Clin Orthop Relat Res (2019) 477:2629-2634
DOI 10.1097/CORR.0000000000001017

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

Clinical Faceoff

Published online: 28 October 2019

Clinical Faceoff: Should Orthopaedic Surgeons Have Strict BMI Cutoffs for Performing Primary TKA and THA?

Benjamin F. Ricciardi MD, Nicholas J. Giori MD, PhD, Thomas K. Fehring MD

Obesity has become an epidemic in the United States, and it is a major risk factor for the development of lower-extremity osteoarthritis [18]. And while both TKA and THA provide durable symptom relief and improved functional outcomes in patients with osteoarthritis of the knee and hip, recent studies [15, 17, 23, 31] have shown a higher risk of readmissions and early complications like prosthetic joint infection (PJI) in patients with obesity (BMI > 35) after THA and TKA.

Given the institutional and national focus on cost reduction in the era of bundled payments and the increased emphasis on surgeon outcomes, a number of institutions and payors are beginning to institute strict cutoffs in BMI to determine eligibility for elective primary THA and TKA. This is a controversial topic because while obesity is an established risk factor for complications after THA and TKA, strict cutoffs at the institutional level may affect access to care and worsen existing disparities in joint replacement care [30].

I have asked two respected leaders in THA and TKA to weigh in: Thomas K. Fehring MD from OrthoCarolina and Nicholas J. Giori MD, PhD from Stanford University. Dr. Fehring is the Co-Director of OrthoCarolina Hip and Knee Center, Professor and Chief of Adult Reconstruction for the Atrium Health Musculoskeletal Institute in Charlotte, NC, USA, and Professor and Chief of Adult Reconstruction Surgery at Atrium Health Musculoskeletal Institute. He was President of the American Association of Hip and Knee Surgeons from 2013-2014 and of the prestigious Knee Society from 2014-2015. He has published more than 130 peer-reviewed publications on topics including outcomes after THA and TKA and treatment of prosthetic joint infection.

Nicholas Giori MD, PhD is a Professor of Orthopedic Surgery at Stanford University in Palo Alto, CA, USA. He is the Chief of Orthopedics at the Palo Alto Veterans Affairs hospital. He has published more than 115 peer-reviewed publications on topics including the effect of obesity on complications in THA and TKA.

Benjamin F. Ricciardi MD: *Given the many recent studies on complications and readmissions in patients with obesity after THA and TKA, and the increased focus on cost reduction at the institutional and national level, to what degree does the evidence support*

A *note from the Editor-in-Chief: We are pleased to present to readers of* Clinical Orthopaedics and Related Research® *another installment of* Clinical Faceoff, *a regular feature. This section is a point-counterpoint discussion between recognized experts in their fields on a controversial topic. We welcome reader feedback on all of our columns and articles; please send your comments to eic@clinorthop.org.*

One of the authors certifies that he (TKF), or a member of his immediate family, has received royalties, during the study period, an amount of more than USD 1,000,000 from Depuy Orthopaedics (Warsaw, IN, USA).

One of the authors certifies that he (TKF), or a member of his immediate family, was a consultant for Depuy Orthopaedics (Warsaw, IN, USA) during the study period, for an amount of USD 10,000 to USD 100,000.

One of the authors certifies that he (TKF), or a member of his immediate family, received less than USD 10,000 from Depuy Orthopaedics, (Warsaw, IN, USA) for educational presentations.

The opinions expressed are those of the writer, and do not reflect the opinion or policy of *CORR*® or The Association of Bone and Joint Surgeons®.

Benjamin F. Ricciardi MD (✉), University of Rochester School of Medicine, Department of Orthopedic Surgery, 601 Elmwood Ave, Rochester, NY 14642 USA, Email: benjamin_ricciardi@urmc.rochester.edu

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*® editors and board members are on file with the publication and can be viewed on request.

B. F. Ricciardi, Department of Orthopaedic Surgery, Center for Musculoskeletal Research, University of Rochester School of Medicine, Rochester, NY, USA
N. J. Giori, Professor, Department of Orthopedic Surgery, Stanford University and Chief of Orthopedic Surgery, VA Palo Alto Health Care System, Palo Alto, CA, USA
T. K. Fehring, Co-Director, Ortho Carolina Hip and Knee Center, Professor and Chief of Adult Reconstruction Atrium Health Musculoskeletal Institute, Charlotte, NC, USA

using a strict BMI cutoff to determine eligibility for primary TKA and THA?

