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The Impact of Gastric Bypass Surgery Compared to Total Knee Arthroplasty on Knee Symptoms

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Abstract

Background: Marked associations between obesity and the development of knee symptoms have been well established. The prevalence of obesity in Western populations has continued to rise over the past decades, and this has been associated with a significant rise in the number of patients with debilitating knee symptoms who are obese. While these patients may be referred to orthopaedic surgeons for assessment and consideration of treatment options, they may lack intra-articular pathology amenable to orthopaedic surgical intervention such as a Total Knee Arthroplasty (TKA). Laparoscopic roux-en-y gastric bypass (LRYGB) surgery is one of the more effective ways to induce and maintain weight loss, and while bariatric surgery has been reported to provide significant reductions in knee symptoms no studies have compared the magnitude of change in symptoms compared to TKA. The purpose of this study was to assess the impact of LRYGB on knee-specific patient reported outcomes, and to compare these findings to a matched cohort of patients who underwent TKA for OA.

Methods and findings: Twenty patients who underwent bariatric surgery were matched on a one-to-two basis to forty patients who had previously undergone unilateral primary TKA at a single institution. WOMAC scores were collected at baseline and at 6 and 12 month follow ups. The mean percentage improvement in knee-specific pain scores was similar between groups at both 6 month (49.9% vs. 58.3%; $p=0.438$) and 1 year (62.7% vs. 68.2%; $p=0.576$) follow-up intervals. Furthermore, patients who underwent LRYGB had significantly greater mean percent improvement in knee-specific WOMAC function scores at 6 month follow-up (66.3% vs. 46.8%; $p=0.048$), and a similar though marginally non-significant improvement at 12 month follow-up (68.4% vs. 51.6%; $p=0.094$).

Conclusion: The relative improvement in symptoms of a group of LRYGB patients was similar to that of a matched group of patients who underwent TKA for end-stage OA. While further work is needed to better delineate the contribution of elevated BMI to knee symptoms, as well as

to ascertain whether these findings are maintained at longer-term follow-up, surgeons should consider bariatric consultation for obese patients with knee symptoms lacking either focal pathology amenable to orthopaedic management or degenerative changes sufficiently advanced to warrant joint arthroplasty.

Keywords: Total knee arthroplasty; Gastric bypass surgery; Knee symptoms; Knee outcome scores

Introduction

Marked associations between obesity and the development of knee symptoms have been well established, with one study reporting that the onset of knee osteoarthritis (OA) and functional limitations may increase by up to 36% for every 2-point increase in BMI [1]. Over the last several decades, total knee arthroplasty (TKA) has been established as the definitive standard in the treatment of knee symptoms associated with end-stage osteoarthritis, providing significantly improved patient-reported outcomes in terms of knee pain and physical function [2,3]. The prevalence of obesity in Western populations has continued to rise over the past decades, and this has been associated with a significant rise in the number of patients with debilitating knee symptoms who are obese [4]. While many of these patients may be referred to orthopaedic surgeons for assessment and consideration of treatment options, in some cases they may lack intra-articular pathology amenable to orthopaedic surgical intervention. While there is often little doubt that these patients are not candidates for knee arthroplasty, it is not always clear where to refer these patients for help with their symptoms.

The benefits of weight loss in providing significant reduction in knee symptoms have been described [5,6]. Based on these studies, several published guidelines recommend weight loss for patients with symptomatic osteoarthritis of the knee, [7,8] including a moderate strength recommendation from the American Academy of Orthopaedic Surgeons [9]. However,

achieving lasting weight loss through diet and exercise alone can be particularly challenging. McGuire et al. reported that 20% of overweight individuals succeed in losing at least 10% of body weight and maintaining the loss for at least 1 year with lifestyle modifications alone, [10] and Wing et al. reported similar prevalence in a review of several other studies [11].

Bariatric surgery has been repeatedly shown to be an effective method to achieve lasting reduction in BMI in patients who are unable to participate in or comply with diet and exercise regimens, or who have otherwise failed conservative treatment. While several bariatric techniques have been described, laparoscopic Roux-en-Y gastric bypass (LRYGB) surgery is one of the more effective ways to induce and maintain weight loss, with a favourable long-term safety profile compared to some other surgical techniques [12-14]. While bariatric surgery has been reported to provide significant reductions in knee symptoms, [15,16] little is known concerning the magnitude of symptomatic improvement when compared to that experienced by patients who undergo total knee arthroplasty.

