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REVIEW ARTICLE

Inequity to the Utilization of Bariatric Surgery: a Systematic Review and Meta-Analysis

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Abstract This systematic review explores the sociodemographic factors associated with the utilization of bariatric surgery among eligible patients. Electronic databases were searched for population-based studies that explored the relationship between sociodemographic characteristics of patients eligible for bariatric surgery to those who actually received the procedure. Twelve retrospective cohort studies were retrieved, of which the results of 9 studies were pooled using a random effects model. Patients who received bariatric surgery were significantly more likely to be white versus non-white (OR 1.54; 95 % CI 1.08, 2.19), female versus male (OR 2.80; 95 % CI 2.46, 3.22), and have private versus government or public insurance (OR 2.51; 95 % CI 1.04, 6.05). Prospective

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cohort studies are warranted to further determine the relative effect of these factors, adjusting for confounding factors.

Keywords Bariatric surgery · Obesity · Sociodemographic disparities · Inequity · Utilization · Systematic review · Meta-analysis

Background

The prevalence of obesity has increased dramatically since the 1970s. Recent estimates indicate that 24 % of Canadian adults and 34 % of American adults are obese, defined as having a body mass index (BMI) ≥30 kg/m^2 [1]. The prevalence of morbid obesity, defined as having a BMI ≥40 kg/m^2, has increased by 400 % in the past two decades [2, 3]. The reduced quality of life and life expectancy associated with obesity due to obesity-related comorbidities [4, 5], such as diabetes mellitus and hypertension, are even more pronounced among those who are classified as morbidly obese [6]. The current obesity epidemic reflects results from both societal and cultural factors that favor overeating and a sedentary lifestyle. Together, these promote a positive energy balance, and in extreme forms, the development of obesity [6]. To date, bariatric surgery has been documented as the only available treatment that results in sustained weight loss, leading to significant improvement in obesity-related comorbidities [7]. Bariatric surgery significantly decreases overall morbidity and mortality in patients receiving such procedures compared to controls [8–12]. Despite the evidence supporting the safety, and clinical benefits of bariatric surgery [8–12], uptake of these procedures in eligible patients remains low [13].

Health inequity, defined as unfair inequalities in population groups which lead to unequal chances to access health care services [14], may be contributory. Studies have shown significant demographic differences between the general obese population and the subset that has access to and/or receives bariatric surgical procedures [15–17]. Compared to the general population, individuals who fulfill the National Institutes of Health (NIH) criteria for bariatric surgery—defined as having a BMI of ≥40 kg/m^2 or ≥35 kg/m^2 with at least one obesity-related comorbidity—are often older, come from racial or ethnic minorities, are economically disadvantaged, and have low levels of education [15, 18]. However, it is believed that this subset of the population is least likely to undergo bariatric surgery [17]. In an effort to create equity in the access to bariatric surgery for the treatment of obesity, a clear understanding of all the apparent disparities, and how they interact with each other, is required.

The acronym PROGRESS-PLUS describes the sociodemographic factors across which disadvantage may exist: *P*lace of residence; *R*ace/ethnicity/culture; *O*ccupation; *G*ender/sex; *R*eligion; *E*ducation; *S*ocioeconomic status; *S*ocial capital; Plus—additional factors (i.e., age) [19]. The objective of this systematic review was to identify the PROGRESS-PLUS factors that differ between obese patients who are eligible for bariatric surgery to those who actually receive the surgery.

Methods

Protocol

We developed a systematic review protocol using the Preferred Items for Systematic Reviews and Meta-analysis for Protocols (or PRISMA-P) Statement [20]. Our systematic review protocol was revised and registered in the PROSPERO registry (CRD42013004920) [21]. Our final protocol is available upon request from the corresponding author (TJ) [22].

Eligibility

Patients

Adult patients over the age of 18 years meeting the NIH or equivalent criteria (i.e., Asian-Pacific Consensus, International Statistics Classification of Disease (ICD) codes) for bariatric surgery were included, irrespective of geographical location. The NIH eligibility criteria for bariatric surgery required an individual to have a BMI ≥40 kg/m^2; or BMI ≥35 kg/m^2 with at least one significant weight-related comorbidity.

Exposures and Comparators

The exposures of interest were the PROGRESS-PLUS sociodemographic factors. *P*lace of residence was categorized by the geographical location of residence classified as urban, and non-urban. *R*ace/ethnicity/culture was defined by race with the following categories: White and others. Others included the following races/ethnicities: Asian, South Asian, Black, Hispanic, Aboriginal, and Other. *O*ccupation was categorized as being working or not working. *G*ender/sex was categorized as being male or female. *R*eligion was categorized as identifying with Christianity/Catholicism, Judaism, Islam, and Other. *E*ducation was defined by the highest level of education attained and categorized as less than secondary education, secondary education, or having obtained post-secondary education. *S*ocioeconomic status was categorized into the following income categories: <$40,000 and ≥$40,000. *S*ocial capital was defined by family support as being full support, some support, or no support. Plus factors included age and health insurance. Age was categorized into the following age categories: 18–49 years, and ≥50 years. Health insurance was defined as having private insurance versus government or public insurance.

