Title

A critical review of weight loss recommendations before total knee arthroplasty

Authors:

Kristine Godziuk[a], Carla M. Prado[b], Lauren Beaupre[c], C.Allyson Jones[c], Jason Werle[d], Mary Forhan[a]

[a]Department of Occupational Therapy, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, AB, Canada
[b]Department of Agricultural, Food and Nutritional Science, Faculty of Agricultural, Life and Environmental Sciences, University of Alberta, Edmonton, AB, Canada
[c]Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, AB, Canada
[d]Section of Orthopaedic Surgery, Department of Surgery, University of Calgary, Calgary, AB, Canada

Corresponding Author:

Kristine Godziuk
Faculty of Rehabilitation Medicine, University of Alberta
8205 – 114 Street, 2-64 Corbett Hall, Edmonton, AB, T6G 2G4
Ph: 780-492-9020, Fax: 780-492-4628, Email: godziuk@ualberta.ca

Declarations of interest: none

Abstract

Objective: Increased infection risk after total knee arthroplasty (TKA) in patients with a higher body mass index (BMI), particularly a BMI ≥40 kg/m^2, suggests that BMI reduction (through weight loss) prior to TKA may be important. However, the impact of weight loss on TKA risk reduction is unclear. Further, weight loss could have detrimental consequences with respect to muscle loss and development of sarcopenic obesity, whereby a potential weight loss paradox in adults with advanced knee OA and obesity may be present. Using a critical review approach, we examined the current evidence supporting weight loss in adults with obesity and advanced knee osteoarthritis (OA). We focused on three key areas: 1) TKA complication risk with severe obesity compared to obesity (BMI ≥40 kg/m^2 versus 30.0-39.9 kg/m^2); 2) weight loss recommendations for individuals with advanced knee OA; and 3) TKA outcomes after pre-surgical weight loss.

Methods: Medline and CINAHL databases were examined from Jan 2010 to May 2020 to identify high-level and/or clinically-influential evidence (systematic reviews, meta-analyses and clinical practice guidelines).

Results: The literature does not show a clear relationship between weight loss and reduction in TKA complications, and no indication that a patients' individual risk is lowered by reducing their BMI from a threshold of ≥40 kg/m^2 to ≤39.9 kg/m^2. Studies that have found a benefit of weight loss for knee OA have not included patients with higher BMIs (≥40 kg/m^2) or more advanced knee OA. Further, there is unclear evidence of a benefit of pre-surgical weight loss on TKA outcomes. These are important evidence gaps, suggesting that recommendations for BMI reduction prior to TKA should be tempered by the current uncertainty in the literature.

Conclusion: Evidence to support a benefit of weight loss prior to TKA is lacking. Until knowledge gaps are clarified, it is recommended that practitioners consider individual patient needs and risk before recommending weight loss (and therefore BMI reduction).

Keywords

Obesity, weight loss, knee osteoarthritis, body mass index (BMI), joint arthroplasty, TKA, body composition

Introduction

Obesity is closely linked with the development and progression of knee osteoarthritis (OA)[1]. As a result, it is routinely labeled as a "modifiable" risk factor in OA care pathways. However this depiction may be too simplistic considering obesity is now understood to be a persistent chronic disease with complex inherent feedback loops that make sustained weight loss challenging[2]. Working with individuals to achieve weight loss is still important for those who have the disease of obesity. Modest weight reduction (5-10% of body weight) is associated with improved metabolic and cardiovascular function[3], and may provide symptomatic and functional benefits for knee OA[4]. However, ongoing support as part of a comprehensive obesity treatment plan, including pharmacotherapy, may be necessary to achieve and maintain this magnitude of weight loss[5]. Obesity is not simply treated through patient effort and motivation[6].

Representations of the modifiability of obesity may be particularly problematic with respect to management of advanced knee OA and access to total knee arthroplasty (TKA). Numerous studies and systematic reviews have been published supporting the association between obesity [defined only using body mass index (BMI) classification] and increased risk for surgical complications, particularly infection, with TKA[7]. In conjunction with an increased focus on healthcare cost savings[8], this has resulted in some orthopedic centres and surgeons establishing maximum BMI thresholds for TKA eligibility[9]. Primarily individuals with a BMI $\geq$40 kg/m^2 (defined as class III obesity[10] or severe obesity[11]) are denied or delayed access to arthroplasty until they take measures to lose weight and reduce their BMI below this threshold[12]. Although there is debate about this practice[13], it persists despite concerns about ensuring equitable access to effective care[14], and unclear indications that weight loss before TKA reduces risk of complications[15]. Fundamentally, this inconsistent messaging creates confusion for clinical practitioners on best-practice[16]. While this issue has drawn significant attention in the U.S.A. due to higher rates of obesity and TKA procedures, this is an internationally identified clinical challenge[17–19].

The potential negative repercussions of weight loss requirements before TKA must also be considered. Patients may use unsupervised energy restriction or fad diets to attempt to lower their BMI to be eligible for TKA access[20]. As a result, muscle mass is lost alongside fat mass,

accounting for 20-30% of weight loss[21]. Bone mass also decreases[22], and overall energy metabolism slows down[23]. This increases the likelihood of weight regain, primarily through increased fat mass[24]. Patients may then be left with a body composition that could predispose or precipitate the onset of sarcopenic obesity (low muscle mass with higher fat mass), a condition with significant negative implications on physical function, mobility, and surgical and mortality risk[25]. Individuals with knee OA are already at high risk for skeletal muscle wasting[26], so additional reductions in muscle mass may be particularly detrimental to overall health. Moreover, many patients with severe obesity may still eventually require a TKA[27], and will likely present with further deteriorated muscle mass and physical function associated with delays in accessing care[28]. They may be catabolic or at high risk of malnutrition as a result of weight loss attempts, which increases their risk for infection after surgery[29]. This suggests a potential weight loss paradox with advanced knee OA, where recommendations for weight loss based on risk of surgical complications could contrarily increase risk and contribute to poorer long-term outcomes.

In view of this uncertainty, the purpose of this paper is to critically examine the current literature regarding weight loss (and therefore BMI reduction) in individuals with severe obesity and advanced knee OA. This is necessary to clarify if substantial evidence of effectiveness exists to support continued weight loss recommendations prior to TKA. This is an important and timely discussion as the prevalence of both OA and severe obesity are projected to increase in the coming decade[30], resulting in further access requests for TKA from this clinical population. Specifically, we aimed to identify, synthesize, and evaluate evidence from the literature in three key areas: 1) TKA complication risk with severe obesity compared to obesity (BMI $\geq$40.0 kg/m^2 versus 30.0-39.9 kg/m^2); 2) weight loss recommendations for individuals with advanced knee OA; and 3) TKA outcomes after pre-surgical weight loss.

Methods

A critical review approach was chosen as it enabled a discernment of current evidence across the breadth of this topic, while supporting the formulation of new ideas as a foundation for future work[31]. Relevant articles were identified using a comprehensive search of Medline and CINAHL databases from January 2010 to May 2020. Higher-level evidence (systematic reviews of randomized trials or observational studies, with or without meta-analyses) and clinically-

relevant literature (clinical practice guidelines and consensus papers) were targeted as these are most likely to influence and guide practice in healthcare settings. MESH headings and truncated keywords (including subsets and acronyms) for knee osteoarthritis, knee arthroplasty, joint replacement, obesity, body mass index, weight, weight loss, systematic review, meta-analysis, consensus, and clinical practice guidelines were used in combination to identify relevant evidence (full search presented in *Supplementary Appendix A*). Full text articles published in English were included in the review. Pertinent findings are summarized and discussed in an integrated and conceptual manner. For consistency in terminology, we have identified a BMI <30 kg/m^2 as no obesity, a BMI 30.0-39.9 kg/m^2 as obesity, and a BMI of ≥40 kg/m^2 as severe obesity.

Evidence regarding TKA complication risk with severe obesity compared to obesity

Our search identified seven systematic reviews[7,32–37] (including five with meta-analyses[7,33–35,37]) specifically examining TKA risk with severe obesity (**Table 1**). The majority of reviews (n=5) compared severe obesity to the reference category of no obesity (BMI <30 kg/m^2) [7,32–34,36]. One review by Chen et al.[37] compared BMI groups >40 kg/m^2 with <40 kg/m^2, reporting an increased odds ratio for infection with severe obesity (4.00, 95% CI 1.23-12.98). Only one review (McElroy et al.[35]) specifically compared TKA risk in severe obesity with obesity, reporting an increased relative risk for perioperative complications (2.85; 95% CI 1.2-6.5) and 5-year implant failure (9.71; 95% CI 1.2-78.8) with severe obesity.