Therefore, the purpose of this study was to assess the impact of LRYGB on knee-specific patient reported outcomes, and to compare these findings to a matched cohort of patients who underwent TKA for OA.

Method

Twenty patients who had self-reported knee pain during pre-operative bariatric consultation and then scheduled to undergo bariatric surgery at a single specialized center between April and August 2011 were enrolled as part of a prospective cohort study. Baseline demographic and clinical data were obtained. All patients underwent LRYGB surgery, which is the standard bariatric procedure performed at our center, performed by one of four fellowship-trained minimally invasive bariatric surgeons using similar surgical and post-operative protocols. The study cohort encompassed 16 women and 4 men, with a mean age of

52 years (range, 45 to 65 years) and a mean BMI of 45.6 kg/m² (range, 34.6 to 64.3 kg/m²). Clinical follow-up data were obtained at 6 months and 1 year following surgery. Institutional review board approval was sought and granted for the present study, which conforms to the provisions of the Declaration of Helsinki (as revised in Tokyo 2004).

Baseline demographic information collected included age, gender, BMI and self-reported osteoarthritis. Ten of 20 patients in the bariatric cohort reported an existing diagnosis of osteoarthritis. Clinical data collected at baseline, as well as at follow-up intervals, included knee-specific Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain and function scores [17].

Bariatric patients enrolled in the present study were matched on a one-to-two basis to forty patients who had previously undergone unilateral primary total knee arthroplasty at a single high-volume specialized adult reconstruction center at the same academic hospital, and who had participated previous separate prospective cohort study. All procedures were performed by one of four fellowship-trained adult reconstruction surgeons through a standard medial parapatellar incision using cemented components. Matching was performed by gender (exact match) and age (nearest neighbour), without replacement. While formal matching by BMI was not done due to a limited number of available TKA candidates, patients with higher BMI were preferentially selected when more than one match candidate was identified in an attempt to more closely approximate the known baseline elevated BMI profile of the bypass cohort. The matched cohort encompassed 8 women and 32 men with a mean age of 56 years (range, 45 to 67 years) and mean BMI of 44.6 kg/m² (range, 34.1 to 64.9 kg/m²). Demographic and clinical data were collected according to similar protocol and follow-up intervals as for the bariatric cohort. While the TKA cohort was significantly older when compared to the LRYGB group (mean age 56 vs. 52 years; $p < 0.001$), no significant differences in BMI were seen (**Table 1**).

Table 1: Comparison of baseline characteristics of matched cohorts.

	Gastric Bypass Cohort	Total Knee Arthroplasty Cohort	p value
Number of patients	20	40	-
Male:Female (percent)	4 (20) : 16 (80)	8 (20) : 32 (80)	-
Mean age in years (range)	52 (45 to 65)	56 (45 to 67)	<0.001
Baseline BMI in kg/m ² (range)	45.6 (34.6 to 64.3)	44.6 (34.1 to 64.9)	0.672
BMI: Body Mass Index			

In addition to comparison of absolute WOMAC pain and function scores, change scores at each follow-up interval were obtained through comparison to baseline pre-operative values. The patients in the bariatric cohort were recruited based on their qualification for LRYGB based on degree of obesity only; they were not screened based on the presence or absence of clinical or radiographic knee osteoarthritis. In contrast, patients in the TKA cohort all had a pre-operative diagnosis of end-stage

osteoarthritis of the knee and failure of non-arthroplasty management. The intent of our study was not to compare the outcomes of TKA vs. gastric bypass in patients with similar knee pathology/symptoms, but rather to compare the magnitude of change in knee symptoms in the two groups, given baseline differences in the magnitude of their knee pain. Consequently, to account for differences in baseline pain and function scores between cohorts, percentage change scores were calculated for

each follow-up interval. These represented the percentage of maximum attainable improvement in score for a given domain and were obtained by subtracting the score obtained at a given follow-up interval from the baseline score and dividing by the baseline score.

