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Obesity: Implications for Patients with Osteoarthritis

A knowledge synthesis of review articles (2010-2017) on treatment of hip and knee osteoarthritis in patients with obesity

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Executive Summary

Introduction

Obesity and osteoarthritis are both chronic diseases with interconnected pathways of development and progression. The elevated prevalence of obesity and osteoarthritis has resulted in increased demand for health services and appropriate osteoarthritis treatment strategies, including a need for hip and knee surgical replacement earlier in the lifespan. This is challenging clinicians and health service delivery teams in appropriately determining care pathways and treatment options for osteoarthritis for patients with concurrent obesity. This is challenged further by few effective obesity treatments, limited resources for severe obesity management in Alberta, divided health care delivery pathways for obesity and osteoarthritis, and inadvertent weight bias.

Purpose

To meet these challenges and identify pragmatic ways to support and improve care for Albertans living with osteoarthritis and obesity, a workshop in June 2017 will bring stakeholders together across the continuum of care to engage in evidence-informed discussion and planning strategies. This white paper and knowledge synthesis was designed to provide a foundation of current evidence to anchor discussions and decisions moving forward.

Methods

The knowledge synthesis amalgamates review articles on hip and knee osteoarthritis treatment in adults with obesity, published from January 2010 to January 2017. Key points and evidence gaps are collected from included articles and presented as recommendations for both non-surgical (conservative management) and surgical management of osteoarthritis in adults with obesity.

Results

The evidence supports non-surgical management that combines diet and physical activity interventions, resulting in improved pain and physical function (regardless of changes to body weight). Separately, weight loss of 5-10% of body weight is associated with improvements in clinical symptoms, however this degree of weight loss may be difficult to attain. Importantly, benefits are still derived without weight loss. Additionally, there is limited evidence on the most appropriate types of physical activities for adults with osteoarthritis and obesity.

For surgical management, the evidence indicates increased risk of surgical infections when body mass index (BMI) is above 30 kg/m^2, particularly in knee arthroplasty, although limitations in the quality and methodology of the research indicate further clarification is necessary. Weight loss before surgery does not decrease infection risk, and there is a lack of information on the impact of extended surgical delays. Using an absolute value of BMI as a cut-off for surgery is not recommended, but shared decision making with the individual patient is strongly recommended, incorporating discussion of risk factors, medical history, disability, and surgical expectations.

Introduction

Osteoarthritis prevalence across Canada has increased in conjunction with an aging population and rising rates of obesity[1,2]. As one of the leading causes of disability for Canadians[3], osteoarthritis can result in joint pain and stiffness that significantly impacts quality of life, mobility, productivity and healthcare resource use[4]. Obesity is a risk factor for development and progression of osteoarthritis, and both osteoarthritis and obesity share interrelated inflammatory, metabolic and biomechanical pathways[5,6]. Both conditions are complex, chronic, progressive, and challenging to treat, especially when they co-occur in a patient.

The Problem

The increased prevalence of both osteoarthritis and obesity has resulted in elevated demand for health services, including early hip and knee joint replacement in an increasingly younger demographic[7]. Clinicians are challenged in identifying and delivering effective optimal treatment approaches for osteoarthritis in patients with obesity. Additionally, patients who live with osteoarthritis and obesity are confronted with navigating their health journeys in a health care environment where these conditions are treated individually rather than in an integrated manner.

Addressing the Problem

Workshop

To address these challenges, the Bone and Joint Health Strategic Clinical Network (BJH SCN) is organizing a workshop on June 13 & 14, 2017. The purpose of the workshop is to provide an opportunity for a broad range of stakeholders in Alberta with direct experience and/or knowledge of this topic (including patients, researchers, health professionals, health administrators, policy makers, and industry representatives) to engage in an evidence-informed discussion to identify pragmatic ways of moving forward to support Albertans living with osteoarthritis and obesity across the continuum of care. A key principle for this workshop approach is shared responsibility in health and the health care system, therefore stakeholder engagement throughout the continuum of care will ensure success is clearly defined and achievable. The workshop will take place over two days. Day 1 (June 13) will be focused on prevention and management (non-surgical) approaches. Day 2 (June 14) will be focused on surgical care, specifically arthroplasty related to osteoarthritis in patients with obesity. The detailed program is available in Appendix 1.