Outcomes

The primary outcome of interest was the utilization of bariatric surgery. The following surgical procedures were considered eligible: Roux-en-Y gastric bypass, sleeve gastrectomy, adjustable gastric band, vertical banded gastroplasty, jejunoileal bypass, biliopancreatic diversion, duodenal switch, mini-gastric bypass, loop gastric bypass, gastric plication, gastric balloon, and the Scopinaro procedure. Both open and laparoscopic approaches were considered. Bariatric surgery may have been either universally implemented or targeted to a specific risk group. Two groups were defined a priori: Patients who were [1] eligible for bariatric surgery and received the procedure; and [2] eligible for bariatric surgery but do not receive the procedure.

Study Designs

Population-based retrospective and prospective cohort and cross-sectional studies were eligible for inclusion. To be included, studies must have compared study participants on at least one of the PROGRESS-PLUS factors.

Information Sources and Search Strategy

The search strategy was developed by an experienced librarian and peer reviewed using Peer Review of Electronic Search Strategy (PRESS) [23] by another experienced librarian (Supplementary Table 1). No language or publication limitations were imposed during the database searches; the search, however, was limited to January 1980 onwards, as bariatric surgery was not widely available prior to this date. Studies were identified through searching the EMBASE and Medline. This was supplemented with hand-searching for difficult to locate or unpublished literature, including technical or research reports (e.g., Canadian Institute of Health Information reports), relevant websites (i.e., Google Scholar; Statistics Canada: http://www.statcan.gc.ca/start-debut-eng.html; Royal College of Physicians and Surgeons of Canada: http://www.royalcollege.ca/; Institute for Clinical Evaluative Sciences: http://www.ices.on.ca/index.html; Canadian Institute for Health Information: http://www.cihi.ca; American College of Surgeons: http://www.facs.org/; National Centre for Health Statistics: http://www.cdc.gov/nchs/; National Institutes of Health: http://www.nih.gov/; Agency for Healthcare Research and Quality: http://www.ahrq.gov/; Royal College of Surgeons of England: http://www.rcseng.ac.uk/; Health and Social Care Information Centre: http://www.hscic.gov.uk/; European Institute for Health Records: http://www.eurorec.org/; Royal Australasian College of Surgeons: http://www.surgeons.org/; Australian Institute for Health and Welfare: http://www.aihw.gov.au/), and reference lists of included studies. The literature search was executed on January 2014.

Study Selection

Three researchers (SKB, JIR, and DG) independently reviewed the title, abstract, or description of all trials identified by the literature search. For level 1 screening, the eligibility criteria were kept broad, as PROGRESS-PLUS factors are poorly reported in titles and abstracts. Studies that aimed to explore bariatric surgery among individuals over the age of 18 years were selected. The eligibility criteria were stricter for full-text review and the type of bariatric surgery, outcomes reported, and study designs were scrutinized to determine if they met the inclusion criteria. Discrepancies were resolved through discussion.

Data Items and Abstraction

The data abstraction form was pilot-tested on a random sample of studies (n=150) to ensure high inter-rater agreement between reviewers (kappa≥0.80). Subsequently, three researchers (SKB, JIR, and DG) independently extracted data from included studies using a pre-specified data collection form. Discrepancies were resolved by discussion. The data items included study characteristics, primary outcome results, PROGRESS-PLUS factors, patient risk factors, including BMI, and details of the surgical intervention. The presence or absence of the following comorbidities was documented: hypertension, dyslipidemia, diabetes, coronary artery disease, cerebrovascular disease, depression, hypothyroidism, sleep apnea, gastroesophageal reflux, osteoarthritis, and cholelithiasis.

Risk of Bias Assessment

Two researchers (SKB, JIR) independently assessed the risk of bias in all of the included studies. Discrepancies were resolved by discussion. The Scottish Intercollegiate Guidelines Network (SIGN) 50 tool was used to quantify the degree of bias in the include studies [24]. The SIGN 50 includes 17 items and evaluates the following criteria: selection and comparability of subjects, ascertainment of exposure/intervention, assessment of outcome measure, identification and minimization of confounding, appropriateness of statistical analysis, and funding.

Data Synthesis and Analysis

The proportion of study participants who received and did not receive bariatric surgery within a PROGRESS-PLUS category was summarized as a percentage. For a PROGRESS-PLUS variable to be considered for inclusion in the meta-analysis, it was determined a priori that at least four trials must be able to be combined for a specific variable [25]. For exploratory purposes, we also conducted secondary meta-analysis for PROGRESS-PLUS factors that were measured in two and/or three studies. Pooled odds ratios (ORs) and 95 % confidence intervals (CIs) were generated using a random effects model and depicted in forest plots to determine whether there was evidence that PROGRESS-PLUS factors were associated with receiving bariatric surgery. All trials were analyzed using R version 3.0.3 software [26], along with the metafor package [27]. To test for sensitivity of results, leave-one-out analysis was conducted. Statistical heterogeneity was assessed using the I^2 statistic [28]. Where significant heterogeneity was detected, and where possible, meta-regression was performed using potential clinical (i.e., eligibility criteria for surgery) and methodological (i.e., source of bariatric surgery-eligible population) covariates (often called moderators in the meta-regression framework). Specifically, covariates used were:

1. Eligibility criteria for surgery (nih criteria vs. other eligibility criteria)
2. Source of bariatric surgery-eligible population (hospital vs. general population)

Results

The initial literature search identified 6482 titles and abstracts of which 3415 were removed for being duplicate citations. Of the remaining 3067, 3055 citations were excluded because the studies (1) did not aim to explore bariatric surgery in the context of managing obesity, (2) did not include an appropriate non-intervention comparison group, (3) were not described as being an observation study, (4) included patients who were under the age of 18 years, (5) did not involve an eligible bariatric surgical intervention, (6) did not use the NIH or an equivalent criteria for bariatric surgery eligibility, (7) did not compare patients on one of the PROGRESS-PLUS factors, and (8) included emergency procedures (Fig. 1).