While findings from these systematic reviews support that risk for TKA complications is higher with severe obesity compared to obesity, they do not indicate how risk varies with changes in BMI. To interpret the results of McElroy et al.[35] as an individual with a BMI of 42 kg/m^2 has an almost threefold risk for complications compared to someone with a BMI of 38 kg/m^2 is inappropriate. This type of clinical inference is prevented by dichotomous comparisons of BMI categories, which are problematic as BMI is a continuous variable[38]. This assumes that risk is flat within BMI categories, whereas it is likely variable and related to increased prevalence of adiposity-related comorbidities with higher BMIs. Further, dichotomous comparisons do not provide information on how risk differs with decrement changes in BMI. This is most relevant when making individual patient-level recommendations regarding weight loss and BMI reduction prior to TKA. This is an important gap in the current literature.

Recently, Wagner et al.[39] examined continuous BMI in a single-institution registry analysis of n= 22,289 consecutive TKA patients. They found a 7% increased risk of superficial or deep infection per unit increase in BMI >35 kg/m^2 (hazard ratio 1.07). While this increased risk of infection suggests that decrement changes in BMI through weight loss may be relevant to reduce risk, a higher BMI was also correlated with diabetes and low albumin in their patients (factors also associated with increased infection risk)[39]. This indicates the importance of separating the component risks of each of these factors.

TKA complications are likely influenced by multiple individual factors associated with a higher BMI, such as increased prevalence of diabetes (with implications on wound healing), longer operating times and deeper incisions required in larger-sized limbs, and under-dosing of prophylactic antibiotics relative to body size[33]. An individual with a BMI ≥40 kg/m^2 and well-controlled comorbidities could have a similar risk profile compared to an individual with a BMI ≤40 kg/m^2 but significant adiposity-related metabolic health impairments. **Figure 1** is presented as an illustration in this regard, based on actual patient data from our previous work[40]. Despite different BMIs, all three patients have similar fat mass percentages and adiposity-related comorbidities. This illustrates the weakness of BMI as a surrogate measure of individual adiposity and related health risk[41], and the limitations of comparisons by BMI categories alone. Suggesting that Patient A is ineligible for TKA unless they lose weight (based on a BMI threshold of <40 kg/m^2 to access TKA), whereas Patient B and C can proceed to surgery discounts the relative greater importance of diabetes, malnutrition, and age as contributors to surgical risk[42,43].

Overall, our search found no indications that a patients' individual risk for TKA complications would decrease by moving their BMI from the threshold of ≥40 kg/m^2 to ≤39 kg/m^2. Further, it is unlikely for a patient to be able to reduce their BMI from a higher to lower category (i.e. from >40 kg/m^2 to <30 kg/m^2) Therefore, there is a critical need for high quality research that can clarify if decrement reductions in BMI through weight loss translate to reductions in risk for TKA complications.

Evidence regarding weight loss recommendations for individuals with advanced knee OA

Our search identified nine clinical practice guidelines (CPGs)[44–52] and three systematic reviews[53–55] that included weight loss recommendations for knee OA. These CPGs (**Table 2**)

were from the American Academy of Orthopedic Surgeons (AAOS)[48,50], the American College of Rheumatology (ACR)[46,51], the Arthritis Foundation[51], the European League Against Rheumatism (EULAR)[47], and the Osteoarthritis Research Society International (OARSI)[49,52]. The majority were published in 2010-2014[44–49], one in 2016[50], and two recently in 2019[51,52]. Weight loss or weight management (for adults with overweight or obesity) was suggested as a core treatment for knee OA in these CPGs, with varied indications that supporting evidence was of strong[46,51,52], good[49], or poor quality[45,48] (Table 2). Three CPGs specifically recommended a loss of ≥5% of body weight to improve clinical symptoms[45,49,51], based on findings from a 2007 meta-analysis[56]. Only one CPG included a contraindication for weight loss, for individuals with polyarticular arthritis and frailty[52]. Evidence limitations regarding weight loss were discussed in only two CPGs[45,47]. Brosseau et al.[45] suggested the literature depth is narrow with risk for bias, as studies regarding weight loss are primarily from three productive laboratories. Further, Fernandes et al.[47] identified a lack of evidence on weight loss maintenance after interventions.

None of the CPGs included specific recommendations based on knee OA severity. Therefore, we examined the supporting references for indications in this regard. Only one systematic review [Christensen et al.[56] (2007): a meta-analysis of four randomized trials (RCTs)] was referenced in the CPGs[44,46,47,49], and the remainder were individual trials. In total, nine unique RCTs were distinguished from all CPG references (**Table 3**). These RCTs were primarily published between 1998[57] and 2011[58,59], and examined weight loss interventions in cohorts with diverse knee OA presence. Three trials[58,60–62] did not consider radiographic presence, with inclusion based on self-reported symptoms. Others limited inclusion to mild or moderate disease presentations (identified on radiographic exam as grade 2-3 on a Kellgren-Lawrence scale[63]). Participants with severe OA[64–71] or functional implications requiring the use of gait aids[64–67,70,72] were specifically excluded from the majority of trials. Messier et al. specifically noted that the Intensive Diet and Exercise for Arthritis (IDEA) trial results were not transferable to individuals with severe knee OA[73]. Additionally, the mean BMI of participants included in trials ranged from 28.9 kg/m^2 to 37.3 kg/m^2 (Table 3). This may reflect the lower prevalence of severe obesity during this time period, with only a more recent rise noted in global rates of class III obesity[74]. Only the IDEA trial explicitly excluded people with BMIs >41 kg/m^2 due to scanning equipment capacity[64,70]. Some trials excluded participants based on a reported lack

of motivation to lose weight[68,69,71] without describing how this was assessed. As participant motivation to lose weight is a subjective concept (and not defined or objectively assessed in these trials), this could suggest selection bias in participant inclusion. Overall, these references do not support that current CPG weight loss recommendations are transferable or relevant to individuals with either advanced knee OA, or severe obesity. Nor do they warrant the conclusion that evidence is strong for weight loss as an effective management strategy for advanced knee OA.

Our search also identified three additional systematic reviews regarding weight loss in knee OA[53–55]. Alrushud et al.[53] examined the effects of combined nutrition and physical activity on weight loss and physical function in adults with knee OA. Their meta-analyses found no evidence of effectiveness. Chu et al.[54] found a 5-10% weight loss resulted in small positive changes in pain, quality of life, and self-reported disability. However their conclusions reflect our findings above, reporting that results were only relevant for adults with a BMI of 33.6-36.4 kg/m^2 and mild to moderate knee OA[54]. A review by Hall et al.[55] compared weight loss through diet alone or combined diet and exercise, reporting that both resulted in moderate effects on function. However, studies where OA presence was not required were included in their analysis, which limits the transferability of results. Although these reviews are more contemporary (published in 2017-2019)[53–55], they primarily included the same RCTs from Table 3 (IDEA, ADAPT, and CAROT trials). This supports the comments from Brosseau et al.[45] regarding the limited depth of literature in this area.

An additional concern is the approaches used to elicit weight loss in these trials. Interventions focused on considerable dietary caloric restriction, ranging from daily energy intake reductions of -600-1000 kcal/day[60–62,64,70], or very low energy diets with total caloric intake of 415-810 kcal/day[68,71]. Basing weight loss recommendations on studies that have involved significant caloric restriction does not follow current recommendations for obesity management[75] that advise of the risks of this practice related to negative long-term implications on bone, muscle mass, and metabolism[76].

A recent study by Houston et al.[77] examined longitudinal body composition after a weight loss intervention in a sample of n=60 older adults, including a subset who were involved in the IDEA trial. They reported that participants' fat mass returned to within 1 kg of their baseline after a

mean 3.5 years, and % fat mass was 2.5% higher. Muscle mass had continued to decline, supporting that individuals involved in caloric restriction were at higher risk for sarcopenic obesity as a result of muscle mass lost in this process.