White paper

The BJH SCN has conducted a knowledge synthesis to inform this white paper, providing an evidence-based foundation for workshop discussions. This paper summarizes current research evidence and recommendations for hip and knee osteoarthritis treatment in adults with obesity.

Background

Osteoarthritis

Definition

Osteoarthritis is a chronic, progressive, and irreversible degenerative joint disease that affects more than 4 million Canadians, with those numbers expected to double in the next 30 years[8]. Multiple risk factors are associated with osteoarthritis development, including age, sex, obesity, genetics and joint trauma[9], yet the underlying mechanisms that impact disease initiation and progression are still unclear. Joint instability, trauma, muscle weakness and increased joint loading due to higher body weight can affect the components of the joint, including the bone, synovium, cartilage and muscle. Additionally, metabolic and inflammatory factors related to obesity and dyslipidemia (abnormal levels of cholesterol, triglycerides, and/or lipoproteins in the blood) contribute to joint changes[10–12], resulting in progressive cartilage deterioration, subchondral bone changes, loss of joint space, boney growths (osteophytes), and loss of joint function[6]. Patients present clinically with symptoms of joint stiffness, reduced range of motion, pain, activity limitations and associated disability.

Treatment

Osteoarthritis treatment is focused on pain reduction, improved mobility and function, and maintaining quality of life while slowing the progression of the disease[13]. Treatment strategies are categorized into non-pharmacologic (i.e. exercise, therapeutic modalities, bracing and use of assistive mobility devices), pharmacologic (i.e. pain and anti-inflammatory medications), and surgical options (i.e. osteotomy to preserve the joint, or joint replacement)[13,14]. A combination of pharmacologic and non-pharmacologic methodologies is considered best practice for treatment of early stages of the disease, along with helping patients self-manage their condition. Patients who are overweight are recommended to lose weight to reduce the load on the joint[14]. If the disease progresses and pain and disability are severe, surgical treatment options are considered.

Obesity

Definition

Obesity is defined by the World Health Organization (WHO) as *abnormal or excessive fat accumulation that may affect health*[15]. The development of obesity is influenced by diverse causes, including genetics, environmental, psychosocial, medications-related, and individual factors. Obesity is also associated with the development of metabolic and cardiovascular conditions, such as diabetes, high blood pressure, dyslipidemia, and metabolic syndrome. Further, obesity is not simply a lifestyle problem, and its multifactorial development and progression highlights the persistence of this condition. Obesity is commonly identified using body mass index (BMI), a ratio of weight to height (calculated as weight in kg/height in m^2). A

BMI of 24.9 kg/m^2 or less is considered normal, a BMI 25-29.9 kg/m^2 is considered overweight, and a BMI over 30 kg/m^2 is considered obesity. Obesity is then further delineated into class I obesity (BMI 30-34.9 kg/m^2), class II/moderate obesity (BMI 35-39.9 kg/m^2), and class III/severe obesity (BMI ≥ 40 kg/m^2). The term morbid obesity is also used to describe patients with class III or severe obesity[16]. Obesity has also been identified using percent body fat, waist circumference, and waist-hip ratio, which consider the location of excess body fat and its impact on health risk (i.e. visceral fat, or fat stored in the abdomen, is associated with higher risk of diabetes, metabolic syndrome and fatty liver compared with subcutaneous fat).