A total of 12 studies met eligibility criteria, all of which were full-text publications (Table 1). Briefly, all studies were retrospective cohort studies, and were deemed to be of acceptable quality (Supplementary Table 2). Eight of the studies were conducted in the USA, two in the UK, and one in Australia and Canada, each. In all studies, patients who received bariatric surgery were identified via inpatient hospital registries or databases; identification of the population eligible to receive bariatric surgery were identified through a variety of sources, including census data [29, 30], national health surveys [15, 18, 31–35], and national hospital inpatient databases [17, 36, 37]. Eligibility for bariatric surgery was defined using the NIH criteria in four studies [15, 18, 32, 33]. The remaining studies based eligibility according to a BMI cut-off point (≥30 kg/m or ≥40 kg/m^2) [29–31, 34], ICD-9 or ICD-10 codes [17, 36, 37], or other hospital diagnosis codes for the primary diagnosis of obesity [35].

The results indicated that eligible patients who underwent bariatric surgery were more likely to be female [15, 17, 18, 29, 31–37], White [15, 17, 32, 33, 37], and hold private insurance [15, 17, 31–33, 37]. One UK study found no differences in the rates of bariatric surgery among White, Asian, or Black bariatric surgery-eligible patients [30]. The majority of the studies also reported that eligible patients who had surgery were more likely to be middle aged or younger [17, 18, 31, 34, 36, 37]. Due to inconsistency in the categorization of socioeconomic status (SES) across studies, we were unable to aggregate SES data (Supplementary Table 3). Eligible patients who had surgery were more likely to have high household incomes [15, 17, 31, 37]. In terms of interaction effects, an inverse relationship was found between rates of bariatric surgery and socioeconomic status among White patients, while a positive relationship between rates of surgery and socioeconomic status was documented for Blacks [29]. Furthermore, men who received bariatric surgery tended to be older, while women who received surgery were younger [34]. Rates of obesity comorbidities differed across the studies with some finding those that had surgery had a very low burden of comorbidities, with the exception of diabetes [18], while others found high rates of obesity-related comorbidities, including liver disease [36].

Nine studies providing data on 64,736,656 patients were included in our meta-analyses. Of the patients eligible for bariatric surgery, only 260,677 (0.4 %) patients received the surgery (Table 2). Across studies, bariatric surgery-eligible patients who received surgery ranged from <1 % [15, 18, 30–33] to 5 % [29, 34, 36].

Characteristics of bariatric surgery-eligible patients who received and did not receive surgery aggregated across studies are presented in Table 3. Of those who received bariatric surgery, 85 % were from urban areas, 81 % were White, 68 % were female, 74 % were between the ages of 18 and 49 years, and 82 % held private insurance. Among those who were identified as being non-White, the majority were Black (69 %), followed by Hispanic (23.2 %), Other (7.4 %), and Asian (0.4 %).

Due to inconsistency in data reporting across the studies (i.e., use of different definitions and categorical cut-offs, and lack of studies reporting a particular factor), the current review was unable to explore the association between the rates of bariatric surgery across the following variables: place of residence, education, occupation, religion, household income, age, and social capital.

Performing a meta-analysis for each characteristic, the utilization of bariatric surgery was significantly associated with