A more recent community study of supervised energy restriction for individuals with advanced knee OA has shown short-term weight loss had positive implications on function, particularly with weight loss ≥7% of initial body weight[78]. However, changes in body composition were not investigated, nor were there indications that weight loss was maintained long-term (past 18 weeks) or resulted in delayed access to TKA. These are important limitations in current knowledge, and areas for further study. Purported benefits of short-term weight loss must be contrasted with potential negative long-term impacts on body composition. Recommending weight loss prior to TKA that is unlikely to be sustained after surgery may not be necessary if it doesn't improve surgical risk, and may be potentially harmful if it increases muscle loss in individuals with predisposing low muscle reserve.

This points to the importance of considering body composition rather than BMI when making recommendations for weight loss. Although many of the trials in Table 3 assessed body composition, these were for outcome assessments rather than pre-identification of participants with relevant high adiposity or low muscularity. Our recent work has shown the variability in body composition that exists in this clinical population within BMI categories (differences of ≥20 kg of fat mass, or ≥16 kg of appendicular muscle mass)[40]. This supports the challenges of identifying individuals with pre-existing low muscle mass using absolute BMI or BMI categories. **Figure 2** is presented as an example, illustrating that sarcopenic obesity can be present but hidden in individuals with the same BMI, even with severe obesity. Therefore, assessment of body composition may be necessary before recommending weight loss, to ensure identification of individuals with pre-existing lower muscle mass who are most at risk for development or worsening of sarcopenic obesity.

Overall, the current recommendations and evidence supporting weight loss as beneficial for knee OA have limited relevance for individuals with advanced knee OA disease, or a BMI >40 kg/m^2. Further, short-term weight loss that cannot be maintained likely has few benefits, and could potentially be harmful. These are important gaps requiring further study.

Evidence regarding TKA outcomes after pre-surgical weight loss

Our search was unable to identify any systematic reviews specifically examining TKA outcomes after pre-surgical weight loss, however we found four reviews that examined total joint arthroplasty (TJA) outcomes (both knee and hip arthroplasty)[79–82]. These reviews were comprised of retrospective studies that either examined pre-TJA weight loss through bariatric surgery (n=3 reviews[79–81]) or non-surgical approaches (indeterminate but likely lifestyle-based changes in diet or physical activity; n=1 review[82]).

There has been a greater examination of bariatric surgery-related weight loss prior to TJA (as indicated by the three reviews found in our search)[79–81]. Li et al.[81] conducted a meta-analysis of nine retrospective studies, finding that bariatric surgery at an indeterminate time prior to TJA improved operating time and length of stay, but did not reduce infections or long-term complications. Similarly, Smith et al.[79] conducted a meta-analysis of five retrospective cohorts, and found no benefit of bariatric surgery prior to TJA on reducing risk for complications (including infection), revision or mortality. Gu et al.[80] found inconsistent results across individual studies and a low quality of evidence, highlighting the need for future prospective rather than retrospective investigations. Contrarily, there has been less examination of lifestyle-based weight loss prior to TKA, as only one review was found in our search[82]. Lui et al.[82] reported that adults who lost ≥5% of body weight using non-surgical and non-pharmacological methods in the year prior to TJA had no difference in risk for surgical infections. However, only two retrospective studies were available to include in their 2015 review[82], suggesting that limited high-quality research has been conducted in this area.

Based on the reviews identified, there was no evidence to indicate a clear benefit of pre-surgical weight loss on TKA outcomes. The predominant literature has examined weight loss through bariatric surgery, with unclear indications that surgical complications were reduced as a result. Importantly, it must be considered that bariatric surgery is not widely available, nor desired by all patients. Therefore, lifestyle-based weight loss remains the prevailing and most realistic option for the majority of individuals with advanced knee OA.

More recent primary studies have been conducted on lifestyle-based weight loss before TKA[83,84]. A randomized controlled trial by Liljensoe et al.[83] with n=77 participants found

no difference in early and 1-year post-TKA outcomes in patients who lost 10% of their body weight prior to surgery using a low calorie diet, compared to a weight stable control group. Although severe obesity was not an exclusion criteria, no participants in the study had a BMI >35 kg/m^2. Alternatively, a retrospective study by Keeney et al.[84] examined weight loss in n=203 patients with severe obesity (BMI ≥40 kg/m^2) during the 90-day pre-TKA period. In their sample, 41% lost ≥5 pounds (2.27 kg) before surgery, 29% lost ≥10 pounds (4.54 kg), and 14% lost ≥20 pounds (9.07 kg). There was no indication of methods used by patients to achieve weight loss. They reported that a loss of ≤10 lbs (4.54 kg) was not associated with operative time, length of stay, discharge to a facility, or physical function outcomes. A loss ≥20 pounds (9.07 kg) was associated with a reduction in hospital stay (mean difference -0.87 day, 95% CI -1.39 to -0.36 days), and lower odds of discharge to a facility (OR 0.28, 95% CI 0.09 to 0.94). This suggests that weight loss of at least 20 lbs (9.07 kg) prior to TKA may have benefits from a healthcare economic perspective, however further data is needed for confirmation. This would align with suggestions that greater weight loss (10-19.9% of baseline body weight) may be necessary for substantial symptomatic improvements in mild-to-moderate knee OA[64]. However it should be considered that a weight loss magnitude >3-5% of body weight is very difficult to maintain without adjunctive pharmacologic or bariatric surgery interventions[75]. It is notable in the study by Keeney et al. that patients who lost weight prior to TKA returned to their baseline BMI one year post-surgery[84], supporting the concern regarding long-term maintenance of weight loss. Further, there was no association with improvement in physical function scores in patients who lost any amount of weight. This should be considered, as improvements in function and mobility may be more important and relevant to patients.

Taken together, the current literature does not show substantive indications that weight loss prior to TKA is beneficial. Critically, this is an understudied research area.

Considerations in clinical practice

This review identified limited evidence to support weight loss recommendations in individuals with advanced knee OA prior to TKA. We were unable to find an indication that a decrement change in BMI <40 kg/m^2 would reduce TKA risk, nor evidence that pre-surgical weight loss results in reduced TKA complications. These evidence gaps are important to consider before suggesting or requiring a patient to lose weight and reduce their BMI before TKA access. Until

substantial new evidence is available, clinicians are encouraged to reflect the uncertainty of benefits on TKA outcomes in their discussions with patients.

Communicating with patients

Patients need to be informed about the TKA infection risk with a higher BMI. However discussions of weight loss should reflect that obesity is a chronic and complex disease, influenced by genetics, socioeconomic status, and the built-environment[85]. Portraying obesity as simple to modify and focused on motivation or personal responsibility reflects weight bias, and inaccurate assumptions that body weight is completely under an individual's control[86]. There should also be a discussion around the challenges with sustained long-term weight loss[2].

Clinicians should refrain from expressing expectations for extreme weight changes before TKA access (i.e. "lose 60 pounds and then we will do your knee surgery"[9]). This magnitude of weight loss is difficult to achieve and maintain using lifestyle-based weight loss approaches (diet and physical activity/exercise). Foreman et al.[27] described their approach of providing a weight loss goal for pre-TKA patients with severe obesity based on a BMI chart, and referring them to an external dietitian and physical therapist. Fewer than 9% of their patients with severe obesity were able to reduce their BMI below 40 kg/m^2 before TKA[27]. Keeney et al.[84] also found fewer than 14% of their patients with severe obesity lost 20 pounds before surgery. Notably, unfeasible expectations for weight loss could unintentionally alienate patients and erode the patient-clinician relationship, resulting in future avoidance of accessing healthcare services[87]. Between 29%[9] to 51%[27] of patients who were told to lose weight before arthroplasty eligibility never returned to the same orthopedic clinic after hearing these weight loss expectations. Their long-term outcomes are unknown. It must be considered that many of these patients may eventually require a TKA, in a likely worse state. Patients attempting unsupervised weight loss multiple times (potentially resulting in frequent weight loss and regain cycles) could increase their risk for muscle loss[88], which would be difficult to regain[89] and would likely impact their mobility and recovery potential.

It should also be considered that weight loss is likely not novel for this clinical population. King et al.[90] found 69.2% of patients who were considered as being overweight or having obesity and seeking a TKA had previously attempted to lose weight. Having a respectful discussion with

patients about their weight history and previous weight loss attempts is relevant to clarify whether they may have already reduced their weight or recently attempted weight loss.