Obesity was recognized as a chronic disease by the American Medical Association in 2013[21], and by the Canadian Medical Association in 2015[22], as it requires lifelong management similar to other chronic diseases. The benefits of this recognition include investment in the development of medications for obesity treatment (similar to those developed for diabetes and high blood pressure that are utilized alongside diet and exercise), and improvements in diagnostic methods to identify and treat those with the disease. This is necessary to help distinguish between individuals whose body fat is impacting their health, and those who are healthy but have a larger body size (those who are fat but fit)[23]. The diagnosis of obesity needs to move away from an anthropometric definition (BMI-centred), to include assessment of multiple clinical factors, as with other disease diagnoses[23]. This will discourage the use of BMI as an independent diagnostic tool, shifting towards a complications-centred approach[24]. This shift may also help distinguish and identify individuals with health risk related to body composition

Table 1. Medical staging models for adiposity-related health

Method	Description
Edmonton Obesity Staging System (EOSS)[16]	Used alongside BMI to identify presence and severity of adiposity-related health problems: Stage 0 = no impairment Stage 1 = subclinical risk factors or mild impairment Stage 2 = presence of obesity-related chronic disease Stage 3 = established end-organ damage (i.e. heart attack, diabetic complications) Stage 4 = severe disability from obesity-related chronic disease(s)
Adiposity-based Chronic Disease model (ABCD)[17]	A complications-centred model to guide treatment decisions for adiposity-related disease: Stage 0 = no identifiable adiposity-based complications Stage 1 = mild to moderate adiposity-based complications Stage 2 = severe adiposity-based complications
King's Obesity Staging Criteria[18,19]	Considers adiposity-related health impact in ten domains: Airways, Body mass index, Cardiovascular disease, Diabetes, Economic complications, Functional limitations, Gonadal (reproductive) axis, Health status (perceived), body Image, and Other medical complications, and scores them from 0-3: Stage 0 = normal health Stage 1 = at risk of disease Stage 2 = established disease Stage 3 = advanced disease
Cardiometabolic Disease Staging (CMDS) system[20]	The stage and severity of adiposity-related cardiometabolic risk is categorized into 4 levels independent of BMI: Stage 0 = metabolically healthy Stage 1 = one or two metabolic syndrome risk factors (waist circumference, elevated blood pressure, triglycerides, or low HDL-C) Stage 2 = impaired fasting glucose (IFG), glucose tolerance (IGT), or metabolic syndrome Stage 3 = two of three (IFG, IGT, and/or metabolic syndrome) Stage 4 = type 2 diabetes or cardiovascular disease

but hidden by BMI. This includes those with a normal BMI (under 25 kg/m^2) but adiposity-related disease due to greater visceral fat, and those with sarcopenic obesity (who have clinically significant decreases in muscle mass that is hidden by higher adiposity)[25].

Several clinical staging systems and assessment models have been developed that utilize a complications-based approach for adiposity-related health (Table 1). These models assist in identifying those individuals who would most benefit from intervention, ensuring limited health care resources are used wisely and focused appropriately, while minimizing the risk of treating healthy individuals and potentially worsening their health with misguided weight loss or unnecessary medications[20].

Treatment of obesity

Obesity treatment strategies for adults can be divided into three categories: 1) lifestyle interventions (utilizing a combination of diet, physical activity, sleep, and psychosocial support), 2) pharmacological (with only two medications currently approved in Canada), and 3) bariatric surgery. While lifestyle treatment is the cornerstone of obesity management, long term weight loss is difficult to maintain using lifestyle change alone due to strong hormonal and biological adaptation systems designed to preserve body weight[26]. As new medications are being developed, improved long term weight loss may be achieved using multimodal approaches that combine lifestyle and pharmacologic treatments. Currently, bariatric surgery is considered the most effective treatment for long term weight loss in adults with a BMI greater than 40 kg/m^2 or a BMI greater than 35 kg/m^2 with significant comorbidity. Unfortunately capacity for bariatric surgery is limited. The 2017 Report Card on Access To Obesity Treatment in Canada[27] highlights that less than 1 in 303 Albertans who need bariatric surgery will have access to it. Additionally, the wait time from referral to surgery in Alberta can take more than 2.5 years[27].