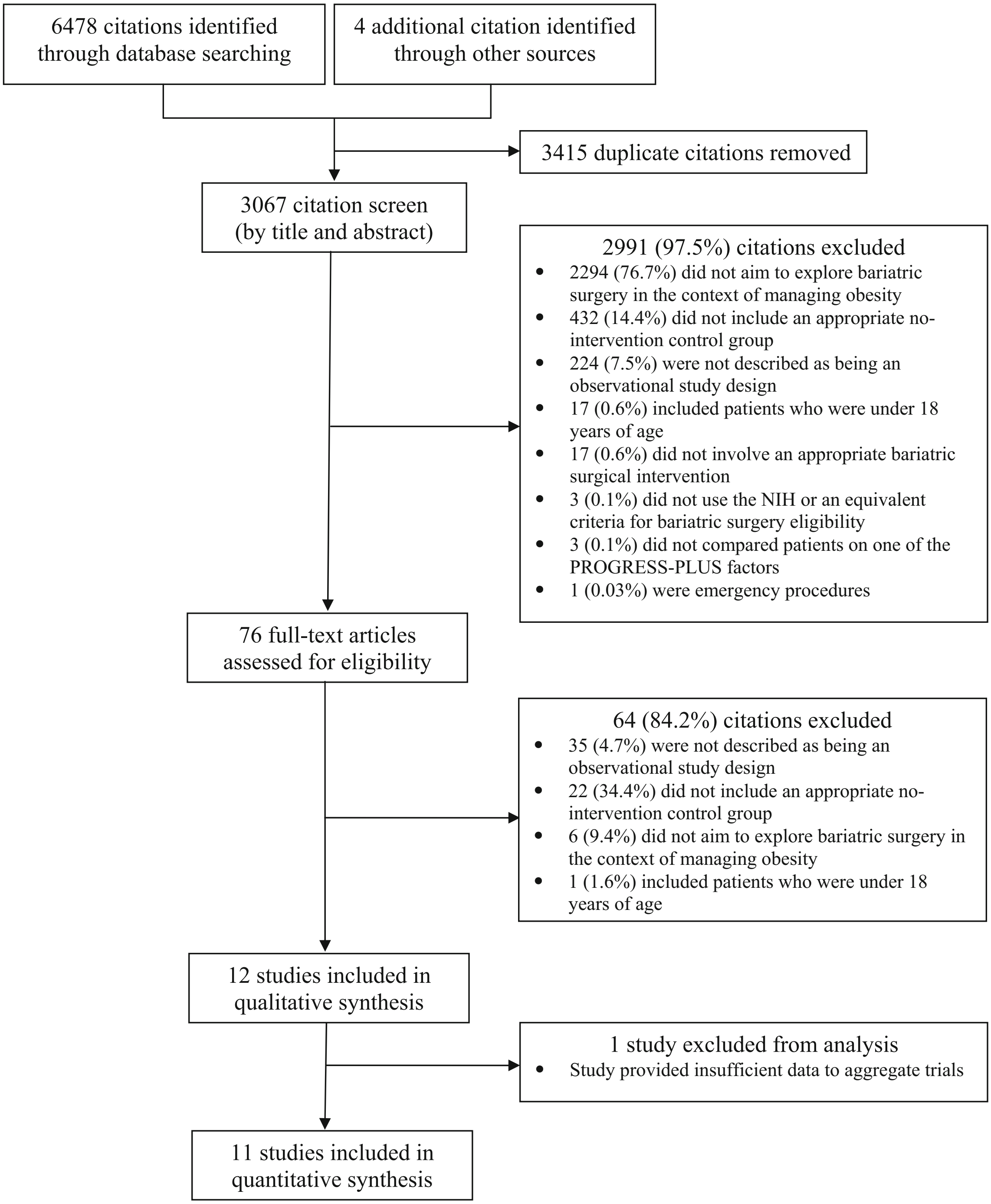

Fig. 1 Trials selected for inclusion in review

ethnicity, insurance type, and sex (Fig. 2). Patients who received bariatric surgery were significantly more likely to be White than non-White (N=4; OR 1.54; 95 % CI 1.08, 2.19), have private insurance than non-private insurance (N=4; OR 2.51; 95 % CI 1.04, 6.05), and be female than male (N=9; OR 2.80; 95 % CI 2.46, 3.22). I^2 test for heterogeneity indicated significant heterogeneity (p<0.0001) among the results.

Additional analysis was done to predict receipt of bariatric surgery with sex, including eligibility criteria as a covariate. This analysis found no evidence that differing eligibility criteria for surgery (NIH vs. other criteria) had an effect on the outcome (p=0.98). A further analysis predicted surgery with sex, and included the source from which the surgery-eligible population was identified from (hospital vs. general population) as a covariate. There was no evidence that these covariates had any effect on the outcome of receiving bariatric surgery (p=0.16). Thus, neither of these covariates was able to explain any heterogeneity.