Thomas K. Fehring MD: There now are more than 502 million people classified as obese worldwide. In the United States, the prevalence of obesity is 35% and is now a major health concern. The benefits of total joint arthroplasty for those with obesity must be balanced against the increased risk of peri-operative morbidity.

The association between complications, deep infection, and a BMI > 40 appears irrefutable. Nowhere are there studies that say patients with morbid obesity have fewer complications than patients who are not obese. Translating this into advocacy for a strict cutoff for elective surgery demands omitting small studies, which can be affected by a selection or investigator bias. To that end, one should focus on three sources of information: (1) Big data registry studies, (2) meta-analysis, and (3) position statements by specialty societies.

Focusing on studies with at least 5000 patients, the findings are extremely consistent. Meller and colleagues looked at 432,000 patients in the Medicare database and found that 9907 had a BMI above 40 [23]. Patients with morbid obesity had increased post-operative complications including PJI (hazard ratio [HR], 3.71). Revision (HR, 1.91), and wound dehiscence (HR, 3.91). A multi-variate regression analysis examined 22,000 patients in the Veterans Affairs Quality Improvement Program and showed that a BMI > 40 is an independent predictor for combined complications including acute kidney injury, cardiac arrest, re-intubation, re-operation, and superficial infection [31]. In evaluating 15,000 patients in a National Surgical Quality Improvement Program database, another study found that a BMI > 40 was an independent predictor of post-operative complications [4]. One study examining approximately 8000 patients noted that if a patient had a BMI > 40, he or she had 3.2 greater odds of infection versus a patient with a BMI < 40 [20]. Another study examining 7181 patients found that patients with a BMI > 40 had an increased infection rate in a multivariate analysis [15]. In a meta-analysis of more than 15,000 patients, infection occurred more often in patients with obesity (odds ratio [OR], 2.38). Additionally, revision for any reason occurred more often in obese patients (OR, 1.30) [17].

In its position statement, the American Association of Hip and Knee Surgeons Evidence Based Committee concluded that there was a clear increase in deep infections in joint replacements in patients with obesity [36]. They found that total knee peri-operative complications (including the risks of infection and revision surgery) increase considerably when the patient's BMI > 40. They also concluded that patients who are morbidly obese have complication profiles that may outweigh the functional benefits of total joint arthroplasty.

The above data underscore the need to have a strict BMI cutoff. However, it is equally important to develop strategies to help this patient population lose weight prior to arthroplasty.

Nicholas Giori MD, PhD: Obesity is undeniably related to complications, but I do not believe that broadly applied hard BMI cutoffs at the administrative level are justifiable for the following reasons:

- BMI is a weak risk factor that is comparable in magnitude to others we commonly accept. In studies with more than 5000 patients, ORs for any complication in patients with BMI > 40kg/m^2 range from 1.18 to 1.47 [4, 8, 31]. Patients older than 80 years of age (OR, 1.94) and American Society of Anesthesiologists (ASA) score > 2 (OR, 1.49) are stronger risk factors [4]. BMI > 40kg/m2 is a weaker independent predictor of complications than elevated bilirubin, dialysis, history of stroke, hypertension, older than 75 years of age, congestive heart failure, chronic obstructive pulmonary disease, low albumin, ASA > 2, and diabetes [30]. The OR for infection for patients with BMI between 40 and 50kg/m^2 is 3.2, which is comparable to patients with diabetes (OR, 3.1) [20].
- Hard BMI cutoffs oversimplify preoperative risk assessment. Risk does not suddenly jump with an incremental change across a BMI threshold, and BMI does not account for variation in body composition or fat distribution. Higher muscle mass mitigates the health effects of BMI [2], and in knee replacement, thickness of prepatellar fat predicts complications better than BMI [32, 35, 37]. A much more sophisticated and accurate way to assess preoperative risk is to use risk calculators, which consider BMI, demographics and other comorbidities [5, 6, 9].
- Obesity is not reversible for most patients. Outpatient weight reduction programs average only 8% body weight loss [1, 10, 29]. Eight percent of patients denied surgery for high BMI eventually reach the BMI cutoff and have total joint arthroplasty [28]. Without a reliable pathway for weight loss, we shouldn't categorically withhold an operation that improves pain and function for patients in all BMI classes [3, 14, 16] to avoid a risk that is comparable to other risks we routinely accept.