Weight bias can inadvertently affect clinical treatment if persons with obesity are viewed as being non-compliant or lacking in self-control or motivation[28]. Obesity has been associated with beliefs that weight is all under the individuals' personal control, and if they were motivated or had willpower they could manage their obesity[29]. These beliefs and biases are inaccurate and can create stigma for patients. Understanding the limitations of current obesity treatment strategies, and the biological and genetic factors that influence body weight regulation, will assist practitioners in engaging thoughtfully with patients to help them manage their osteoarthritis and obesity.

Osteoarthritis and obesity

Obesity contributes to osteoarthritis development and progression through multiple pathways, including increased biomechanical joint load, adiposity-related systemic inflammation, and associated metabolic influences[12]. Reciprocally, the pain and disability associated with osteoarthritis may influence obesity development or magnification[5]. This interrelated cycle can have significant impacts, increasing the risk of accelerated osteoarthritis progression and

leading to surgical management consideration at a younger age[7]. Total joint arthroplasty (TJA) is most commonly performed in adults over 65 years old[30], but when patients have obesity surgery rates are highest in those age 45-64[7]. This need for earlier joint replacement can have important health and economic repercussions. The prosthetic components will likely require replacement within the individuals' lifespan, often starting 10-15 years after the primary surgery[31,32]. Revision surgery is then required, which is a more complicated and lengthy procedure that can be limited by the quality and amount of bone available to hold new prosthetic components.

There is a lack of information on how to slow the advanced progression of osteoarthritis in individuals with obesity. Obesity is commonly considered a "modifiable risk factor" for osteoarthritis[10,33], and current clinical practice guidelines simply recommend weight loss for individuals who are overweight or have obesity[13,34,35]. Specifically, recommendation for weight loss of 5-10% of body weight in 20 weeks are suggested to clinically reduce knee pain and disability (based on a meta-analysis of randomized controlled trials)[13,14,35,36]. Yet this degree of weight loss may be difficult to achieve considering the limitations of lifestyle-based obesity treatments[18], particularly when patients don't have the support and restriction of a controlled trial environment. These expectations can create frustration in both patients and healthcare practitioners when body weight does not change, but pain persists and physical function deteriorates, leading to significant challenges in determining best options for treatment. There is a need to identify and provide earlier non-surgical management interventions for individuals with metabolic, inflammatory or body composition changes that are impacting their symptoms and contributing to disease progression[37].

Knowledge Synthesis

Methods

A scoping review was conducted to capture and synthesize current published review articles regarding treatment recommendations for adults with obesity and osteoarthritis of the hip and knee joints. Scoping review methodologies are appropriate to summarize the breadth of evidence on a topic and identify knowledge gaps[38]. A systematic search of the published literature was utilized, and review articles were included if they were published between January 2010 and January 2017, in English, with human subjects, relevant to treatment of knee and hip osteoarthritis in adults with obesity. In addition, reference lists of included studies were reviewed to identify any articles that may have been missed. The complete search strategy is detailed in Appendices 2, 3 and 4.

Included articles were categorized by the methodology the authors used for their review (Table 2). Category 1 review articles systematically searched the literature, reported the search results, and assessed the bias/quality of included studies. Category 2 review articles systematically searched the literature and reported the search results, but did not include an assessment of bias/quality. Category 3 review articles did not report a systematic search strategy or results, and didn't assess bias/quality of included studies.

Table 2. Consideration of methodologies of included review articles

Category of Methodology used in the Review Article	Utilized a systematic search of literature	Reported results of literature search	Assessed included studies for bias/quality	Examples of types of review articles
1	Yes	Yes	Yes	Clinical practice guidelines and systematic reviews
2	Yes	Yes	No	Scoping and evidence mapping reviews
3	No/Unclear	No	No	Narrative reviews

Results

The knowledge synthesis incorporated 50 review articles, with approximately half (n=24) being category 3 reviews. Second were category 1 reviews (n=15), then category 2 reviews (n=8), and a few articles (n=3) fit between categories. The full list of included review articles, their category of evidence, and key findings are reported in Appendix 6.