Table 1 Characteristics of included studies

Study	Design and quality appraisal	Participants and Setting	Study aim	Bariatric surgery eligibility definition	Progress PLUS criteria examined	Summary results
Flum 2004 [36]	Retrospective cohort study Quality: acceptable	Washington State Comprehensive Hospital Abstract Reporting System database (1987–2001), USA	To examine the impact of bariatric procedures on survival	ICD-9 diagnostic code for morbid obesity: 278.01	1. Sex 2. Age 3. Comorbidities	Surgery group more likely to be female, younger, and have higher rates of liver disease with lower rate of diabetes and renal disease
Livingston 2004 [32]	Retrospective cohort study Quality: acceptable	National Health Information Survey (2000), USA; Agency for Healthcare Cost and Utility Project (2000), USA; National Hospital Discharge Surgery (2000), USA	To investigate the ethnicity, education level, financial and health insurance status, and pattern of health care access and utilization for individuals who undergo obesity surgery	BMI ≥40 kg/m^2 or a BMI of 35–39.9 kg/m^2 who responded affirmatively to the NHIS variable AFLHCA18 (weight problem causes difficulty with activity)	1. POR 2. Ethnicity 3. Sex 4. Insurance	Surgery group more likely to be female, white, and have private health insurance More operations performed in the northeast and fewer in the Midwest than would be predicted by the surgery-eligible population living in the areas
Poulose 2005 [34]	Retrospective cohort study Quality: acceptable	Nationwide Inpatient sample (2002), USA; Behavioral Risk Factor Surveillance System (2002), USA	To analyze national rates of bariatric surgery and the burden of obesity by gender, census region, and age	BMI ≥40 kg/m^2	1. POR 2. Sex 3. Age	Surgery group more likely to be female. Men patients tended to get surgery older (50–59) and women were younger (<49) Rate of procedures highest in Northeast and West but the burden of obesity was lowest in these regions
Ells 2007 [35][a]	Retrospective cohort study Quality: acceptable	Hospital Episode Statistics (HES) database (1996–2005), UK; Heath Survey for England (1998–2003), UK	To examine the uptake of bariatric surgery across England	Codes for primary diagnosis of obesity E66.0, E66.8, E66.9	1. POR 2. Sex	Surgery group more likely to be female
Martin 2010 [15]	Retrospective cohort study Quality: acceptable	NHANES (2005–06), USA; Nationwide Inpatient Sample (2006), USA	To analyze the socioeconomics of the morbidly obese patient population and the impact on access to bariatric surgery	BMI ≥40 kg/m^2 or a BMI of 35–39.9 kg/m^2 and a major obesity-related comorbidity	1. Ethnicity 2. Sex 3. SES 4. Insurance	Surgery group more likely to be female, white, of a higher household income, and privately insured
Wallace 2010 [17]	Retrospective cohort study Quality: acceptable	Nationwide Inpatient Sample (2006), USA	To examine more current rates of bariatric surgery within sociodemographic, economic, and rural–urban subgroups	ICD9-CM code for morbid obesity 278.01	1. POR 2. Ethnicity 3. Sex 4. SES 5. Age 6. Insurance	Surgery group more likely to be younger, white, female, of a high income status, privately insured, and an urban resident
Birkmeyer 2012 [29]	Retrospective cohort study Quality: acceptable	Census (2000), USA; Driver and personal identification holder databases, USA; Michigan state inpatient and ambulatory surgery databases (2004–05), USA	To examine disparities in the use of bariatric surgery according to gender, race, and socioeconomic status	BMI ≥40 kg/m^2	1. Sex 2. SES	Surgery group more likely to be female. Inverse relationship between SES and rates of bariatric surgery for whites Positive relationship between SES and rate of bariatric surgery for ethnic minorities
Korda 2012 [31]	Retrospective cohort study Quality: acceptable	45 and Up study (2006–08), Australia; NSW Registry of Births, Deaths and Marriages (to 30 June 2010), Australia; NSW Admitted Patient Data Collection (2000–10), Australia	To quantify socioeconomic inequalities in bariatric surgery and examine the extent to which holding private health insurance explains these inequalities	BMI ≥30 kg/m^2	1. POR 2. Sex 3. Education 4. SES 5. Age 6. Insurance 7. Comorbidities	Surgery group more likely to be female, younger, in the highest income bracket, an urban resident, have private insurance, and have diabetes and other chronic conditions
Padwal 2012 [18]	Retrospective cohort study Quality: acceptable	Canadian Health Measures Survey, (2007–2009), Canada; The Canadian Institute for Health Information Discharge Abstract Database (2007–2008), Canada; National Ambulatory Care Reporting System (2007–2008), Canada	To characterize the population eligible for bariatric surgery in Canada and to compare them with patients currently receiving bariatric surgery	BMI ≥40 kg/m^2 or a BMI of 35–39.9 kg/m^2 and a major obesity-related comorbidity	1. Sex 2. Age 3. Comorbidities	Surgery group more likely to be younger, female, and appear to have a very low burden of comorbidities (with the exception of diabetes)

Table 1 (continued)

Study	Design and quality appraisal	Participants and Setting	Study aim	Bariatric surgery eligibility definition	Progress PLUS criteria examined	Summary results
Worni 2012 [37]	Retrospective cohort study Quality: acceptable	Nationwide Inpatient Sample (2002–2008), USA	To examine how the racial distribution of patients undergoing LGBS differs from racial distribution of other hospitalized obese patients	ICD-9 codes 278.0–278.02, V77.8, V85.35-V85.39 or V85.4	1. Ethnicity 2. Sex 3. SES 4. Age 5. Insurance	Surgery group more likely to be white, younger, female, have private insurance, and older than 34 years of age
Mainous 2013 [33]	Retrospective cohort study Quality: acceptable	National Hospital Discharge Survey (1999–2010), USA; NHANES (1999–2010), USA	To examine national trends in bariatric surgery for eligible adults with a focus on potential differences by race and access to health care	BMI ≥40 kg/m^2 or a BMI of 35–39.9 kg/m^2 and a major obesity-related comorbidity	1. Ethnicity 2. Sex 3. Age 4. Insurance	Surgery group more likely to be white, female, and have private health insurance Black women aged 20–40 more likely to receive surgery; Black men aged 20–40 least likely to receive surgery
Old 2013 [30]	Retrospective cohort study Quality: acceptable	National Bariatric Surgery Registry (2011), UK and Ireland; Census data (2001), UK; Census data (2011), Ireland; The health survey for England: The health of ethnic minority groups (2004), UK	To estimate the rate of bariatric surgery among ethnic minorities	BMI >40 kg/m^2	1. Ethnicity	No difference between rates of bariatric surgery among white, Asian, or black surgery-eligible patients

POR place of residence, *SES* socioeconomic status

[a] Study not included in the quantitative synthesis as the presentation of data did not allow for data extraction

Exploratory analysis revealed that odds of having bariatric surgery was more likely among those living in urban areas versus non-urban areas (N=2; OR 1.45; 95 % CI 1.42, 1.48); and who were between the ages of 18 and 50 years versus over 50 years of age (N=3; OR 2.39; 95 % CI 1.28, 4.48). There was no evidence to suggest a difference in the odds of having bariatric surgery based on whether or not an individual had diabetes mellitus (N=3; OR 1.21; 95 % CI 0.60, 2.41). However, due to a lack of studies included in these analyses, the results must be interpreted with caution as they are not very robust.

Discussion

This review identified 12 retrospective cohort studies exploring the rate of bariatric surgery across a variety of sociodemographic factors. Nine of these were included in a meta-analysis. Our review found that less than 1 % of bariatric surgery-eligible patients received surgery. Eligible patients were more likely to receive surgery if they were White, female sex, and held private insurance. Bariatric surgery was also more likely among eligible patients from urban areas, and those between 18 and 50 years of age.