- It is not clear that weight reduction prior to surgery reduces risk. Most studies on this topic involve dramatic weight loss from bariatric surgery and have had mixed results [13, 19, 21, 22, 24, 27]. Moderate non-surgical weight loss has thus-far not been shown to affect risk [12].

Dr. Ricciardi: *One recent study [30] suggested that using a strict BMI cutoff as a criterion for arthroplasty surgery may reduce access to care for individuals of particular races, for women, and for patients who live in poverty. Given the expansion of strict BMI cutoffs at the administrative level, how should safety (non-maleficence) be balanced against access to care?*

Dr. Giori: BMI criteria aim to avoid complications, but we must be aware of unreasonably limiting access to care. In the Veterans Affairs healthcare system, enforcing a strict BMI eligibility criterion of 40kg/m^2 would deny complication-free surgery to 14 patients to avoid one complication [8]. For a BMI cutoff of 35, it is 16 to 1. To put this in perspective, if you flipped a coin to determine surgical eligibility, it would be 19 to 1. Though hard BMI cutoffs are well-intended, currently-used BMI cutoffs nearly have the effect of arbitrarily rationing care without medical justification. This is because BMI does not strongly predict complications. It is troubling that the effects are actually not arbitrary, but disproportionally affect minorities, women and patients in low socioeconomic classes.

Administrative mandates on surgical eligibility also interfere with the doctor-patient relationship. Total joint arthroplasty at any BMI level is cost effective to society [25, 26]. The Quality Adjusted Life Years gained with total joint arthroplasty at any BMI level are thus "worth it" to society when benchmarked against the costs and benefits of other health interventions that society willingly pays for. I believe that the decision to proceed with surgery should be based on traditional shared-decision making between the patient and surgeon. Different patients and different surgeons have different tolerances to risk and reward. Giving patients and surgeons freedom to determine the balance that is right for them is, in my opinion, the right way to proceed. One factor that upsets this potential balance is the drive toward bundled payment models, which, without risk-adjusting reported quality metrics and compensation, strongly discourages surgeons from accepting somewhat higher risk patients. Accurate risk adjustment is difficult and needs improvement, but I believe this is the only way to avoid this perverse incentive in the future.

Dr Fehring: I agree with Dr. Giori that strict institutional cutoffs, while well intentioned, may have unintended consequences concerning access to care. Taken to an extreme, such a cutoff could be likened to other cutoffs such as a speed limit on a highway or alcohol consumption while driving. While such risks have inherent limitations, they also prevent serious injury. The question before us is a BMI cutoff useful to prevent a similar disaster such as a PJI.

I respect Dr. Giori's published work on this subject, but the patient with a BMI of 50 who develops an infection really doesn't care about statistics when they are looking at multiple operations ending possibly in an amputation. Such patients frequently say they were better off before their surgery.

As a revision surgeon with a strong interest in infection working at the OrthoCarolina Prosthetic Joint Infection Center, the vast majority of patients I treat for PJI have morbid obesity and have life- and limb-threating problems on arrival. Multiple large studies from the Mayo Clinic on the risk of complications in the obese demonstrate that the complication risk is linear, that is, the higher the patient's BMI, the higher the risk of infection and complications. For every incremental increase in BMI, the risk goes up [33, 34].

I agree that every major care decision should include shared-decision making between patient and his or her surgeon. However, can any patient in pain with limited function really understand the serious ramifications of a PJI? Can (s)he really tell that (s)he has a four to five times higher risk of infection due to BMI?

I respect Dr. Giori's concern to protect access and his opinion that there should not be a cutoff, but at a certain point, the risk outweighs the benefits and an attempt to operate on all patients regardless of BMI becomes dangerous. Where you draw that cutoff line can be different for each surgeon. Is it a BMI of 50, a BMI of 60, a BMI of 70, or is it a BMI of 40 where most of the data on this subject lies?