Category 1 reviews included four clinical practice guidelines: a) Ottawa panel guidelines for management of osteoarthritis in adults who are obese or overweight (published in 2011)[39], b) Osteoarthritis Research Society International (OARSI) guidelines for the non-surgical management of knee osteoarthritis (published in 2014)[40], c) American Academy of Orthopaedic Surgeons (AAOS) guidelines for surgical management of knee osteoarthritis (published in 2015)[41], and d) American Association of Clinical Endocrinologists (AACE) and American College

of Endocrinology (ACE) guidelines for medical care of patients with obesity (published in 2016)[42]. The remainder (n=11) were systematic reviews on: patellofemoral pain[43] (n=1), total knee arthroplasty (TKA) outcomes[44–46] (n=3), total hip arthroplasty (THA) outcomes[47,48] (n=2), bariatric surgery for osteoarthritis symptoms[49,50] (n=2), bariatric surgery before total joint arthroplasty (TJA)[51] (n=1), weight loss before TJA[52] (n=1), and weight loss after TJA[53] (n=1).

Topic distribution of articles relative to joint favoured the knee (n=23), with relatively fewer articles specific to hip (n=2) and the remainder on both hip and knee or non-specific (n=25). Few articles were on conservative (non-surgical) treatment (n=8), with the majority focused on surgical treatment or weight loss. Treatment recommendations specific for osteoarthritis patients with obesity were extracted from the articles and sorted into non-surgical (conservative) treatment and surgical treatment recommendations under topic themes.

Non-surgical osteoarthritis treatment (conservative management) for adults with obesity

Development of integrated treatment interventions that address both osteoarthritis and obesity concurrently are recommended[10,54]. Pharmacotherapies that address the inflammatory pathways relative to both osteoarthritis and obesity could be beneficial, particularly if combined with weight management interventions[11]. There is no indication that BMI can predict response to non-surgical treatment[55].

Physical activity

Considerations for adapting physical activity recommendations should be based on the patients' comorbid conditions (i.e. diabetes, cardiac disease)[56], and physical limitations related to their obesity[40]. Fear of movement or activity avoidance should be assessed, as it is common in patients with mobility limitations[57]. Obesity, mobility disability and environmental factors can reduce patients' confidence, motivation and ability to access community activity programs, so recommendations should be patient-focused[58]. Additionally, as increased physical activity could increase pain and fatigue, health care practitioners should educate patients on pacing and rest breaks to reduce symptom exacerbation, which could lead to discontinuation and avoidance of the activity[56,59,60].

The evidence is unclear if there are specific types of physical activities that may be beneficial or harmful for individuals with osteoarthritis and obesity[54]. Khoja et al[61] compared randomized controlled trials that investigated aerobic, resistance and combination physical activity interventions for osteoarthritis in patients with overweight and obesity. Both aerobic and resistance activity appear to be independently beneficial for reducing pain and improving function[61]. Walking may be less tolerable for individuals with joint pain and obesity, and non-weight bearing activities such as cycling, aquatic walking or arm ergometers may be preferable[61]. While resistance exercise can improve pain and function, clarity is needed on the specific dose and types of exercises[61]. The evidence is limited by the low number of studies, inclusion of individuals without obesity, and only including participants without obesity-related

chronic diseases and mild to moderate osteoarthritis. The relevance and effectiveness of physical activity interventions in patients with comorbid conditions, higher BMIs, and more severe osteoarthritis is not known[61].