Shared-decision making

Conversations with patients about surgery risk and expectations are relevant to a shared decision making approach[91]. Patients' individual needs, health conditions, and weight loss history must be considered and discussed. Support for weight management should be provided in the context of sound evidence-based interventions that are delivered and supervised by healthcare professionals with expertise in obesity management[75]. Body composition assessment may be needed to clarify whether weight loss could potentially increase the risk of sarcopenic obesity. Strategies that support optimization of body composition (by preserving or increasing muscle mass and function while potentially lowering fat mass) may be more beneficial.

Addressing evidence gaps

Further research is urgently needed to clarify the identified gaps. Future studies need to define obesity more comprehensively (beyond BMI) when looking at TKA complication risk. Studies should examine body size on a continuum, adjust for relevant comorbidities, and consider individual differences in body composition to clarify the separate implications of high adiposity or low muscularity on treatment outcomes. Pragmatic and prospective research studies are needed, rather than retrospective examinations that are prone to selection bias. Individuals with severe obesity, advanced knee OA, and functional limitations must be included in intervention trials. Researchers should also consider how to address barriers to including participants with a bigger body size in studies, such as equipment weight limitations, providing a bariatric-friendly environment, and weight-bias training for research team members. Patient-oriented research approaches and engagement with individuals living with severe obesity and knee OA should be a fundamental component in future work.

Limitations

This review aimed to provide a critical overview and novel perspective on the state of current evidence, but it has some limitations. Primarily, our findings are specific to weight loss implications on advanced knee OA and TKA outcomes, and not on other potential health benefits of weight management for individuals with severe obesity[75]. It is possible that support

for sustained weight loss provided earlier in the OA-disease continuum, before progression to an advanced stage, is warranted for this patient population. Although a comprehensive search strategy was used in this review, it was not exhaustive and some relevant studies may have inadvertently been missed. We focused our search on specific publication types (systematic reviews, meta-analyses, and CPGs) to represent literature that influences and impacts clinical practice. Thus these synthesized sources may not reflect more recent findings and directions in primary research on this topic, although more recently published individual studies were considered in the discussions under each section. Inclusion of literature was focused on knee OA, so reviews that combined results from patients with hip and knee OA in analyses were not included (except in one area with limited publications, see *TKA outcomes after pre-surgical weight loss*). Our decision to focus only on knee OA is reflective of the more integrated relationship between obesity and OA of the knee, compared to the hip[92]. Regardless of these limitations, this critical perspective stimulates reflection on evidence gaps, to work towards improving person-centered care for individuals living with obesity and advanced knee OA.

Conclusion

Important knowledge gaps exist with respect to a benefit of weight loss prior to TKA. Clinicians providing OA care should discuss these limitations in evidence with their patients, and consider individual patient needs and risk before requiring weight loss (and therefore BMI reduction) prior to TKA access.. Until substantial new evidence is available, more personalized approaches to knee OA management for adults with severe obesity are needed. Shared-decision making with patients is necessary, considering individual adiposity-related health risk, physical function, weight-loss history, and patient-preferences. Patients and providers need to have realistic expectations for weight loss, and patients should be provided with appropriate support for sustained weight management. Practitioners should also consider whether muscle lost in conjunction with weight loss could potentially be harmful for individual patients.

References

1. Teichtahl AJ, Wang Y, Wluka AE, Cicuttini FM. Obesity and knee osteoarthritis: new insights provided by body composition studies. *Obesity*. 2008;16(2):232-240.

2. Hall KD, Kahan S. Maintenance of lost weight and long-term management of obesity. *Med Clin North Am*. 2019;102(1):183-197.

3. Ryan DH, Yockey SR. Weight loss and improvement in comorbidity: Differences at 5%, 10%, 15% and Over. *Curr Obes Rep*. 2017;6(2):187-194.

4. Riddle DL, Stratford PW. Body weight changes and corresponding changes in pain and function in persons with symptomatic knee osteoarthritis: A cohort study. *Arthritis Care Res*. 2013;65(1):15-22.

5. Van Gaal L, Dirinck E. Pharmacological Approaches in the Treatment and Maintenance of Weight Loss. *Diabetes Care*. 2016;39;Suppl2:260-267.

6. Lau DC, Wharton S. The science of obesity. Canadian Adult Obesity Clinical Practice Guidelines. https://obesitycanada.ca/guidelines/science. Published 2020. Accessed October 12, 2020.

7. Si H, Zeng Y, Shen B, et al. The influence of body mass index on the outcomes of primary total knee arthroplasty. *Knee surgery, Sport Traumatol Arthrosc*. 2015;23(6):1824-1832.

8. Ponnusamy K, Marsh JD, Somerville LE, McCalden RW, Vasarhelyi EM. Ninety-Day Costs, Reoperations, and Readmissions for Primary Total Hip Arthroplasty Patients of Varying Body Mass Index Levels. *J Arthroplasty*. 2019;34(3):433-438.

9. Springer BD. American Association of Hip and Knee Surgeons Annual Meeting Symposium: Management of the Bariatric Patient. What Are the Implications of Obesity and Total Joint Arthroplasty : The Orthopedic Surgeon's Perspective? *J Arthroplasty*. 2019:2018-2020.

10. World Health Organization. Body Mass Index - BMI. http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed October 3, 2018.

11. Centers for Disease Control and Prevention. https://www.cdc.gov/obesity/index.html. Accessed October 14, 2020.

12. Springer B, Parvizi J, Austin M, et al. Obesity and total joint arthroplasty. A literature based review. *J Arthroplasty*. 2013;28(5):714-721.

13. Ricciardi BF, Giori NJ, Fehring TK. Clinical Faceoff: Should Orthopaedic Surgeons Have Strict BMI Cutoffs for Performing Primary TKA and THA? *Clin Orthop Relat Res*. 2019;477(12):2629-2634.

14. 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(12):2301-2308.

15. Inacio MCS, Kritz-silverstein D, Raman R, et al. The impact of pre-operative weight loss

on incidence of surgical site infection and readmission rates after total joint arthroplasty. *J Arthroplasty*. 2014;29(3):458-64.e1.

16. Hill DS, Freudmann M, Sergeant JC, Board T. Management of symptomatic knee osteoarthritis in obesity: a survey of orthopaedic surgeons' opinions and practice. *Eur J Orthop Surg Traumatol*. 2018;28(5):967-974.

17. Yeung E, Jackson M, Sexton S, Walter W, Zicat B. The effect of obesity on the outcome of hip and knee arthroplasty. *Int Orthop*. 2011;35(6):929-934.

18. Parratte S, Pesenti S, Argenson JN. Obesity in orthopedics and trauma surgery. *Orthop Traumatol Surg Res*. 2014;100(1 S):S91-S97.

19. Guenther D, Schmidl S, Klatte T, et al. Overweight and obesity in hip and knee arthroplasty: Evaluation of 6078 cases. *World J Orthop*. 2015;6(1):137-144.

20. Pellegrini CA, Ledford G, Hoffman SA, Chang RW, Cameron KA. Preferences and motivation for weight loss among knee replacement patients: Implications for a patient-centered weight loss intervention. *BMC Musculoskelet Disord*. 2017;18(1):1-7.

21. Cava E, Yeat NC, Mittendorfer B. Preserving Healthy Muscle during Weight Loss. *Adv Nutr*. 2017;8:511-519.

22. Seimon R V, Wild-taylor AL, Keating SE, Mcclintock S, Harper C, Gibson AA. Effect of Weight Loss via Severe vs Moderate Energy Restriction on Lean Mass and Body Composition Among Postmenopausal Women With Obesity The TEMPO Diet Randomized Clinical Trial. *JAMA Netw*. 2019;2(10):1-19.

23. Johannsen DL, Knuth ND, Huizenga R, Rood JC, Ravussin E, Hall KD. Metabolic Slowing with Massive Weight Loss despite Preservation of Fat-Free Mass. *J Clin Endocrinol Metab*. 2012;97(7):2489-2496.

24. Beavers KM, Lyles MF, Davis CC, Wang X, Beavers DP, Nicklas BJ. Is lost lean mass from intentional weight loss recovered during weight regain in postmenopausal women? *Am J Clin Nutr*. 2011;94(3):767-774.