One must understand that as surgeons, we can make things worse and we have an obligation to our patients to first do no harm. I believe a BMI cutoff of 40 is a reasonable goal for the safety of our patients.

Dr. Ricciardi: *If a patient with morbid obesity is to undergo arthroplasty, what steps should be taken before surgery to make hip or knee arthroplasty surgery safer (if any)?*

Dr. Fehring: The most effective step is to focus on improving the patient's modifiable risk factors to make sure they are in the best possible health they can be prior to elective surgery to avoid complications. At OrthoCarolina, we have put into place

an optimization program for hip and knee arthroplasty and spine surgery where patients are required to have their possible modifiable risk factors such as body weight, blood glucose control, serum albumin, and smoking status addressed before embarking on elective surgery. We delay surgery if the BMI > 40, hemoglobin A1C > 8, albumin < 3.5, or the patient is a smoker. We give this patient population the tools to meet these goals. We refer patients with obesity to a bariatric center. We refer patients who smoke to a smoking-cessation program. We refer those patients with low albumin to a nutritionist, and those with an elevated A1C to their primary care physician or an endocrinologist. When a patient is found to be non-optimized, we delay elective surgery until (s)he is healthier. Upon hearing this, patients are frequently disappointed and occasionally angry. This is understandable as the non-optimized patient is just looking for a solution to diminish their pain and improve their function. These are frequently difficult and time-consuming conversations, and can be problematic for other reasons as well, in an era of social media or online physician surveys. Therefore, when surgery is delayed because the patient is not healthy enough for surgery, this conversation must be done carefully and with empathy. We need to make sure the patient understands the purpose and that the surgeon is doing his or her best to try to prevent a serious complication. It is much easier just to say "yes", keep the surgery schedule full, and hope a serious complication does not occur. As surgeons, we must understand that we are not just arthroplasty technicians. We are physicians first and it is our obligation to treat not only an arthritic hip or knee but to treat the patient as a whole.

Performing elective surgery on a patient with morbid obesity, who is malnourished, who smokes cigarettes, and who has poorly controlled diabetes has ethical considerations in addition to being costly to the healthcare system. Therefore, the most-important step in making arthroplasty safe for the patient with morbid obesity is to have the strength and conviction to put an optimization program in place and stick to its principles.

Dr Giori: I agree that we must be physicians first and that we must work with our patients to reduce risks to the extent possible. I applaud the programs implemented at OrthoCarolina and other centers to improve patient health and reduce complications. We have a similar program in our center. The difference is that we do not hold a hard line on so-called reversible risk factors such as obesity that, in practice, are not very reversible. Some people succeed, which is wonderful. However, a majority of obese patients, even when offered a program, do not [28]. I agree that a patient who smokes and has morbid obesity, poorly controlled diabetes, and malnutrition clearly should not have surgery. However, in isolation, the risk of obesity is comparable in magnitude to risks that we commonly accept and operate through. Holding a hard line on BMI in all patients can amount to erecting a poorly-justified barrier to care.

The best we can now do regarding obesity is to provide encouragement and education, and to refer to a structured weight-reduction program. The best the patient can do is engage in the program and honestly try to succeed. After good-faith efforts on both sides and a reasonable amount of time spent, some patients will succeed in losing enough weight to get below a BMI threshold. For the rest, the patient and surgeon should reassess progress and discuss overall predicted risk, benefit, and goals. Through shared decision-making, a plan should be made regarding how to proceed. This may or may not involve surgery. In this way, both the patient and the surgeon engage in this important decision.