Weight loss

Adults with osteoarthritis and a BMI greater than 30 kg/m^2 are recommended to lose weight to reduce joint stress, delay further osteoarthritis progression, and improve physical function[54,62–64], with a goal of a loss of 10% or more of body weight. However, weight loss is difficult through diet and exercise alone[10], especially for those with joint pain and mobility limitations[6,39,52,58,65,66]. Plow et al[58] reviewed mean weight loss in patients with mobility limitations in 23 intervention studies. Although limited, results show a mean weight loss of 4.11 kg with targeted intervention. Patients attempting weight loss on their own may have less success, and are likely to regain weight once the intervention ceases[6,58]. Treating obesity is difficult, and individuals must battle strong biological and environmental influences that promote weight gain[6].

Rather than focusing on weight loss, the focus should be on healthy lifestyle changes (with diet and physical activity) to assist in reducing pain and improving quality of life and function[65]. As health care professionals play an important role with patients[52], they need to be educated on appropriate obesity treatment recommendations and health behaviour change strategies that promote patient self-management and engagement in change[54]. It is ineffective to simply tell a patient to lose weight or increase physical activity[60]. Non-surgical weight loss in adults requires long term behavioural support to assist with lifestyle changes and prevention of weight regain[67]. Referral to weight management services may be recommended[54].

Long term weight loss in older adults (over 65 years old) with osteoarthritis should consider that changes in body composition as a result of weight loss can negatively impact function and health, such as loss of muscle or bone mass, or decreased muscle strength[6,11,57]. This patient group is also susceptible to sarcopenia[58], a condition of low muscle mass and/or muscle function. Measuring changes in body composition may be more appropriate than focusing on a change in BMI after treatment interventions[39,58].

Physical activity versus diet

Treatment interventions that combine physical activity and diet are strongly recommended[39,42,59–61]. Although this combined intervention may not result in significant weight loss (defined as equal to or greater than 5% of body weight), the results are clinically effective to reduce pain, increase strength, and improve physical function and quality of life compared to either intervention alone[39].

Bariatric surgery for reducing osteoarthritis related pain and disability

Two systematic reviews examined the benefit of bariatric surgery for osteoarthritis-related knee and hip pain[50,68]. While both reviews conclude that bariatric surgery is likely to reduce

osteoarthritis-related pain, there was no determination of clinically important differences, and the low quality of evidence prevented clear conclusions[50,68].

Surgical osteoarthritis treatment in adults with obesity

General surgical considerations

Choosing an appropriate surgical procedure is important for individuals with OA and obesity. Obesity has been associated with greater failure rates in high tibial osteotomy (a procedure that reshapes the tibia bone when osteoarthritis affects only one side of the joint) and poorer outcomes in uni-compartmental knee replacement (a partial knee replacement procedure when damage is limited to one area of the knee)[69]. Other surgical recommendations include the use of specialized surgical instruments such as leg holders[66,70], use of thromboembolic prophylaxis to reduce the risk of blood clots, and positioning of the patient to avoid ventilator concerns[70]. Management of sleep apnea and hyperglycemia before surgery is essential, as they may be the most relevant factors related to surgical risk in patients with morbid obesity[66].

Patients with greater limb adiposity may require larger incisions and longer operating time[71], which may result in increased infection rates due to increased surgical exposure, greater wound tension and metabolic factors that influence wound healing[45,66,72]. Particular attention to wound closure in patients with obesity may assist in preventing infections[72].

Reported surgical complications in patients with obesity include avulsion of the medial collateral ligament related to knee hyperflexion, which may be associated with limited ROM or surgical technique[45,66]. If limb adiposity limits knee flexion to less than 60 degrees, there may not be access to insert the tibial component of the knee prosthesis[66]. Patients whose knees are difficult to access due to severe adiposity or an abdominal pannus may require bariatric intervention[66].

Assessing suitability for total joint arthroplasty (TJA)

The best risk stratification method for TJA in patients with obesity is unclear[73]. Current practice relies on clinical judgement[33], considering disease severity and individual characteristics that may influence surgical results, such as age, BMI, psychosocial health, and comorbid conditions[33].