Statistical method

Descriptive statistics were obtained for the study cohort. Univariate analysis was performed using matched tests (paired t-test) to compare baseline demographic characteristics, as well as baseline and follow-up clinical measures. Additionally, comparisons were repeated, stratified by the presence or absence of self-reported OA among the bariatric cohort. Given the relatively low number of observations, comparisons were repeated using non-parametric paired tests, with no relevant differences in findings identified. No a priori sample size calculation was performed, as our study sample size was fixed secondary to the number of LRYGB patients recruited for a separate prospective study and available for analysis. However, post hoc analysis given the 20 matched pairs available, and

assuming a two-tailed alpha of 0.05 and power of 0.8 (i.e. 20% risk of type II error), revealed that our study was sufficiently powered to detect a minimum effect size of 0.45 in both WOMAC pain and function relative change scores. This is equivalent to a 'moderate' effect size according to the work of Cohen, [18] and is smaller than then effect sizes seen with 7 days of ibuprofen use in patients with knee and hip OA (0.54 and 0.65, respectively) [19]. For comparison, the reported effect size of TKA on 12-month WOMAC pain and function scores is 2.54 and 2.51, respectively [20].

Results

Bariatric surgery patients reported significant improvements in mean knee-specific WOMAC pain scores at both 6-month (2.95 vs. 6.95; $p<0.001$) and 1-year (2.30 vs. 6.95; $p<0.001$) follow-up compared to baseline (**Table 2**). Similarly, significant improvements in mean knee-specific WOMAC function scores were observed at both 6-month (20.60 vs. 41.25; $p<0.001$) and 1-year (19.53 vs. 41.25; $p<0.001$) follow-up.

Table 2: Comparison of WOMAC pain and function absolute and change scores between matched cohorts.

		Gastric Bypass Cohort (n=20)	Total Arthroplasty Cohort (n=40)	Knee Cohort	p value
Baseline	Mean WOMAC Pain score (range)	6.95 (0 to 13)	12.58 (4 to 19)		<0.001
	Mean WOMAC Function score in points (range)	21.35 (0 to 44)	41.25 (7 to 63)		<0.001
6 month follow-up	Mean WOMAC Pain score in points (range)	2.95 (0 to 9)	4.83 (0 to 12)		0.058
	Mean WOMAC Pain change score in points (range)	4.00 (0 to 12)	7.75 (-3 to 16)		0.007
	Mean WOMAC Function score in points (range)	6.25 (0 to 24)	20.60 (0 to 43)		<0.001
	Mean WOMAC Function change score in points (range)	15.10 (0 to 44)	20.65 (-18 to 54)		0.132
12 month follow-up	Mean WOMAC Pain score in points (range)	2.30 (0 to 9)	3.98 (0 to 15)		0.057
	Mean WOMAC Pain change score in points (range)	4.65 (0 to 13)	8.60 (0 to 16)		0.003
	Mean WOMAC Function score in points (range)	7.05 (0 to 39)	19.53 (0 to 51)		<0.001
	Mean WOMAC Function change score in points (range)	14.30 (-5 to 44)	22.44 (-14 to 57)		0.075

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

The mean percentage improvement in scores was similar between groups for most assessment periods (**Table 3**). Patients in the LRYGB cohort had significantly better mean WOMAC pain (6.95 vs. 12.58; $p<0.001$) and function (21.35 vs. 41.25; $p<0.001$) scores at baseline when compared to patients who underwent TKA, and lower absolute mean change scores at all follow-up assessments. However, the mean percentage improvement in knee-specific pain scores was similar between groups at both 6-

month (49.9% vs. 58.3%; $p=0.438$) and 1-year (62.7% vs. 68.2%; $p=0.576$) follow-up intervals. Furthermore, patients who underwent LRYGB had significantly greater mean percent improvement in knee-specific WOMAC function scores at 6-month follow-up (66.3% vs. 46.8%; $p=0.048$), and a similar though marginally non-significant improvement at 12-month follow-up (68.4% vs. 51.6%; $p=0.094$).