25. Prado CM, Purcell SA, Alish C, et al. Implications of low muscle mass across the continuum of care: a narrative review. *Ann Med*. 2018;50(8):675-693.

26. Shorter E, Sannicandro AJ, Poulet B, Goljanek-Whysall K. Skeletal Muscle Wasting and Its Relationship With Osteoarthritis: a Mini-Review of Mechanisms and Current Interventions. *Curr Rheumatol Rep*. 2019;21(40).

27. Foreman CW, Callaghan JJ, Brown TS, Elkins JM, Otero JE. Total Joint Arthroplasty in the Morbidly Obese: How Body Mass Index ≥40 Influences Patient Retention, Treatment Decisions, and Treatment Outcomes. *J Arthroplasty*. 2019;35(1):39-44.

28. Struessel T, Balter J, Stevens-Lapsley J. Does Delay in Total Knee Arthroplasty Impact Postoperative Performance? A Case-Based Illustration. *J Knee Surg*. 2013;26(S1):S81-88.

29. Demling RH. Nutrition, anabolism, and the wound healing process: an overview. *Eplasty*. 1954;9:65-94.

30. Ward ZJ, Bleich SN, Cradock AL, et al. Projected U.S. state-level prevalence of adult obesity and severe obesity. *N Engl J Med*. 2019;381(25):2440-2450.

31. Grant MJ, Booth A. A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Info Libr J*. 2009;26(2):91-108.

32. Boyce L, Prasad A, Barrett M, et al. The outcomes of total knee arthroplasty in morbidly obese patients: a systematic review of the literature. *Arch Orthop Trauma Surg*. 2019;139(4):553-560.

33. Chaudhry H, Ponnusamy K, Somerville L, McCalden RW, Marsh J, Vasarhelyi EM. Revision rates and functional outcomes among severely, morbidly, and super-obese patients following primary total knee arthroplasty. A systematic review and meta-analysis. *JBJS Rev*. 2019;7(7):e9.

34. Sun K, Li H. Body mass index as a predictor of outcome in total knee replace: A systemic review and meta-analysis. *Knee*. 2017;24(5):917-924.

35. McElroy MJ, Pivec R, Issa K, Harwin SF, Mont MA. The effects of obesity and morbid obesity on outcomes in TKA. *J Knee Surg*. 2013;26(2):83-88.

36. Samson AJ, Mercer GE, Campbell DG. Total knee replacement in the morbidly obese: A literature review. *ANZ J Surg*. 2010;80(9):595-599.

37. Chen J, Cui Y, Li X, Miao X. Risk factors for deep infection after total knee arthroplasty: a meta-analysis. *Arch Orthop Trauma Surg*. 2013:675-687.

38. Froslie KF, Røislien J, Laake P, Henriksen T, Qvigstad E, Veierød MB. Categorisation of continuous exposure variables revisited. A response to the Hyperglycaemia and Adverse Pregnancy Outcome (HAPO) Study. 2010.

39. 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 Jt Surg*. 2016;98:2052-2060.

40. Godziuk K, Prado CM, Woodhouse LJ, Forhan M. Prevalence of sarcopenic obesity in adults with end-stage knee osteoarthritis. *Osteoarthr Cartil*. 2019;27(12):1735-1745.

41. Gonzalez MC, Correia MITD, Heymsfield SB. A requiem for BMI in the clinical setting. *Curr Opin Clin Nutr Metab Care*. 2017;20(5):1.

42. Belmont PJ, 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 Jt Surg*. 2014;96(1):20-26.

43. Briguglio M, Gianola S, Aguirre MI, et al. Nutritional support for enhanced recovery programs in orthopedics: Future perspectives for implementing clinical practice. *Nutr Clin métabolisme*. 2019;33(3):190-198.

44. Zhang W, Nuki G, Moskowitz RW, et al. OARSI recommendations for the management of hip and knee osteoarthritis. Part III: Changes in evidence following systematic cumulative update of research published through January 2009. *Osteoarthr Cartil*.

2010;18(4):476-499.

45. Brosseau L, Wells GA, Tugwell P, et al. Ottawa Panel Evidence-Based Clinical Practice Guidelines for the Management of Osteoarthritis in Adults Who Are Obese or Overweight. *Phys Ther*. 2011;91(6):843-861.

46. Hochberg MC, Altman RD, April KT, et al. 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*. 2012;64(4):465-474.

47. Fernandes L, Hagen KB, Bijlsma JWJ, et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Ann Rheum Dis*. 2013;72(7):1125-1135.

48. Jevsevar DS, Manner PA, Bozic KJ, et al. The American Academy of Orthopaedic Surgeons evidence based guideline on treatment of osteoarthritis of the knee, 2nd edition. *J Bone Jt Surg*. 2013:1885-1886.

49. McAlindon TE, Bannuru RR, Sullivan MC, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthr Cartil*. 2014;22(3):363-388.

50. McGrory B, Weber K, Lynott JA, et al. The American Academy of Orthopaedic Surgeons Evidence-Based Clinical Practice Guideline on Surgical Management of Osteoarthritis of the Knee. *J Bone Joint Surg Am*. 2016;98(8):688-692.

51. Kolasinski SL, Neogi T, Hochberg MC, et al. 2019 American College of Rheumatology/Arthritis Foundation Guideline for the Management of Osteoarthritis of the Hand, Hip and Knee. *Arthritis Rheumatol*. 2020;72(2):220-233.

52. Bannuru RR, Osani MC, Vaysbrot EE, et al. OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis. *Osteoarthr Cartil*. 2019;27(11):1578-1589.

53. Alrushud AS, Rushton AB, Kanavaki AM, Greig CA. Effect of physical activity and dietary restriction interventions on weight loss and the musculoskeletal function of overweight and obese older adults with knee osteoarthritis : a systematic review and mixed method data synthesis. *BMJ Open*. 2017;7(6):1-17.

54. Chu IJ, Lim A, Ng C. Effects of meaningful weight loss beyond symptomatic relief in adults with knee osteoarthritis and obesity: a systematic review and meta-analysis. *Obes Rev*. 2018;19(November):1597-1607.

55. Hall M, Castelein B, Wittoek R, Calders P, Ginckel A Van. Diet-induced weight loss alone or combined with exercise in overweight or obese people with knee osteoarthritis: A systematic review and meta-analysis. *Semin Arthritis Rheum*. 2019;48:765-777.

56. Christensen R, Bartels EM, Astrup A, Bliddal H. Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: a systematic review and meta-analysis. *Ann Rheum Dis*. 2007:433-439.

57. Toda Y, Toda T, Takemura S, Wada T, Morimoto T. Change in body fat, but not body weight or metabolic correlates of obesity, is related to symptomatic relief of obese patients

with knee osteoarthritis after a weight control program. *J Rheumatol*. 1998;25(11).

58. Foy CG, Lewis CE, Hairston KG, et al. Intensive lifestyle intervention improves physical function among obese adults with knee pain: Findings from the look AHEAD trial. *Obesity*. 2011;19(1):83-93.

59. Bliddal H, Leeds AR, Stigsgaard L, Astrup A, Christensen R. Weight loss as treatment for knee osteoarthritis symptoms in obese patients: 1-Year results from a randomised controlled trial. *Ann Rheum Dis*. 2011;70(10):1798-1803.

60. Miller GD, Nicklas BJ, Davis C, Loeser RF, Lenchik L, Messier SP. Intensive Weight Loss Program Improves Physical Function in Older Obese Adults with Knee Osteoarthritis. *Obesity*. 2006;14(7):1219-1230.

61. Wang X, Miller GD, Messier SP, Nicklas BJ. Knee strength maintained despite loss of lean body mass during weight loss in older obese adults with knee osteoarthritis. *J Gerontol A Biol Sci Med Sci*. 2007;62(8):866-871.

62. Jenkinson CM, Doherty M, Avery AJ, et al. Effects of dietary intervention and quadriceps strengthening exercises on pain and function in overweight people with knee pain: Randomised controlled trial. *BMJ*. 2009;339(7721):606-609.

63. Kellgren J, Lawrence J. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16:494-502.

64. Messier SP, Resnik AE, Beavers DP, et al. Intentional Weight Loss in Overweight and Obese Patients With Knee Osteoarthritis: Is More Better? *Arthritis Care Res*. 2018;70(11):1569-1575.