Our finding that individuals identified as White had an odds of receiving bariatric surgery almost twice that of those identified as being non-White is consistent with the literature demonstrating that ethnic minorities tend to have poorer access to healthcare services compared with non-minorities [38]. Understanding these disparities requires careful consideration of patient, systemic, and provider factors [39–41]. With respect to patient factors, lower rates of bariatric surgery may reflect cultural differences in how ethnic minorities perceive their weight status and quality of life at higher body weights [42, 43]. In addition, it could be linked to patients' beliefs regarding the need for, and risks involved with surgical interventions for weight loss [44]. Evidence suggests that Black and Hispanic patients are less likely to choose surgical interventions for various conditions compared to their White counterparts [45, 46]. However, this "choice" may stem from a lack of trust in the healthcare system [47]; an issue that is strongly associated with negative patient-physician communication experiences [48], and decreased use (avoidance) of the healthcare system [49–52]. Finally, there is emerging evidence that bias, stereotyping, and clinical uncertainty on the part of healthcare providers may contribute more generally to racial and ethnic disparities in health, an issue that requires further investigation [41, 53]. In interpreting our findings, we do acknowledge that race is often confounded by socioeconomic status [54], and that racial disparities may be a result of residential segregation [55]. Unfortunately, difficulties in analyzing or interpreting racial disparities often arise as a result of using national data, which does not account for differences

Table 2 Proportion of bariatric surgery-eligible patients who received surgery

Study	Bariatric surgery-eligible patients N	Eligible patients who received bariatric surgery N	%
• Padwal [18]	15,153,000	847	0.01
• Livingston [32]	5,324,123	20,771	0.39
• Martin [15]	22,151,116	87,749	0.40
• Mainous [33]	14,925,046	63,141	0.42
• Old [30]	1,107,970	5270	0.48
• Korda [31]	49,364	312	0.65
• Birkmeyer [29]	935,870	9769	1.04
• Poulose [34]	5,024,058	69,490	1.38
• Flum [36]	66,109	3328	5.03
Combined	64,736,656	260,677	0.40

Wallace and Worni were not included in this analysis because of overlapping patient population due to the use of the same database during the same time period with Martin and Poulose

Table 3 Characteristics of bariatric surgery eligible patients who received and did not receive bariatric surgery

	Received bariatric surgery	
	Yes N=260,677	No N=64,475,989
Place of residence, *N* (%)		
[*N* study=2] [15, 17]	*n*=88,610	*n*=732,465
Urban	75,658 (85.4 %)	567,828 (77.5 %)
Non-urban	12,952 (14.6 %)	164,637 (22.5 %)
Race, *N* (%)		
[*N* study=4] [15, 30, 23, 33]	*n*=157,598	*n*=42,568,521
White	127,600 (81 %)	30,686,918 (72.1 %)
Non-white	29,998 (19 %)	11,881,603 (27.9 %)
•Asian	128 (0.4 %)	24,412 (0.2 %)
•Black	20,683 (68.9 %)	8,543,710 (71.9 %)
•Hispanic	6969 (23.2 %)	2,208,143 (18.6 %)
•Other	2218 (7.4 %)	1,105,338 (9.3 %)
Sex, *N* (%)		
[*N* study=8] [15, 18, 29, 31–34, 36]	*n*=65,275	*n*=49,749,181
Female	44,090 (67.5 %)	31,027,000 (62.4 %)
Male	21,185 (32.5 %)	18,722,181 (37.6 %)
Age, *N* (%)		
[*N* study=3] [31, 34, 37]	*n*=114,016	*n*=6,664,348
18–49 years	83,746 (73.5 %)	3,688,199 (55.3 %)
≥50 years	30,270 (26.5 %)	2,976,149 (44.7 %)
Health insurance, *N* (%)		
[*N* study=4] [15, 31–33]	*n*=163,528	*n*=36,475,150
Private insurance	134,240 (82.1 %)	27,650,868 (75.8 %)
Government supplemented (e.g., Medicare/Medicaid)	29,288 (17.9 %)	8,824,282 (24.2 %)
Comorbidities: diabetes, *N* (%)		
[*N* study= 3] [18, 31, 36]	*n*=4488	*n*=1,626,285
Diabetes	698 (15.6 %)	248,802 (15.3 %)
No diabetes	3790 (84.4 %)	1,377,483 (84.7 %)

resulting from residential segregation. Moreover, adjusting for socioeconomic status alone in multivariate models may be insufficient to detangle the effects of race on health care access [55].

Our analysis also identified that privately insured patients are on average 2.5 times more likely to receive bariatric surgery compared to those who are not privately insured. This finding is consistent with other studies exploring health inequities across various medical conditions, which also demonstrate that those who are not privately insured have poorer access to health care services compared to those with private insurance [40]. In the USA, individuals unable to obtain private insurance coverage from their employers often obtain coverage through public programs, including Medicare and Medicaid [56]. Given that these public programs only pay physicians a percentage of what is paid by private insurance companies, there is financial disincentive for physicians to accept patients who are insured through such public programs [57]. It is important to note that insurance status is positively associated with socioeconomic status; however, we were unable to include socioeconomic status in the current meta-analysis due to inconsistency in defining socioeconomic status across the primary studies. Previous studies have documented lower rates of bariatric surgery among surgery-eligible patients who were considered socioeconomically disadvantaged [13, 58], even in countries with a public healthcare system such as Canada [58]. In aggregate, these findings support the conclusion that multiple factors, and not just access to healthcare funding, have impact on access to bariatric surgical procedures. Why rates of bariatric surgery would differ according to socioeconomic status in a publicly funded healthcare system is unclear. Further research is warranted to explore disparities in access to bariatric surgery within publicly funded healthcare systems.

