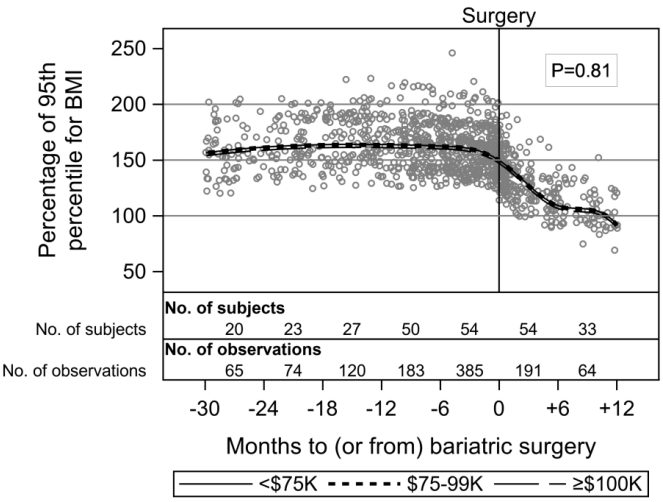

Figure 3: Change in percent of 95th percentile for BMI over time by census tract household income.

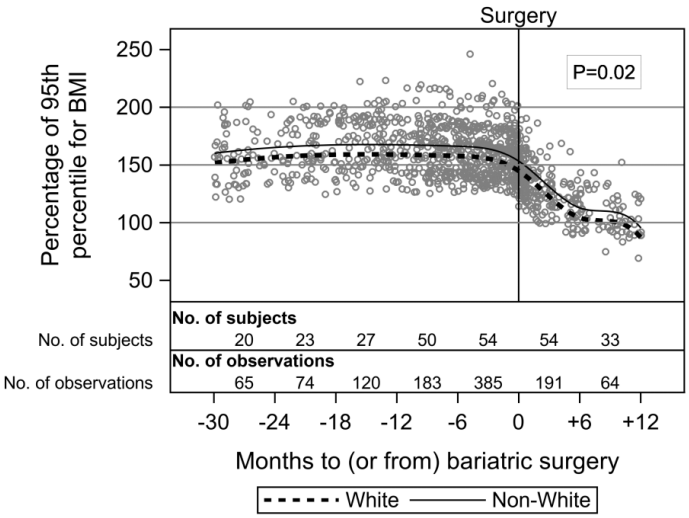

Figure 4: Change in percent of 95th percentile for BMI over time for Non-White vs. White patients

Table 3: Effect of covariates on change in percentage of 95th percentile for BMI.

Covariate	Difference (95% CI)	P
Sex (ref. female)	2.5 (-6.0, 10.9)	0.6
Race (ref. white)	8.5 (1.4, 15.5)	0
Age ≥ 18y at surgery (ref. <18y)	7.0 (0.1, 14.0)	0.1
Household income*	-	0.8
$ 75,000-<$ 100,000 (ref. <$ 75,000)	-0.5 (-10.2, 9.3)	
≥ $ 100,000 (ref. <$ 75,000)	-2.8 (-12.6, 7.0)	
≥ $ 100,000 (ref.$ 75,000-<$ 100,000))	-2.3 (-10.6, 6.0)	
Census tract minority percentage ≥ 40% (ref. <40%)	8.3 (0.7, 15.8)	0
Census tract poverty percentage ≥ 10% (ref. <10%)	-5.9 (-13.1, 1.4)	0.1
Sleeve surgery (ref. bypass)	-0.2 (-8.2, 7.7)	1
Length of stay at surgery	-	0.6
3 days (ref. 2 days)	3.6 (-3.8, 11.0)	
4 days (ref. 2 days)	1.5 (-10.3, 13.3)	
4 days (ref. 3 days)	-2.1 (-13.9, 9.6)	
Number of post-op visits	beta=-0.5 ± 0.6	0.4

*Household income estimated by Federal Financial Institutions Examination Council (FIFEC) census tract data for patient's zip code at time of surgery