Establishing an absolute value of BMI as a cut-off for TJA has been suggested in the literature[46,48,74] (particularly for those with a BMI greater than 40kg/m^2)[46,74]. Yet identification of high risk versus low risk patients is unclear from current evidence[46,75], so a BMI cut-off remains controversial[65]. BMI cut-offs may limit access to important surgery that improves quality of life, creating a bias for patients with obesity[73,76]. The positives of improved function, quality of life and patient satisfaction may outweigh any increased risk[65]. These risks and advantages need to be discussed with each individual patient[44,75].

The impact of not doing surgery should also be considered. If surgery is not provided, the patient's health may deteriorate, worsening physical function, quality of life, and independence. This can increase the burden on patients, their families, and society as a whole relative to increased healthcare costs and loss of productivity[33]. A 2016 study examined the economic costs of knee and hip arthroplasty in patients with obesity[77], and while BMI was associated with higher hospital-related treatment costs, rehabilitation, outpatient and ambulatory care, individual patient costs, and societal costs were not considered.

Total hip arthroplasty (THA)

Two systematic reviews and meta-analyses examined impact of obesity on THA outcomes[47,48]. Liu et al[48] compared BMI groups (BMI less than 30 kg/m^2, between 30 and 40 kg/m^2, and greater than 40 kg/m^2) and reported higher overall complications, dislocations, and deep infections after THA in those with obesity, and longer operating times but no difference in length of stay[48]. The higher complication rates in those with obesity may be related to the longer surgery times, which could increase exposure and soft tissue damage[48]. Haverkamp et al[47] compared groups with a BMI less than 30 kg/m^2 to those with a BMI greater than 30 kg/m^2, and found higher rates of aseptic loosening, infection, and venous thromboembolism in those with a BMI above 30 kg/m^2. The meta-analysis was unable to compare patient reported functional outcomes due to heterogeneity[47]. The data included in these two reviews were not adjusted for comorbidities, which could impact the results[47,48].

Total knee arthroplasty (TKA)

Five studies conducted systematic reviews to examine the impact of obesity on TKA outcomes[44–46,72,75]. Two[44,46] included meta-analyses. Kerkhoffs et al[44] compared BMI groups (BMI less than 30 kg/m^2 to greater than 30 kg/m^2) and found increased rates of deep and superficial infection and revision in those with a BMI greater than 30 kg/m^2, but no difference in venous thromboembolism or pulmonary embolism[44]. Si et al[46] compared BMI groups (BMI less than 30 kg/m^2 to greater than 30 kg/m^2, greater than 35 kg/m^2, and greater than 40 kg/m^2) and found increased rates of revision and superficial infection in those with BMI greater than 30 kg/m^2 compared to less than 30 kg/m^2. With a BMI greater than 40 kg/m^2, there were higher rates of overall infections, superficial and deep infections, and deep vein thrombosis compared to BMI less than 30 kg/m^2. Those with BMI greater than 40 kg/m^2 did not have higher rates of revision after 5 years compared to BMI less than 30 kg/m^2.

Three of the studies examined the impact of morbid obesity on TKA outcomes[45,72,75]. Samson et al[45] found 3-9 times greater rates of deep infection with BMI greater than 40 kg/m^2 compared to less than 30 kg/m^2, but comparable improvements in Knee Society Scores. Vaishya et al[72] compared BMI less than 30 kg/m^2 to greater than 40 kg/m^2, and found a BMI greater than 40 kg/m^2 was associated with higher rates of overall complications and superficial infections, but no difference in deep infection rates, prosthetic survival, and Knee Society Scores. McElroy et

al[75] compared BMI groups 30-39 kg/m^2 and 40-49.9 kg/m^2 against BMI less than 30 kg/m^2. Implant failure and perioperative complications were higher in BMI 40-49.9 kg/m^2, and this group had poorer Knee Society Scores after surgery compared to BMI less than 30 kg/m^2. Several of the systematic reviews indicated that results may have been impacted by a lack of control for confounding comorbidities[44,46,75].