Dr. Ricciardi: *If a patient with morbid obesity is to undergo THA or TKA, what steps (if any) should be taken during and after surgery to make it safer?*

Dr. Giori: Surgery on patients with obesity is technically challenging. The surgeon must be ready. Appropriate retractors and additional assistance are commonly needed. Gaining adequate exposure is critical, and requires long incisions. I find headlamps useful. I use certain tricks to help with exposure. For example, I try to avoid using deep blades for the Charnley retractor during posterior approach hip replacement as I have found that they effectively make the wound deeper and the operation more difficult. Rather, I make a long incision, slide the superficial skin and fat away from the wound, then use the shortest possible Charnley retractor blades. I have found that this makes the wound shallower and exposure easier. In knee replacement, if there is a thick soft-tissue envelope, I sometimes flip the patella into a pocket created between the retinaculum and the subcutaneous fat. It is critical to handle and retract soft tissues gently as this will help to avoid wound healing problems. Again, this requires long incisions. Intraoperative radiographs can be helpful to confirm satisfactory implant positioning prior to closure. Finally, I close the subcutaneous tissue with multiple layers of absorbable suture to minimize dead space, and I try not to tie the knots too tightly to avoid fat necrosis. With wide exposure, good lighting, sufficient help, gentle soft tissue management, intraoperative

radiographs, multilayer closure, and experience with the tricks required to handle these challenging surgeries, I believe that the operation can be done expeditiously and safely, and the components can be placed accurately.

I use short cemented tibial stems for primary knee replacement in patients with morbid obesity, though there are insufficient data to strongly advocate for them. I do not alter the standard 24-hour regimen for perioperative antibiotics, and generally do not change my usual skin closure or postoperative routine for obese patients.

Dr Fehring: I have a strict BMI cutoff of 40. However, when a decision-making mistake has been made in a referred patient with a BMI over 40 that has had surgery and now has a complication, I feel an obligation to revise that patient. Procrastination with regard to a loose or infected implant usually leads to further bone loss. During such revision surgery, careful templating, adequate help, and weight-based antibiotics are critical to success. Technically large incisions without raising large sub-q flaps are important to facilitate safe adequate exposure. Deep self-retaining retractors are frequently useful as are extra-long basic retractors. The choice of implant may differ in morbidly obese patients. Cementless hip implants are easier to perform than cemented hips recognizing that longevity if bone in growth occurs may be superior with cementless femoral implants versus cemented constructs.

On the knee side, we have reported a series of late tibial varus collapse in obese patients with small tibial plateaus [7]. With such a large force the threshold strength of cancellous bone can be exceeded leading to bony fatigue failure and varus collapse. We use short extended length tibial stems in obese patients as this can diminish stress on the tibial component.

Finally, post-operative care needs to be modified. In patients with obesity, we frequently use incisional wound vacs to facilitate healing and minimize drainage. Additionally, we occasionally use an extended course of oral antibiotics in this subset of patients. One retrospective cohort study found that oral antibiotic prophylaxis for 7 days lowered the risk of infection in patients deemed at high risk for PJI [11]. The study, however, did include a control group of high-risk patients, highlighting a need for further study before any potential adoption of this protocol.