65. Messier SP, Loeser RF, Miller GD, et al. Exercise and Dietary Weight Loss in Overweight and Obese Older Adults With Knee Osteoarthritis: The Arthritis, Diet and Activity Promotion Trial. *Arthritis Rheum*. 2004;50(5):1501-1510.

66. Focht BC, Rejeski WJ, Ambrosius WT, Katula JA, Messier SP. Exercise, self-efficacy, and mobility performance in overweigt and obese older adults with knee osteoarthritis. *Arthritis Rheum*. 2005;53(5):659-665.

67. Shea MK, Houston DK, Nicklas BJ, et al. The effect of randomization to weight loss on total mortality in older overweight and obese adults: The ADAPT study. *Journals Gerontol - Ser A Biol Sci Med Sci*. 2010;65 A(5):519-525.

68. Christensen R, Astrup A, Bliddal H. Weight loss: the treatment of choice for knee osteoarthritis? A randomized trial. *Osteoarthr Cartil*. 2005;13(1):20-27.

69. Christensen P, Bliddal H, Riecke BF, Leeds a R, Astrup A, Christensen R. Comparison of a low-energy diet and a very low-energy diet in sedentary obese individuals: A pragmatic randomized controlled trial. *Clin Obes*. 2011;1(8):31-40.

70. Messier SP, Legault C, Mihalko S, et al. The Intensive Diet and Exercise for Arthritis (IDEA) trial: design and rationale. *BMC Musculoskelet Disord*. 2009;10(93):1-14.

71. Riecke BF, Christensen R, Christensen P, et al. Comparing two low-energy diets for the

treatment of knee osteoarthritis symptoms in obese patients: A pragmatic randomized clinical trial. *Osteoarthr Cartil*. 2010;18(6):746-754.

72. Messier SP, Loeser RF, Mitchell MN, et al. Exercise and weight loss in obese older adults with knee osteoarthritis: A preliminary study. *J Am Geriatr Soc*. 2000;48:1062-1072.

73. Messier SP, Mihalko SL, Legault C, et al. Effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes among overweight and obese adults with knee osteoarthritis: the IDEA randomized clinical trial. *Jama*. 2013;310(12):1263-1273.

74. Hales CM, Carroll MD, Fryar CD, Ogden CL. *Prevalence of Obesity and Severe Obesity Among Adults: United States, 2017-2018. NCHS Data Brief No. 350*.; 2020.

75. Wharton S, Lau DC, Vallis M, et al. Obesity in adults: a clinical practice guideline. *CMAJ*. 2020;192(31).

76. DiMilia PR, Mittman AC, Batsis JA. Benefit-to-Risk Balance of Weight Loss Interventions in Older Adults with Obesity. *Curr Diab Rep*. 2019;19(11):114.

77. Houston DK, Miller ME, Kitzman DW, et al. Long-term effects of randomization to a weight loss intervention in older adults: A pilot study. *J Nutr Gerontol Geriatr*. 2019;38(1):83-99.

78. Atukorala I, Makovey J, Lawler L, Messier SP, Bennell K, Hunter DJ. Is There a Dose-Response Relationship Between Weight Loss and Symptom Improvement in Persons With Knee Osteoarthritis? *Arthritis Care Res*. 2016;68(8):1106-1114.

79. Smith TO, Aboelmagd T, Hing CB, MacGregor A. Does bariatric surgery prior to total hip or knee arthroplasty reduce post-operative complications and improve clinical outcomes for obese patients? Systematic review and meta-analysis. *Bone Joint J*. 2016;98-B(9):1160-1166.

80. Gu A, Cohen JS, Malahias MA, Lee D, Sculco PK, McLawhorn AS. The Effect of Bariatric Surgery Prior to Lower-Extremity Total Joint Arthroplasty: A Systematic Review. *HSS J*. 2019;15(2):190-200.

81. Li S, Luo X, Sun H, Wang K, Zhang K, Sun X. Does Prior Bariatric Surgery Improve Outcomes Following Total Joint Arthroplasty in the Morbidly Obese? A Meta-Analysis. *J Arthroplasty*. 2019;34(3):577-585.

82. Lui M, Jones CA, Westby MD. Effect of non-surgical, non-pharmacological weight loss interventions in patients who are obese prior to hip and knee arthroplasty surgery: a rapid review. *Syst Rev*. 2015;4(1):121.

83. Liljensøe A, Laursen JO, Bliddal H, Søballe K, Mechlenburg I. Weight loss intervention before total knee replacement: A 12-month randomized controlled trial. *Scand J Surg*. 2019:doi.org/10.1177/1457496919883812.

84. Keeney B, Austin D, Jevsevar D. Preoperative weight loss for morbidly obese patients undergoing total knee arthroplasty. *J Bone Jt Surg*. 2019;101:1440-1450.

85. Albuquerque D, Nóbrega C, Manco L, Padez C. The contribution of genetics and

environment to obesity. *Br Med Bull*. 2017;123:159-173.

86. Rubino F, Puhl R, Cummings DE, et al. Joint international consensus statement for ending stigma of obesity. *Nat Med*. 2020;26:485-497.

87. Phelan SM, Burgess DJ, Yeazel MW, Hellerstedt WL, Griffin JM, van Ryn M. Impact of weight bias and stigma on quality of care and outcomes for patients with obesity. *Obes Rev*. 2015;16(4):319-326.

88. Rossi AP, Rubele S, Calugi S, et al. Weight Cycling as a Risk Factor for Low Muscle Mass and Strength in a Population of Males and Females with Obesity. *Obesity*. 2019;27(7):1068-1075.

89. Kalyani RR, Corriere M, Ferrucci L. Age-related and disease-related muscle loss: The effect of diabetes, obesity, and other diseases. *Lancet Diabetes Endocrinol*. 2014;2(10):819-829.

90. King LK, Marshall DA, Faris P, et al. Use of recommended non-surgical knee osteoarthritis management in patients prior to total knee arthroplasty: a cross-sectional study. *J Rheumatol*. 2019;47(8):1253-1260.

91. Riddle DL, Sando T, Tarver T, Slover J. Shared Decision Making Applied to Knee Arthroplasty: A Systematic Review of Randomized Trials. *Arthritis Care Res*. 2020:https://doi.org/10.1002/acr.24240.

92. Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: An epidemiological study in the general population with 10 years follow-up. *BMC Musculoskelet Disord*. 2008;9:1-6.

Table 1. Systematic reviews examining severe obesity and TKA outcomes (2010-2020)

Year, Author	Relevant Aim	Meta-analysis	Number of studies included	Obesity criteria	Comparisons with severe obesity (by BMI, kg/m^2)
2010, Samson et al.[36]	Review TKA outcomes in adults with severe obesity	no	9	BMI	≥40 vs <30
2013, Chen et al.[37]	Identify the risk factors for postoperative infection after TKA	yes	12	BMI	>40 vs <40
2013, McElroy et al.[35]	Compare implant survivorship, complications, function, and radiographic outcomes after TKA in adults with severe obesity, obesity, and no obesity	yes	12	BMI	40-49.9 vs 30-39.9 40-49.9 vs <30
2015, Si et al.[7]	Evaluate the influence of BMI on the outcomes following primary TKA	yes	28	BMI	>40 vs <30
2017, Sun and Li[34]	Examine perioperative and post-operative TKA outcomes in adults with obesity	yes	7	BMI	≥40 vs <30
2019, Boyce et al.[32]	Compare revision rates, function, and complications after TKA in adults with severe obesity and no obesity	no	9	BMI	≥40 vs <30
2019, Chaudhry et al.[33]	Compare influence of obesity severity on TKA functional outcomes and risk of revision	yes	37	BMI	≥40 vs <25

BMI = body mass index, TKA = total knee arthroplasty, TJA = total joint arthroplasty

Table 2. Weight-related recommendations in clinical practice guidelines for knee osteoarthritis (2010-2020)