DISCUSSION

The pediatric obesity epidemic continues unabated, but disproportionately affects those least able to access high-quality healthcare. Within the obesity epidemic overall, the most severe form of obesity, Class III obesity, defined as BMI>140% of the 95%, has doubled in prevalence from approximately 1% in 2000 to nearly 2% of the population now. The socioeconomic and racial/ethnic disparities within the pediatric obesity epidemic are persistent and the magnitude of these disparities is growing, with obesity prevalence increasing more rapidly among children that are Hispanic versus White, and among children from low-income, low-education households. There has been a recent effort to advance bariatric surgery as an option for youth with severe obesity, with the American Academy of Pediatrics recently endorsing the surgery as safe and effective. However, there is growing recognition that, if only children with private insurance and higher socioeconomic status can access bariatric surgery, the surgery may ultimately exacerbate inequity. It is therefore incumbent upon centers performing pediatric bariatric surgery to ensure they are reaching the populations most impacted by severe obesity. In this study, we report the demographics of our centre's surgical patients from 2011-2019, and their weight loss at one year post-surgery by race, household income, and payer type [1,9,19].

We report that 83% of patients were female, a skewed proportion relative to the national pool of adolescents and young adults eligible for bariatric surgery, but mirroring the sex disparities reported elsewhere in the adolescent and adult literature. One large, multi-center study found that, among adolescents, severe obesity was disproportionally enriched in females as compared to males (61% vs. 39%, respectively) but our population, like those reported by large national databases of adolescent surgery, reflects an even larger imbalance by sex in those who undergo surgery

versus those who qualify for it. Similarly, in multiple large adult studies, although men comprise nearly 40% of those eligible for surgery, they represent only 20% of the population who undergo surgery. The reasons for this disparity are multifactorial, likely stemming partially from strong cultural pressures for women and girls to seek thinness [20-24].

In addition to disparities by sex, racial disparities in bariatric surgery access have been reported. For example, White adults are more than 1.5 times as likely to undergo bariatric surgery as patients from other races. In a large national cohort of pediatric bariatric patients (to which our center contributes), 60%-70% were White. Our population was slightly more than half (54%) White, mirroring these national trends. Of note, more than 40% of the residents of Boston, the city in which our center is located, are Black or Hispanic, and the prevalence of obesity among Black and Hispanic adults in Boston is nearly twice that of White adults. The drivers of this racial disparity in access to bariatric surgery are multifactorial, including differing attitudes toward and education about bariatric surgery by race, decreased likelihood of PCP referral to surgery of Black and Hispanic patients relative to White patients, and increased likelihood of racial minorities to be publically insured relative to White patients. Differential insurance status by race is important because multiple studies have demonstrated that patients with private insurance are significantly more likely to undergo bariatric surgery and have better outcomes than patients with public insurance. We report that only 12/54 (22%) of the patients who underwent bariatric surgery at our center were solely covered by public insurance at time of surgery (**Table 1**). This proportion is not representative of insurance coverage of the overall pool of patients who meet clinical criteria for bariatric surgery, most of whom have public insurance.. Although public insurance in Massachusetts, where our center is located, covers bariatric surgery, patients with public insurance often face barriers including insurance denials which they may be inadequately resourced to appeal. Additionally, qualifying for bariatric surgery typically requires six months of supervised medical weight loss management, including frequent visits which may represent an untenable burden to patients of lower financial means and prevent them from sucessfully completing pre-surgery programs [9,10,13,25-34].

With regards to outcomes, we found no difference in weight loss trajectory by sex (**Table 3**), suggesting that weight loss surgery is equally effective in young females and males and pointing to the need for increased awareness of and access to this surgery among male adolescents and young adults. This is in line with the adult literature on bariatric surtery outcomes, which largely reports no difference in weight loss by sex [35].

We additionally found that POC patients had less weight loss relative to White patients post-surgery, with no difference by surgery type. Since the weight loss curves generated by our model are parallel, the differences in weight loss by race are likely attributable to POC patients presenting at heavier weights overall, rather than suggesting some physiologically different response to bariatric surgery by race. In the adult literature, White patients have a higher percentage of excess weight loss than do Black or Hispanic patients with Roux-en-Y gastric bypass, but not with sleeve gastrectomy, potentially due to bypass being preferentially performed among patients with increased comorbidities. Cultural factors may contribute to decreased weight loss among POC patients. These factors including meal sharing within extended families among Hispanic communities and the valuing of larger body types in POC populations. Systemic racism, which has resulted in POC populations living in neighbourhoods that have built environments that do not promote physical activity and low availability of healthy foods also likely drives poorer weight loss outcomes for POC patients. Other potential reasons for this discrepancy in weight loss by race may be related to the limitations of BMI measurement (i.e., for a given BMI, White children have greater body fatness than Black children) or indicative of the need for greater support and follow-up post-surgery for minority children at our center [36-40].