Table 3: Comparison of percent of maximum attainable improvement in WOMAC scores compared to baseline.

		Gastric Bypass Cohort (n=20)	Total Knee Arthroplasty Cohort (n=40)	p value
6 month follow-up	Mean percent improvement in WOMAC Pain score (range)	49.9 (0 to 100)	58.3 (-43 to 100)	0.438

	Mean percent improvement in WOMAC Function score (range)	66.3 (0 to 100)	46.8 (-95 to 100)	0.048
12 month follow-up	Mean percent improvement in WOMAC Pain score (range)	62.7 (0 to 100)	68.2 (0 to 100)	0.576
	Mean percent improvement in WOMAC Function score (range)	68.4 (-15 to 100)	51.6 (-74 to 100)	0.094
WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index				

Comparatively, LRYGB patients with self-reported OA had greater knee pain and worse function pre-operatively when compared to those without OA (Table 4), as well a smaller mean percentage improvement in pain (50.5% vs. 74.9%) and function (55.0% vs. 81.8%) scores at final follow-up.

Table 4: Comparison of WOMAC pain and function absolute and change scores between matched cohorts with bypass patients stratified by presence or absence of self-reported OA.

		Gastric Bypass Cohort without self-reported OA (n=10)	Gastric Bypass with self-reported OA (n=10)	Total Knee Arthroplasty subgroup (n=20)	p value*
Baseline	Mean WOMAC Pain score (range)	6.3 (0 to 12)	7.6 (0 to 13)	13.0 (8 to 16)	0.006
	Mean WOMAC Function score in points (range)	18.6 (2 to 41)	24.1 (0 to 44)	41.8 (19 to 56)	0.010
6 month follow-up	Mean WOMAC Pain score in points (range)	2.9 (0 to 9)	3.0 (0 to 6)	3.25 (0 to 6)	0.795
	Mean WOMAC Pain change score in points (range)	3.4 (0 to 11)	4.6 (0 to 12)	9.75 (6 to 15)	0.016
	Mean percent improvement in WOMAC Pain score (range)	52.8 (0 to 100)	46.9 (0 to 92)	74.6 (53 to 100)	0.038
	Mean WOMAC Function score in points (range)	6.6 (0 to 24)	5.9 (0 to 12)	16.8 (6 to 28)	0.003
	Mean WOMAC Function change score in points (range)	12.0 (0 to 29)	18.2 (0 to 44)	25.0 (13 to 37)	0.236
	Mean percent improvement in WOMAC Function score (range)	67.8 (0 to 100)	64.7 (0 to 80)	59.0 (37 to 83)	0.603
12 month follow-up	Mean WOMAC Pain score in points (range)	1.60 (0 to 9)	3.00 (0 to 6)	3.5 (0 to 9)	0.665
	Mean WOMAC Pain change score in points (range)	4.7 (0 to 11)	4.6 (0 to 13)	9.5 (6 to 16)	0.018
	Mean percent improvement in WOMAC Pain score (range)	74.9 (0 to 100)	50.5 (0 to 100)	73.7 (39 to 100)	0.070
	Mean WOMAC Function score in points (range)	5.7 (0 to 39)	8.4 (0 to 19)	18.9 (2 to 39)	0.013
	Mean WOMAC Function change score in points (range)	20.6 (4 to 46)	15.7 (0 to 44)	22.9 (6 to 47)	0.200
	Mean percent improvement in WOMAC Function score (range)	81.8 (-15 to 100)	55.0 (0 to 100)	56.6 (15 to 97)	0.890

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; OA: osteoarthritis

* p values are for comparison of bypass patients with self-reported OA to a matched subset of patients who underwent TKA

When compared to patients who underwent TKA, the sub cohort of LRYGB patients with self-reported OA had significantly lower percentage improvement in pain at 6-month follow-up (46.9% vs. 74.6%; $p=0.038$) and trended toward significantly lower percentage improvement at 12 months (50.5% vs. 73.7%;

$p=0.070$). No significant differences in percentage improvement in function were seen at either time point (Table 5). It should be noted, however, that the ability to detect significant differences in this sub-analysis was limited by low patient numbers. Nevertheless, even in the presence of self-reported OA, patients

still experienced a mean 50% improvement in knee-specific pain and function scores 12 months following LRYGB.