Year, Author	Clinical practice guideline or consensus report	Weight-related recommendations	Reference(s) provided to support recommendations
2010, Zhang et al.[44]	OARSI recommendations for the management of hip and knee osteoarthritis. Part III: Changes in evidence following systematic cumulative update of research published through January 2009	• Pooled ESs from four published randomized trials provide evidence for small improvement in pain and function after weight loss in patients with knee OA [pooled ESs (95% CI) for improvement in pain and physical function were 0.20 (0.00, 0.39) and 0.23 (0.04, 0.42) following an average reduction in weight of 6.1 kg (4.7, 7.6)]	*Christensen et al. 2007[56]
2011, Brosseau et al.[45]	Ottawa Panel evidence-based clinical practice guidelines for the management of osteoarthritis in adults who are obese or overweight	• No evidence that weight loss of >5% will slow OA disease progression, but it may improve clinical outcomes when used in combination with physical activity • Available evidence for weight loss is primarily based on studies from three laboratories, and may misrepresent depth of literature and increase bias in conclusions • Debate on whether BMI, waist circumference and body weight are valid clinical indicators as they do not discern between fat and lean mass. Body composition measurements recommended	Focht et al. 2005[66] Messier et al. 2000[72] Messier et al. 2004[65] Messier et al. 2009[70] Miller et al. 2006[60] Wang et al. 2007[61]
2012, Hochberg et al.[46]	ACR recommendations for the use of non-pharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee	• Strong recommendations that patients with symptomatic knee OA receive counselling for weight loss	*Christensen et al. 2007[56]
2013, Fernandes et al.[47]	EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis.	• Weight is a modifiable risk factor for knee OA and should be addressed if patient is overweight or has obesity • Evidence of effectiveness of weight loss on pain and function was small but significant (ES, 95% CI, pain 0.20, 0.00 to 0.39; physical function 0.23, 0.04 to 0.42; mean weight loss, 95% CI, 6.1 kg, 4.7 to 7.6) and suggests programs be delivered as weekly supervised sessions for 8 weeks to 2 years • No evidence on maintenance of weight loss after interventions in patients with knee OA	Bliddal et al. 2011[59] *Christensen et al. 2007[56] Foy et al. 2011[58] Jenkinson et al. 2009[62] Miller et al. 2006[60] Riecke et al. 2010[71] Shea et al. 2010[67]
2013, Jevsevar et al.[48]	AAOS treatment of osteoarthritis of the knee; evidence-based guideline 2nd edition	• Weight loss recommended for patients with symptomatic knee OA and a BMI ≥ 25 kg/m^2 • Supported by low quality evidence, but public and patient health benefits of weight loss warranted an upgrade of the recommendation strength to moderate • Combinations of diet and exercise will improve results	Bliddal et al. 2011[59] Christensen et al. 2005[68] Jenkinson et al. 2009[62] Miller et al. 2006[60] Riecke et al. 2010[71]
2014, McAlindon et al.[49]	OARSI guidelines for the non-surgical management of knee osteoarthritis	• Good quality evidence to support weight management recommendation to improve pain and disability • 2007 systematic review supports weight loss of 5% of body weight within a 20-week period to be efficacious	*Christensen et al. 2007[56]
2016, McGrory et al.[50]	AAOS Surgical management of osteoarthritis of the knee: Evidence-based guideline.	• Strong evidence of BMI as a risk factor for arthroplasty • Reasonable to delay surgery for up to 8 months to allow a patient with severe obesity to lose weight	AAOS 2013 guidelines[48]
2019, Kolasinski et al.[51]	ACR & Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip and knee	• Strong recommendation for weight loss in patients with knee OA who have overweight or obesity	Messier et al. 2018[64]

Year, Author	Clinical practice guideline or consensus report	Weight-related recommendations	Reference(s) provided to support recommendations
		• Dose-response of weight loss suggested, with goals of ≥5% of body weight to improve clinical and mechanistic outcomes, and increased improvements with a loss of 5–10%, 10–20%, and >20% of body weight • Weight loss-associated OA symptom improvements are enhanced by the addition of concomitant exercise	
2019, Bannuru RR et al.[52]	OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis	• Strong evidence for dietary weight management in combination with exercise for knee OA • Dietary weight management contraindicated for individuals with polyarticular OA and frailty	Consensus voting

AAOS = American Academy of Orthopedic Surgeons, ACR = American College of Rheumatology, BMI = body mass index, CI = confidence interval, ES = effect size, ESCEO = European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis, EULAR = European League Against Rheumatism, OA = Osteoarthritis, OARSI = Osteoarthritis Research Society International.

* a systematic review and meta-analysis of four randomized trials (Christensen et al. 2005[68], Messier et al. 2000[72], Messier et al. 2004[65], Toda et al. 1998[57])

Table 3. Randomized trials referenced in clinical practice guidelines (from Table 2) supporting weight-related recommendations

Trial name or study location	Referenced study(s)	% Female in cohort	Obesity definition	Mean BMI in cohort (±SD)	Knee OA criteria	Body composition assessment	Relevant exclusion criteria
Japan	Toda et al. 1998[57] †	100	BMI >26.4	28.9 ± 1.8	KL ≥2 and self-report symptoms	BIA	Age <45 years; taking medications for hypertension, diabetes, or dyslipidemia
USA	Messier et al. 2000[72] †	71	BMI ≥28	36.4 ± 5.6	Radiographic indication and self-report pain	NI	Age <60 years; using gait aids for ambulation; unable to exercise
ADAPT (Arthritis, Diet and Activity Promotion Trial)	Messier et al. 2004[65] † Focht et al. 2005[66] Shea et al. 2010[67]	72	BMI ≥28	34.0 ± 5.0	KL 1-3 and self-report pain	NI	Age <60 years; using gait aids for ambulation; symptomatic cardiac or lung disease; severe hypertension or insulin-dependent diabetes
Physical Activity, Inflammation, and Body Composition Trial	Miller et al. 2006[60] Wang et al. 2007[61]	62	BMI ≥30	34.6 ± 4.4	Self-report symptoms	DXA	Age <60 years; medical conditions where rapid weight loss is contraindicated; allergy to meal replacements
Denmark	Christensen et al. 2005[68] † Bliddal et al. 2011[59]	89	BMI >28	35.9 ± 5.1	KL 2 or 3	DXA	Age <18 years; diabetes, endocrine, cardiac or rheumatic disease; lack of motivation to lose weight
United Kingdom	Jenkinson et al. 2009[62]	66	BMI >28	33.6	Self-report knee pain	NI	Age <45 years
CAROT (Influence of weight loss on CARtilage in Osteoarthritis Trial)	Riecke et al. 2010[71]	81	BMI >30	37.3 ± 4.8	Radiographic indication and symptoms based on ACR criteria	DXA	Age <50 years; planning to have TKA; taking weight loss medications; lack of motivation to lose weight
Look AHEAD (Action for Health in Diabetes) trial	Foy et al. 2011[58]	65	BMI ≥25	37.1 ± 6.1	Self-report knee pain	NR	Age <45 or >74 years; no type II diabetes; hypertension
IDEA (Intensive Diet and Exercise for Arthritis)	Messier et al. 2009[70] Messier et al. 2018[64]	72	BMI ≥27 but ≤41	33.4 ± 3.8	KL 2 or 3 and self-report knee pain	DXA	Age <55 years; use of gait aids; cardiac disease; moderately active

ACR = American College of Rheumatology, BIA = bioelectrical impedance analysis, BMI = body mass index (expressed in kg/m^2), DXA = dual-energy x-ray absorptiometry, KL = Kellgren-Lawrence radiographic osteoarthritis grade, NI = not included, NR = not reported, OA = osteoarthritis, SD = standard deviation, USA = United States of America.