Finally, we found no difference in change in BMI over time by either insurance status (publicly insured vs. privately insured) or by census tract average annual household income (>$ 75,000 vs. <$ 75,000) (Figures 2 and 3). This is in keeping with the adult literature, which suggests that public insurance status itself is not associated with poor weight loss outcomes, after controlling for race. The lack of differences in weight loss at one year by these markers of socioeconomic status suggests that bariatric surgery is effective, at least in the short-term, for patients regardless of payer or household income, and highlights the need to engage publicly insured patients in bariatric surgery centers.

Our study has several strengths and limitations. The strengths of our study include the granularity of the anthropometric data over time, permitting a robust model of weight change by various demographic and socioeconomic markers in a relatively limited patient population. The standardized follow up in our center permits comparison of matched weights over time. Many other studies reporting disparities in obesity outcomes rely on administrative databases that do not include this level of detail. However, our study is retrospective and from single center with a relatively small number of patients, and may thus be underpowered to detect differential outcomes for certain variables. Given the lack of patient reported income data, we, like other authors, used census code zip code as a proxy for income, which may obscure patient level variability within zip codes? Finally, our primary outcome of weight loss at one year is short-term and may not reflect long term results. The one year cut off was necessary to ensure a robust data set, given significant attrition to long-term follow up, a common challenge of working with young adults undergoing bariatric surgery. However, recent data suggests that short-term weight loss outcomes are useful predictors of long-term success, as the majority of weight loss among adolescents and young adults undergoing bariatric surgery takes place within the first year after surgery and short-term metrics such as greater % excess weight loss at three months can predict the long-term durability of weight loss.

CONCLUSION

In conclusion, we report that our centers demographic data echoes that of a nationally representative sample of adults demonstrating that the majority of bariatric surgeries are performed in White, privately insured patients, although those eligible for bariatric surgery have lower family incomes, lower education levels, and greater proportion of POC race than those not eligible for surgery. Our results point to several potential areas for quality improvement and further research. Most notably, our center and other bariatric centers like it must strive to under-

stand the referral patterns and patient access issues that drive the population of surgical patients to differ significantly from the overall population of eligible patients with severe obesity. Many paediatricians remain reticent to refer adolescents for bariatric surgery regardless of race or socioeconomic status. The adult literature demonstrates, however, that patients who have been recommended bariatric surgery by their physicians are nearly five times as likely to undergo surgery than those whose physicians do not recommend it, and that men and patients who are Black are less likely to be referred for surgery than are women and patients who are White. Similarly, one study found that 85% of parents counselled by their paediatrician about bariatric surgery would consider it for their child, compared to only 35% of parents who did not receive counselling. It is clear, therefore, that education of primary care providers will be a key tool to ensure that all patients, including/especially those who are POC, male, and/or publicly insured have equal access to bariatric surgery. Additionally, insurance reform must provide coverage for bariatric surgery in medically qualified patients.

Our institution, like many other pediatric academic hospitals nationwide, recently announced the establishment of an institute for health equity. Given the clear benefits of bariatric surgery for severe obesity, the disproportionate burden of severe obesity on already marginalized populations, and the multifactorial nature of barriers to accessing bariatric surgery, the field of Pediatrics has a profound opportunity to advance health justice by diversifying the population of patients who have access to this life-saving intervention.

AUTHOR CONTRIBUTIONS

- Erin Mauney made substantial contributions to the analysis and interpretation of data for the work, drafted the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
- Paul Mitchell made substantial contributions to the analysis and interpretation of data for the work, drafted the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
- Camilla Richmond made substantial contributions to the analysis and interpretation of data for the work, drafted the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
- Brian Carmine made substantial contributions to interpretation of data for the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
- Annemari Fayemi made substantial contributions to interpretation of data for the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
- Nirav Desai made substantial contributions to the analysis and interpretation of data for the work, drafted the work, gives final approval of the version to be published, and agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

The authors declare they have no conflicts of interest.

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