Table 5: Comparison of WOMAC pain and function absolute and change scores between matched cohorts for the subgroup of bypass patients with self-reported OA.

		Gastric Bypass subgroup with self-reported OA (n=10)	Total Knee Arthroplasty subgroup (n=20)	p value
Baseline	Mean WOMAC Pain score (range)	7.6 (0 to 13)	13.0 (8 to 16)	0.006
	Mean WOMAC Function score in points (range)	24.1 (0 to 44)	41.8 (19 to 56)	0.010
6 month follow-up	Mean WOMAC Pain score in points (range)	3.0 (0 to 6)	3.25 (0 to 6)	0.795
	Mean WOMAC Pain change score in points (range)	4.6 (0 to 12)	9.75 (6 to 15)	0.016
	Mean WOMAC Function score in points (range)	5.9 (0 to 12)	16.8 (6 to 28)	0.003
	Mean WOMAC Function change score in points (range)	18.2 (0 to 44)	25.0 (13 to 37)	0.236
12 month follow-up	Mean WOMAC Pain score in points (range)	3.00 (0 to 6)	3.5 (0 to 9)	0.665
	Mean WOMAC Pain change score in points (range)	4.6 (0 to 13)	9.5 (6 to 16)	0.018
	Mean WOMAC Function score in points (range)	8.4 (0 to 19)	18.9 (2 to 39)	0.013
	Mean WOMAC Function change score in points (range)	15.7 (0 to 44)	22.9 (6 to 47)	0.200

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; OA: osteoarthritis

Discussion

Given the rising prevalence of obesity, and the known associations between increased BMI and knee pain, orthopaedic surgeons may find themselves advising obese patients with marked knee symptoms in the absence of intra-articular pathology amenable to surgical intervention. While studies and clinical practice guidelines have suggested that weight loss may be beneficial for the management of such symptoms, many patients fail to achieve lasting reductions in BMI with diet and exercise alone. Bariatric surgery, and LRYGB in particular, has been reported to be safe and effective in achieving lasting weight loss, and also concomitant reductions in knee symptoms. However, the magnitude of symptomatic improvement is unclear. Thus, we endeavoured to evaluate the changes in knee-specific WOMAC pain and function scores following LRYGB, as compared those attained in patients who underwent TKA.

We acknowledge several limitations to the present study. First, the patients in the present study underwent surgery for different indications. While the TKA group underwent surgery for end-stage OA of the knee, the LRYGB patients presented for management of refractory obesity. While patients in the bariatric cohort were assessed for self-reported OA, they were not selected based on either severity of knee symptoms, or on the presence of degenerative changes in the joint. Second, while a matched cohort design was used in an attempt to control for potentially confounding demographic factors, the use of a nearest-neighbor algorithm for age, rather than an absolute maximum caliper width, resulted in a persistent significant difference in age between cohorts. Third, patients in the TKA group were preferentially selected to have elevated BMIs to more closely reflect the BMI profile of the LRYGB cohort. In a

cohort study of 13,673 primary TKAs, Baker et al. recently reported that increasing BMI is associated with poorer pre and post-operative patient-reported outcomes as measured using the Oxford Knee Score, although no differences in absolute change scores were seen [21]. Similarly, Rajgopal et al. reported differences in absolute but not change scores with the use of the WOMAC following TKA, although outcomes stratified by individual WOMAC domains were not reported [22]. Consequently, given the high mean BMI of the TKA group in the present study, their clinical outcomes may not be generalizable to the wider population of all patients who undergo this procedure. However, a recent large database study reviewed 20,308 patients from approximately 250 medical centers who underwent laparoscopic bariatric surgery [23]. The mean BMI of this study cohort was 46.0 kg/m², which is broadly similar to the mean BMI of both the bariatric (45.6 kg/m²) and TKA (44.6 kg/m²) cohorts in our study, suggesting that our findings are generalizable to the wider population of patients who are suitable candidates for bariatric surgical procedures. Fourth, our follow-up time was limited to 12 months, which we expected would capture the majority of differences in outcome scores associated with the procedures performed. Multiple authors have reported that clinical and functional outcomes following TKA plateau within 1 year of surgery [24-27], although Williams et al. reported that overall Oxford Knee Scores and certain sub-components may not peak until several years following surgery [28]. Longitudinal study of patients who underwent gastric bypass revealed that most of the maximal weight change occurs within the first year of surgery, although some return of body weight may occur years later [29]. Consequently, while these data suggest that maximal change in clinical outcome scores can be reasonably expected to occur within the first year after surgery, further variation in scores may occur at longer follow