†= trials included in the 2007 meta-analysis by Christensen et al.[56]

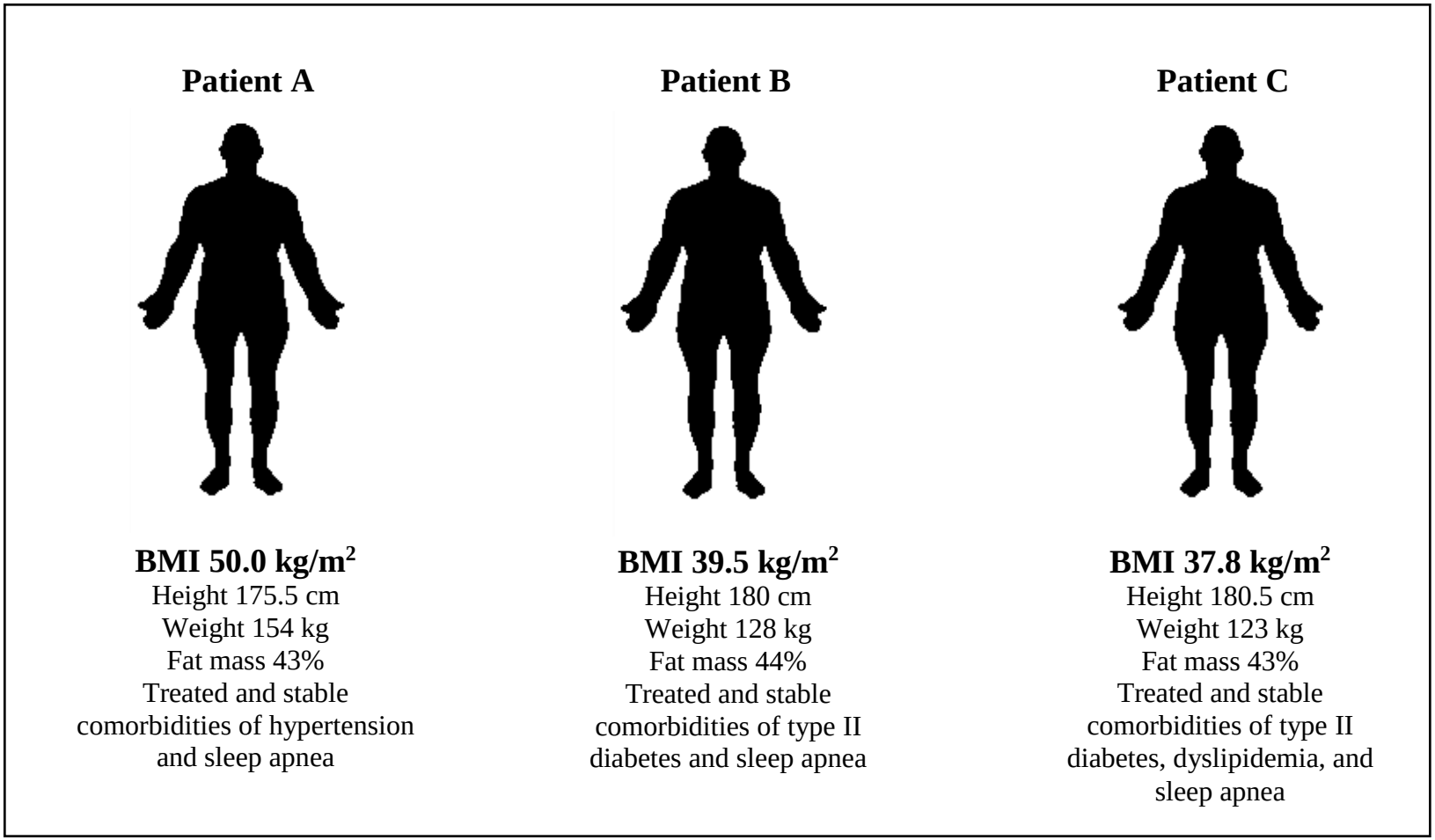

Figure 1. Comparison of three male patients with advanced knee osteoarthritis considering total knee arthroplasty

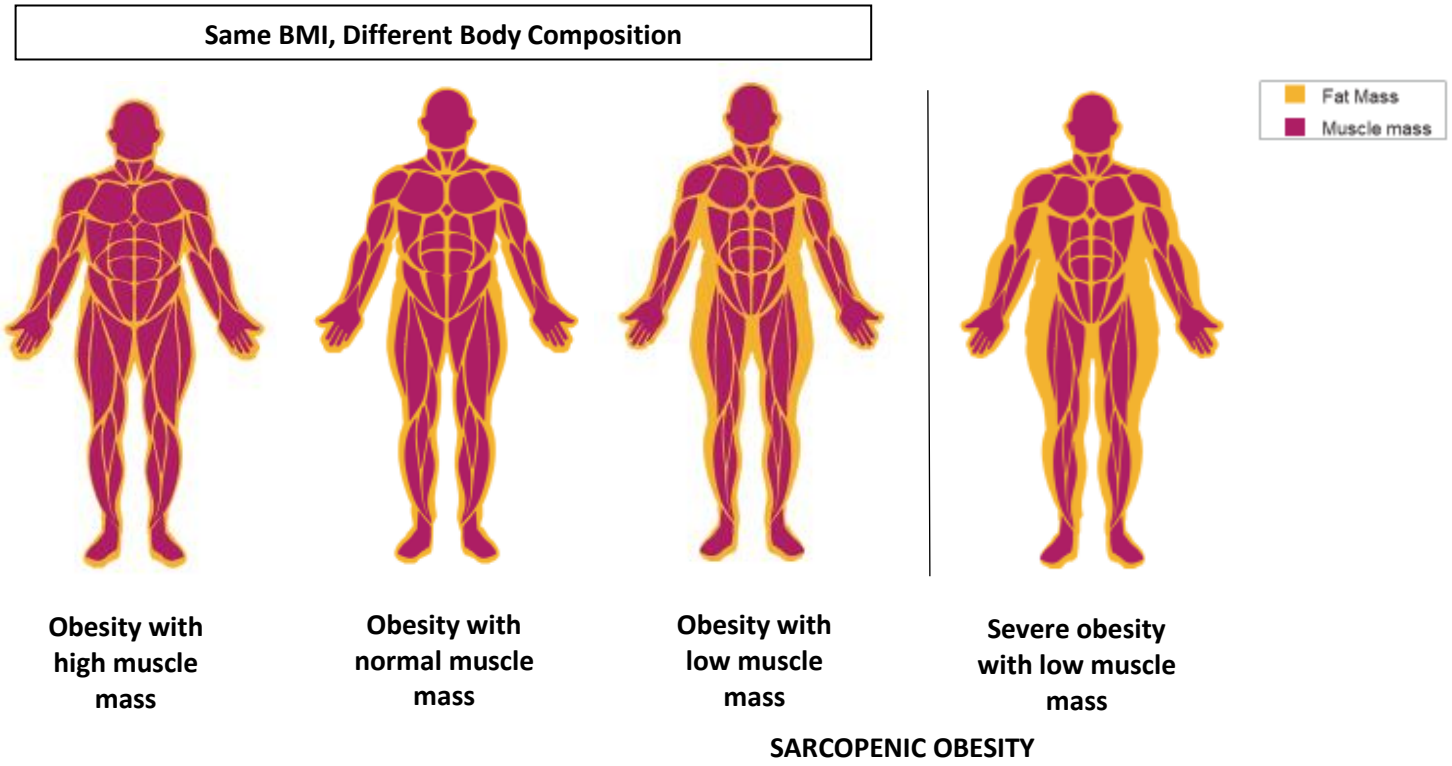

Figure 2. Illustration of body composition differences present at the same BMI; which also occurs in severe obesity

Image adapted from Prado et al. *Annals of Medicine*, 2018[26]

Supplementary Appendix A

Search strategy MEDLINE via Ovid (n=722)

1. exp Knee Joint/ or exp Osteoarthritis, Knee/ or exp Osteoarthritis/

2. exp Knee Joint/ or exp Arthroplasty/ or exp Arthroplasty, Replacement, Knee/

3. (knee replacement or joint replacement or knee replacement or total knee replacement or knee arthroplasty or total knee arthroplasty or TKA).mp.

4. exp Obesity/ or exp Obesity, Morbid/

5. (obesity or morbid obesity or body mass index or BMI or weight or weight loss or body composition).mp.

6. ("systematic review" or "meta-analysis" or "meta analysis" or "consensus" or "position statement" or "clinical practice guideline*" or "practice guideline*" or "guideline*").mp.

7. (1 or 2 or 3) and (4 or 5) and 6

8. Limit 2010 to 2020

Search strategy CINAHL (n=573)

(osteoarthr* or arthroplas* or “joint replacement” or “total joint replacement” or “total knee arthroplasty” or TKA or TKR or “knee arthroplasty”) AND (“obes*” or “morbid obes*” or “body mass index” or “BMI” or weight or “weight loss” or “body composition”) AND (“systematic review” or “meta-analysis” or “meta analysis” or consensus or “position statement” or “clinical practice guideline*” or “practice guideline*” or guideline*)