References

1. Aadland E, Robertson L. Physical activity is associated with weight loss and increased cardiorespiratory fitness in severely obese men and women undergoing lifestyle treatment. *J Obes.* 2012;2012:810594.
2. Abramowitz MK, Hall CB, Amodu A, Sharma D, Androga L, Hawkins M. Muscle mass, BMI, and mortality among adults in the United States: A population-based cohort study. *PLoS One*. 2018;13:e0194697.
3. Baker P, Petheram T, Jameson S, Reed M, Gregg P, Deehan D. The association between body mass index and the outcomes of total knee arthroplasty. *J Bone Joint Surg Am*. 2012;94:1501-1508.
4. Belmont PJ Jr, Goodman GP, Waterman BR, Bader JO, Schoenfeld AJ. Thirty-day postoperative complications and mortality following total knee arthroplasty: Incidence and risk factors among a national sample of 15,321 patients. *J Bone Joint Surg Am*. 2014;96:20-26.
5. Bilimoria KY, Liu Y, Paruch JL, Zhou L, Kmiecik TE, Ko CY, Cohen ME. Development and evaluation of the universal ACS NSQIP surgical risk calculator: A decision aid and informed consent tool for patients and surgeons. *J Am Coll Surg*. 2013;217:833-842.
6. Bozic KJ, Ong K, Lau E, Berry DJ, Vail TP, Kurtz SM, Rubash HE. Estimating risk in Medicare patients with THA: An electronic risk calculator for periprosthetic joint infection and mortality. *Clin Orthop Relat Res*. 2013;471:574-583.
7. Fehring TK, Fehring KA, Anderson LA, Otero JE, Springer BD. Catastrophic varus collapse of the tibia in obese total knee arthroplasty. *J Arthroplasty*. 2017;32:1625-1629.
8. Giori NJ, Amanatullah DF, Gupta S, Bowe T, Harris AHS. Risk reduction compared with access to care: Quantifying the trade-off of enforcing a body mass index eligibility criterion for joint replacement. *J Bone Joint Surg Am*. 2018;100:539-545.
9. Harris AHS, Kuo AC, Weng Y, Trickey AW, Bowe T, Giori NJ. Can machine learning methods produce accurate and easy-to-use prediction models of 30-day complications and mortality after knee or hip arthroplasty? *Clin Orthop Relat Res*. 2019;477:452-460.
10. Hofsø D, Nordstrand N, Johnson LK, Karlsen TI, Hager H, Jenssen T, Bollerslev J, Godang K, Sandbu R, Røislien J, Hjelmesaeth J. Obesity-related cardiovascular risk factors after weight loss: A clinical trial comparing gastric bypass surgery and intensive lifestyle intervention. *Eur J Endocrinol*. 2010;163:735-745.
11. Inabathula A, Dilley JE, Ziemba-Davis M, Warth LC, Azzam KA, Ireland PH, Meneghini RM. Extended oral antibiotic prophylaxis in high-risk patients substantially reduces primary total hip and knee arthroplasty 90-day infection rate. *J Bone Joint Surg Am*. 2018;100:2103-2109.
12. Inacio MC, Kritz-Silverstein D, Raman R, Macera CA, Nichols JF, Shaffer RA, Fithian DC. The impact of pre-operative weight loss on incidence of surgical site infection and readmission rates after total joint arthroplasty. *J Arthroplasty*. 2014;29:458-64.
13. Inacio MC, Paxton EW, Fisher D, Li RA, Barber TC, Singh JA. Bariatric surgery prior to total joint arthroplasty may not provide dramatic improvements in post-arthroplasty surgical outcomes. *J Arthroplasty*. 2014;29:1359-1364.
14. Jameson SS, Mason JM, Baker PN, Elson DW, Deehan DJ, Reed MR. The impact of body mass index on patient reported outcome measures (PROMs) and complications following primary hip arthroplasty. *J Arthroplasty*. 2014;29:1889-1898.