up, which would not have been captured in our study. Finally, the group sizes in the study were relatively small, increasing the likelihood of underpowering to detect differences between groups, as well as increasing the theoretical susceptibility to outliers. Specifically, post hoc analysis revealed that our study was sufficiently powered to detect a minimum effect size of 0.45, with a greater than 20% risk of failing to identify significant differences in relative WOMAC change scores associated with smaller effect sizes. However, given that our study was sufficiently powered to detect effect sizes smaller than those seen with short-term ibuprofen use for knee and hip OA [19], the clinical relevance of even smaller effect sizes is debatable. Nevertheless, we believe that the findings of the present study, namely that LRYGB in obese patients can provide similar percentage improvement in knee symptoms when compared to TKA in patients with end-stage osteoarthritis, can provide valuable guidance to orthopaedic surgeons and other health care providers when counselling obese patients with marked knee symptoms in the absence of surgical pathology.

It is important to note that two cohorts in the present study were not matched for baseline WOMAC scores. Given the important differences between cohorts in underlying pathology/pathologies potentially contributing to patients' knee symptoms, as well as pathophysiologic effects of TKA vs. LRYGB on knee pain, there were expected significant differences in baseline, follow-up, and absolute WOMAC change scores between groups. However, it is well recognized that from the patient perspective, the magnitude of change in absolute scores needed to achieve a minimal clinically important difference in symptoms is related to the baseline state (in other words, patients who have worse symptoms need to experience a greater change in score to consider themselves improved) [30,31]. Consequently, relative change scores may be better representative of the magnitude of change in symptoms from the patients' perspective, especially given differences in baseline status. In the present study, we found that patients who underwent LRYGB had considerably milder baseline symptoms (as evidenced by higher WOMAC pain and function scores), as well as a smaller improvement in absolute scores at final follow-up. However, given the similar relative change scores at final follow-up, it is likely that the magnitude of improvement in knee symptoms was more comparable between groups than would be suggested by examination of absolute scores in isolation.

To date, there have been few studies evaluating the impact of bariatric surgery on knee symptoms. A systematic review by Gill et al. published in 2011 identified 5 studies that assessed the influence of bariatric surgery on lower limb joint pain in patients with osteoarthritis [15]. While two studies assessed both hip and knee joint pain, the other three evaluated knee symptoms only. All five studies identified benefits in terms of reduction pain and/or improved function following bariatric surgery. More recently, Edwards et al. evaluated 24 patients with radiographically-confirmed symptomatic osteoarthritis of the knee (mean Kellgren-Lawrence grade of 1.85 in left knee and 1.89 in right knee; ranges not reported) [16]. The authors reported significant improvements in all domains of the WOMAC and Knee Injury and Osteoarthritis Outcome Scores (KOOS) at 1 year follow up. The mean improvement in WOMAC pain scores

was 5.3 points, and the mean improvement in WOMAC function scores was 19.2 points. These findings were broadly similar to mean change scores of 4.7 and 14.3, respectively, for the LRYGB cohort in the present study.

There are a range of non-surgical options available to patients to help with weight loss, including dietary, exercise, pharmacologic and psychotherapeutic interventions alone or in combination. Bariatric patients are best managed using a multidisciplinary approach, with bypass surgery indicated in the subset of patients who have failed one or more conservative treatment options, and who have met a range of clinical and psychological qualification criteria [32-34]. Consequently, it is important to recognize that the goal of bariatric consultation is to provide patients with expert assessment and advice concerning the full range of options to achieve and maintain meaningful weight loss.