Our finding that women are more likely to receive bariatric surgery generates two interesting questions. First, what is the relationship between sex, insurance status, and socioeconomic status on access to bariatric surgery? Given the positive association between socioeconomic status and private insurance to receiving bariatric surgery, further research is needed to detangle the relative effect of sex on access to bariatric surgery. Second, how do the treatment-seeking behaviors between men and women impact access to bariatric surgery? A recent study found that women were four times more likely than men to seek weight-loss surgery [59]. By the time men actually sought medical assistance from a doctor regarding bariatric surgery, they are more obese and sicker than women [59].

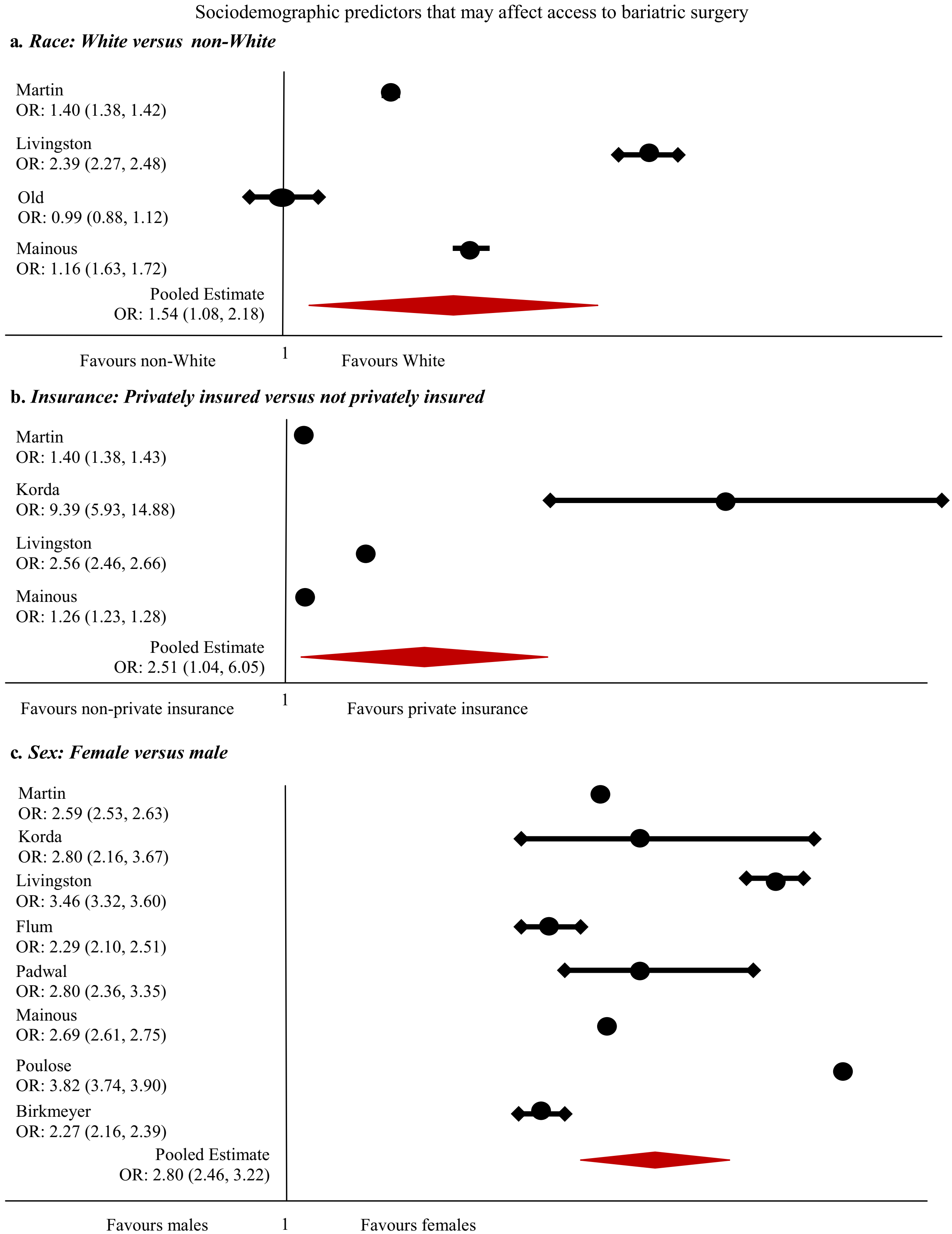

Fig. 2 Figure 2 illustrates the point estimates of the odds of receiving bariatric surgery based on race (**a**), insurance (**b**), and sex (**c**). Point estimates are presented as unadjusted odds ratio (95 % confidence interval). The pooled effect size is presented as an unadjusted pooled odds ratio (95 % CI), and represented as a *diamond*. The width of the *horizontal line* represents the 95 % CI around the point estimate (*black circle*). The size of the point estimates represents the weight of the particular estimate on the pooled effect. The *vertical line* is the line of no effect; with *1* representing no effect for odds ratio