15. Jämsen E, Nevalainen P, Eskelinen A, Huotari K, Kalliovalkama J, and Moilanen T. Obesity, diabetes, and preoperative hyperglycemia as predictors of periprosthetic joint infection: A single-center analysis of 7181 primary hip and knee replacements for osteoarthritis. *J Bone Joint Surg Am*. 2012;94:e101.
16. Judge A, Batra RN, Thomas GE, Beard D, Javaid MK, Murray DW, Dieppe PA, Dreinhoefer KE, Peter-Guenther K, Field R, Cooper C, Arden NK. Body mass index is not a clinically meaningful predictor of patient reported outcomes of primary hip replacement surgery: prospective cohort study. *Osteoarthritis Cartilage*. 2014;22:431-439.
17. Kerkhoffs GM, Servien E, Dunn W, Dahm D, Bramer JA, Haverkamp D. The influence of obesity on the complication rate and outcome of total knee arthroplasty: A meta-analysis and systematic literature review. *J Bone Joint Surg Am*. 2012;94:1839-44.
18. Koonce RC, Bravman JT. Obesity and osteoarthritis: more than just wear and tear. *J Am Acad Orthop Surg*. 2013;21: 161-169.
19. Kulkarni A, Jameson SS, James P, Woodcock S, Muller S, Reed MR. Does bariatric surgery prior to lower limb joint replacement reduce complications? *Surgeon*. 2011;9:18-21.
20. Malinzak RA, Ritter MA, Berend ME, Meding JB, Olberding EM, Davis KE. Morbidly obese, diabetic, younger, and unilateral joint arthroplasty patients have elevated total joint arthroplasty infection rates. *J Arthroplasty*. 2009;24(6 Suppl): 84-88.
21. Martin JR, Watts CD, Taunton MJ. Bariatric surgery does not improve outcomes in patients undergoing primary total knee arthroplasty. *Bone Joint J*. 2015;97B:1501-1505.
22. McLawhorn AS, Levack AE, Lee YY, Ge Y, Do H, Dodwell ER. Bariatric surgery improves outcomes after lower extremity arthroplasty in the morbidly obese: A propensity score-matched analysis of a New York statewide database. *J Arthroplasty*. 2018;33:2062-2069.
23. Meller MM, Toossi N, Gonzalez MH, Son MS, Lau EC, Johanson N. Surgical risks and costs of care are greater in patients who are super obese and undergoing THA. *Clin Orthop Relat Res*. 2016;474:2472-2481.
24. Nearing EE 2nd, Santos TM, Topolski MS, Borgert AJ, Kallies KJ, Kothari SN. Benefits of bariatric surgery before elective total joint arthroplasty: Is there a role for weight loss optimization*? Surg Obes Relat Dis.* 2017;13:457-462.
25. Ponnusamy KE, Vasarhelyi EM, McCalden RW, Somerville LE, Marsh JD. Cost-effectiveness of total hip arthroplasty versus nonoperative management in normal, overweight, obese, severely obese, morbidly obese, and super obese patients: A Markov model. *J Arthroplasty*. 2018;33:3629-3636.
26. Ponnusamy KE, Vasarhelyi EM, Somerville L, McCalden RW, Marsh JD. Cost-effectiveness of total knee arthroplasty vs nonoperative management in normal, overweight, obese, severely obese, morbidly obese, and super-obese patients: A Markov model. *J Arthroplasty*. 2018;33: S32-S38.
27. Severson EP, Singh JA, Browne JA, Trousdale RT, Sarr MG, Lewallen DG. Total knee arthroplasty in morbidly obese patients treated with bariatric surgery: A comparative study. *J Arthroplasty*. 2012; 27:1696-1700.
28. Springer BD, Roberts KM, Bossi KL, Odum SM, Voellinger DC. What are the implications of withholding total joint arthroplasty in the morbidly obese? A prospective, observational study. *Bone Joint J*. 2019;101B:28-32.
29. Unick JL, Beavers D, Bond DS, Clark JM, Jakicic JM, Kitabchi AE, Knowler WC, Wadden TA, Wagenknecht LE, Wing RR; Look AHEAD Research Group. The long-term effectiveness of a lifestyle intervention in severely obese individuals. *Am J Med*. 2013;126: 236-242.
30. Wang AY, Wong MS, Humbyrd CJ. Eligibility criteria for lower extremity joint replacement may worsen racial and socioeconomic disparities. *Clin Orthop Relat Res*. 2018;476:2301-2308.
31. Ward DT, Metz LN, Horst PK, Kim HT, Kuo AC. Complications of morbid obesity in total joint arthroplasty: Risk stratification based on BMI. *J Arthroplasty*. 2015;30:42-46.
32. Wagner RA, Hogan SP, Burge JR, Bates CM, Sanchez HB. The radiographic prepatellar fat thickness ratio correlates with infection risk after total knee arthroplasty. *J Arthroplasty*. 2018;33: 2251-2255.
33. Wagner ER, Kamath AF, Fruth KM, Harmsen WS, Berry DJ. Effect of body mass index on complications and reoperations after total hip arthroplasty. *J Bone Joint Surg Am*. 2016;98:169-179.
34. Wagner ER, Kamath AF, Fruth K, Harmsen WS, Berry DJ. Effect of body mass index on reoperation and complications after total knee arthroplasty. *J Bone Joint Surg Am*. 2016;98: 2052-2060.
35. Watts CD, Houdek MT, Wagner ER, Taunton MJ. Subcutaneous fat thickness is associated with early reoperation and infection after total knee arthroplasty in morbidly obese patients. *J Arthroplasty*. 2016;31:1788-1791.
36. Workgroup of the American Association of Hip and Knee Surgeons Evidence Based Committee. Obesity and total joint arthroplasty: A literature based review. *J Arthroplasty*. 2013;28:714-721.
37. Yu S, Siow M, Odeh K, Long WJ, Schwarzkopf R, Iorio R. Periarticular soft tissue envelope size and postoperative wound complications following total knee arthroplasty. *J Arthroplasty*. 2018; 33:S249-S252.