In summary, bariatric surgery provides significant improvements in patient-reported knee pain and physical function up to one year following surgery, although the effect on patient-reported outcomes was somewhat less in those who reported concurrent OA. The relative improvement in symptoms was similar to that of a matched group of patients who underwent TKA for end-stage OA. While further work is needed to better delineate the contribution of elevated BMI to knee symptoms, as well as to ascertain whether these findings are maintained at longer-term follow-up, surgeons should consider bariatric consultation for obese patients with knee symptoms lacking either focal pathology amenable to orthopaedic management or degenerative changes sufficiently advanced to warrant joint arthroplasty.

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Compliance with Ethical Standards

Conflict of interest

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Ethical Board Review Statement

IRB approval was sought and granted for this study

References

1. March LM, Bagga H (2004) Epidemiology of osteoarthritis in Australia. *Med J Aust* 180: S6-S10.
2. Dieppe P, Basler HD, Chard J, Croft P, Dixon J, et al. (1999) Knee replacement surgery for osteoarthritis: effectiveness, practice

- variations, indications and possible determinants of utilization. *Rheumatology (Oxford)* 38: 73-83.
3. Woolhead GM, Donovan JL, Dieppe PA (2005) Outcomes of total knee replacement: A qualitative study. *Rheumatology (Oxford)* 44: 1032-1037.
 4. Odum SM, Springer BD, Dennon AC, Fehring TK (2013) National obesity trends in total knee arthroplasty. *J Arthroplasty* 28: 148-151.
 5. Messier SP, Loeser RF, Miller GD, Morgan TM, Rejeski WJ, et al. (2005) Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the arthritis, diet, and activity promotion trial. *Arthritis Rheum* 50: 1501-1510.
 6. Christensen R, Astrup A, Bliddal H (2005) Weight loss: the treatment of choice for knee osteoarthritis? A randomized trial. *Osteoarthritis Cartilage* 13: 20-27.
 7. Hochberg MC, Altman RD, April KT, Benkhalti M, Guyatt G, et al. (2012) American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. *Arthritis Care Res (Hoboken)* 64: 465-474.
 8. National Institute for Health and Clinical Excellence (2008) Osteoarthritis: the care and management of osteoarthritis in adults.
 9. Jevsevar DS (2013) Treatment of osteoarthritis of the knee: evidence based guideline. *J Am Acad Orthop Surg* 21: 571-576.
 10. McGuire MT, Wing RR, Hill JO (1999) The prevalence of weight loss maintenance among American adults. *International journal of obesity and related metabolic disorders. Int J Obes Relat Metab Disord* 23: 1314-1319.
 11. Wing RR, Phelan S (2005) Long-term weight loss maintenance. *Am J Clin Nutr* 82: 222S-225S.
 12. Tice JA, Karliner L, Walsh J, Petersen AJ, Feldman MD (2008) Gastric banding or bypass? A systematic review comparing the two most popular bariatric procedures. *Am J Med* 121: 885-893.
 13. Arterburn D, Powers JD, Toh S, Polsky S, Butler MG, et al. (2014) Comparative effectiveness of laparoscopic adjustable gastric banding vs. laparoscopic gastric bypass. *JAMA Surgery* 149: 1279-1287.
 14. Dogan K, Gadiot RM, Aarts E, Betzel B, van Laarhoven CHM, et al. (2014) Effectiveness and Safety of Sleeve Gastrectomy, Gastric Bypass, and Adjustable Gastric Banding in Morbidly Obese Patients: a Multicenter, Retrospective, Matched Cohort Study. *Obes Surg* 25: 1110-1118.
 15. Gill RS, Al-Adra DP, Shi X, Sharma AM, Birch DW, et al. (2011) The benefits of bariatric surgery in obese patients with hip and knee osteoarthritis: a systematic review. *Obes Rev* 12: 1083-1089.