We identified that only a minority of bariatric surgery-eligible patients received the surgery. This finding was consistent across the included studies, regardless of whether bariatric surgery was publically or privately funded. This access to care issue is largely manifested by the high cost of bariatric procedures and the lack of government funding or insurance coverage available to compensate for these high costs. However, several physician-level barriers across the healthcare continuum may be contributing not only to the low rates of bariatric surgeries completed but also to the disparities present in the patients who are receiving it. Primary care physicians (PCPs) and surgeons both play a crucial role in patient access to bariatric surgery: PCPs are responsible for recommending bariatric surgery for weight loss and educating patients of the procedure, while surgeons are responsible for accepting patients to be under their care for the procedure. Several barriers have been identified that may prevent PCPs from recommending surgical obesity treatment to patients, including inadequate training and knowledge of the tools needed to diagnose and treat obesity, lack of time, and negative physician attitudes toward obese patients [60]. For instance, findings from telephone interviews with obese patients eligible for bariatric surgery revealed that only 20 % reported they had ever received a recommendation to undergo bariatric surgery from their PCP [61]. In regards to surgeon approval for surgery, a national survey of 820 bariatric surgeons from the USA indicated that sex and race did not influence surgeons' decisions to operate; however, public insurance, poor social support, and older age were associated with a decreased odds to selection for surgery [62].

The results of our systematic review are strengthened by the methods employed. Our systematic review included only population-based studies, thereby increasing the representativeness of the bariatric surgery-eligible population. We obtained confirmation of methodology and data, as well as additional data from primary authors, as required. We used the validated SIGN 50 to assess internal validity of the included studies [24]; which the Canadian Agency for Drugs and Technologies in Health deemed to be the most appropriate tool for assessing observational studies [63]. All included studies were deemed to be of acceptable quality. There was no evidence of funding bias. However, our findings should be interpreted in the light of the following limitations. First, our review only included retrospective cohort studies. Due to the inherent nature of the retrospective cohort design, variables of interest within the primary studies were limited by what was available in the chosen database for the analysis, and may not have accounted for unknown confounders. Second, while the majority of included studies analyzed data that was to be representative of the national bariatric surgery population, many studies indicated a possibility of underestimating the rates of patients eligible for bariatric surgery. Furthermore, synthesis of the included studies was limited by inconsistent categorization and reporting of sociodemographic factors; inconsistent coding of comorbidities and surgical procedures may contribute to underrepresentation of the bariatric surgery population. Third, due to the use of surveys and administrative datasets in the included studies, we were unable to fully capture prevalence of specific obesity-related comorbidities (i.e., sleep apnea). Moreover, we were unable to account for the relative effect of race that may have resulted from residential segregation, insurance status, and socioeconomic status. Fourth, the majority of included studies compared two different databases, collected using different sampling methods to compare the bariatric surgery-eligible population and the population which received bariatric surgery, thereby potentially introducing variance and bias. Fifth, we were unable to aggregate data concerning education, occupation, religion, household income, and social capital due to inconsistency of categorizing variables across studies. Consequently, we were not able to perform meta-analysis to distinguish the relative effect of individual PROGRESS-PLUS factors on the utilization of bariatric surgery. Sixth, while the risk of publication bias cannot be excluded, given the population size of many of the studies included, and that most confidence intervals were quite narrow, small studies that may have been missing would likely have little effect on our results. Finally, we were not able to distinguish at what point in the care process inequities were introduced. Although there was evidence of significant heterogeneity in the results, given that heterogeneity tends to bias the results toward the null, our significant findings demonstrate robustness.

In summary, the utilization of bariatric surgery remains low. Within this group receiving bariatric surgery, significant disparities exist in access to bariatric surgery including race, insurance type, and sex. We conclude that prospective cohort studies are warranted to further determine the relative effect of these factors, adjusting for socioeconomic status, place of residence, social support, and confounding sociodemographic factors. More consistent categorization and reporting of sociodemographic factors in future studies would be beneficial to further identify health inequities in access to bariatric surgical care. Furthermore, studies exploring where along the care continuum these disparities come into play will provide leads to the barriers to accessing bariatric surgery. Our recommendations for future studies would help prioritize solutions to bridge the care gap and inform policies to the referral and approval process of patients for bariatric surgery.

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Author's Contributions SKB collaborated in the development of the study protocol, study selection, data abstraction, methodology assessment, data management and entry, data interpretation, and writing of the final manuscript. JIR collaborated in the design of the study, development of the study protocol, study selection, data abstraction, methodology assessment, data management and entry, data interpretation, and writing of the final manuscript. ODR conceived of the study, collaborated in the design of the study, development of the protocol, data interpretation, and writing of the final manuscript. AC was responsible for the analysis, collaborated in data interpretation, assisted in writing of the manuscript, and critically reviewed the manuscript for important statistical content. DG collaborated in the development of the study protocol, study selection, data abstraction, and methodology assessment. ACT collaborated in data interpretation, assisted in the writing of the manuscript, and critically reviewed the manuscript for important methodological content. JKS collaborated in the design of the study, protocol development, and data interpretation. SAG collaborated in the interpretation of the results. JP collaborated in the design of the study, protocol development, and data interpretation. LGC collaborated in the design of the study, development of the study protocol, and data interpretation. TJ collaborated in the design of the study, development of the study protocol, data interpretation, and supervised the overall development, and writing of the study. All authors read and approved the final manuscript.

Conflict of Interest The authors declare that they have no conflict of interest.

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