 16. Edwards C, Rogers A, Lynch S, Pylawka T, Silvis M, et al. (2012) Effects of Bariatric Surgery Weight Loss on Knee Pain in Patients with Osteoarthritis of the Knee. *Arthritis* 50:4189.
 17. Angst F, Aeschlimann A, Steiner W, Stucki G (2001) Responsiveness of the WOMAC osteoarthritis index as compared with the SF-36 in patients with osteoarthritis of the legs undergoing a comprehensive rehabilitation intervention. *Ann Rheum Dis* 60: 834-840.
 18. Cohen J (1992) A power primer. *Psychol Bull* 112: 155-1559.
 19. Davies GM, Watson DJ, Bellamy N (1999) Comparison of the responsiveness and relative effect size of the western Ontario and McMaster Universities Osteoarthritis Index and the short-form Medical Outcomes Study Survey in a randomized, clinical trial of osteoarthritis patients. *Arthritis Care Res* 12: 172-179.
 20. Giesinger K, Hamilton DF, Jost B, Holzner B, Giesinger JM (2014) Comparative responsiveness of outcome measures for total knee arthroplasty. *Osteoarthritis Cartilage* 22: 184-189.
 21. Baker P, Petheram T, Jameson S, Reed M, Gregg P, et al. (2012) The association between body mass index and the outcomes of total knee arthroplasty. *J Bone Joint Surg Am* 94: 1501-1508.
 22. Rajgopal V, Bourne RB, Chesworth BM, MacDonald SJ, McCalden RW, et al. (2008) The impact of morbid obesity on patient outcomes after total knee arthroplasty. *J Arthroplasty* 23: 795-800.
 23. Sanni A, Perez S, Medbery R, Urrego HD, McCready C, et al. (2014) Postoperative complications in bariatric surgery using age and BMI stratification: a study using ACS-NSQIP data. *Surg Endosc* 28: 3302-3309.
 24. Kennedy DM, Stratford PW, Riddle DL, Hanna SE, Gollish JD (2008) Assessing recovery and establishing prognosis following total knee arthroplasty. *Phys Ther* 88: 22-32.
 25. Page MG, Katz J, Romero Escobar EM, Lutzky-Cohen N, Curtis K, et al. (2015) Distinguishing problematic from nonproblematic postsurgical pain: a pain trajectory analysis after total knee arthroplasty. *Pain* 156: 460-468.
 26. Zhou Z, Yew KS, Arul E, Chin PL, Tay KJ, et al. (2015) Recovery in knee range of motion reaches a plateau by 12 months after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 23: 1729-1733.
 27. Matharu GS, McBryde CW, Robb CA, Pynsent PB (2014) An analysis of Oxford hip and knee scores following primary hip and knee replacement performed at a specialist centre. *Bone Joint J* 96-B: 928-935.
 28. Williams DP, Blakey CM, Hadfield SG, Murray DW, Price AJ, et al. (2013) Long-term trends in the Oxford knee score following total knee replacement. *Bone Joint J* 95-B: 45-51.
 29. Courcoulas AP, Christian NJ, Belle SH, Berk PD, Flum DR, et al. (2013) Weight change and health outcomes at 3 years after bariatric surgery among individuals with severe obesity. *JAMA* 310: 2416-2425.
 30. Tubach F, Ravaud P, Baron G, Falissard B, Logeart I, et al. (2005) Evaluation of clinically relevant changes in patient reported outcomes in knee and hip osteoarthritis: the minimal clinically important improvement. *Ann Rheum Dis* 64: 29-33.
 31. Riddle DL, Stratford PW, Binkley JM (1998) Sensitivity to change of the Roland-Morris Back Pain Questionnaire: part 2. *Phys Ther* 78: 1197-1207.
 32. Elte JW, Castro Cabezas M, Vrijland WW, Ruseler CH, Groen M, et al. (2008) Proposal for a multidisciplinary approach to the patient with morbid obesity: the St. Franciscus Hospital morbid obesity program. *Eur J Intern Med* 19: 92-98.
 33. Monkhouse SJ, Morgan JD, Bates SE, Norton SA (2009) An overview of the management of morbid obesity. *Postgrad Med J* 85: 678-681.
 34. Dimitrov DV, Ivanov V, Atanasova M (2011) Advantages of bariatric medicine for individualized prevention and treatments: multidisciplinary approach in body culture and prevention of obesity and diabetes. *EPMA J* 2: 271-276.