The AAOS clinical guidelines reported that patients with obesity (defined with BMI) have poorer TKA outcomes[41], and a short term delay in TKA (up to 8 months to provide time for weight loss) does not appear to worsen outcomes, although it may negatively impact patients' pain, disability, productivity and income[41].

Recovery and rehabilitation after TJA

Recovery after TKA is influenced by many factors, and evidence on the impact of obesity on recovery is controversial[78]. Strength, age, range of motion, and pain seem to have the strongest relationship with recovery, whereas obesity, timing of the surgery, and sex (male or female) have less influence[78]. Further research is needed to determine if specific treatment modalities improve rehabilitation outcomes after TKA in patients with obesity[64]. Physical activity programs after TJA were recommended for patients with obesity to increase energy expenditure and assist with weight loss[79]. While there are concerns about the longevity of the prosthetic implant, low and moderate physical activity was still advised[79].

Revision after TJA

With currently increased rates of TJA, it is expected that rates of revision surgeries will also increase[80]. Evidence suggests that medium to long term survival of the prosthesis is poorer in patients with obesity, but this may be related to earlier age when arthroplasty is needed (often 10 years earlier)[80]. Early prosthetic failure, within 2 years of arthroplasty, is often related to infection and instability, whereas mechanical wear and loosening is associated with later failure[80]. Revision surgery is often more complex, with higher associated healthcare costs[80].

Weight loss prior to TJA

Even though many authors recommend that patients with obesity lose weight before TJA[45,46,71], there is little evidence on safety and effectiveness to support this recommendation[74]. In a systematic review, Lui et at[52] found limited evidence to support non-surgical, non-pharmacological weight loss on TJA outcomes. They found only 2 retrospective cohort studies (by the same author), and 2 randomized controlled trial abstracts (no full text available)[52]. In the two cohort studies (where weight loss was ≥5% of body weight lost and maintained in the year prior to surgery, but no information on methods used for weight loss), weight loss was associated with either no difference or increased odds of deep infection and 90 day re-admission with TJA[52]. This may be related to inadvertent malnourishment related to weight loss[52]. In 2016 the AACE/ACE clinical practice guidelines removed previous recommendation for weight loss prior to TJA due to gaps in the current evidence[42]. Optimization of comorbidities

prior to TJA may be more important than weight loss[47], as malnourishment or skeletal muscle loss associated with weight loss may increase surgical risk[52].

The impact of bariatric surgery before TKA on surgical outcomes was investigated by Smith et al[51] in 2016. Meta-analysis revealed no significant difference in superficial infection, deep infection, pulmonary embolism, revision surgery (up to 14 years post TJA) or mortality when comparing those who had bariatric surgery prior to TJA to those who did not[51]. While reduced infection rates were seen in individuals who had bariatric surgery, the quality of evidence was low and studies were underpowered[51]. Additionally, the long wait times for bariatric surgery and extended post-bariatric surgery recovery would delay TKA several years, which can be a long time to wait for individuals with severe end stage osteoarthritis[66]. Currently there is insufficient evidence to recommend bariatric surgery before arthroplasty[33,51,73,81].

Weight loss after TJA

Inacio et al[53] conducted a systematic review to examine weight loss after TJA[53]. The evidence is inconsistent, but the small sample sizes and low methodological quality of studies limit definitive conclusions. Currently, there is inconclusive evidence that weight or body composition increases, decreases or remains stable after TJA[53].

Limitations in current evidence

Osteoarthritis literature on TJA contains few prospective controlled trials, and most conclusions are based on retrospective cross-sectional or cohort studies[5]. Conducting systematic reviews and meta analyses has been difficult or prevented by heterogeneity in the literature[74]. Many studies have used different outcomes or report them differently, which prevents effective comparisons or pooling of results.

Conflicting evidence has been reported regarding the impact of obesity. Differences in cohort sample sizes (ie. in Liu et al[48], some studies had 50 THAs compared to others with 2495 THAs), low event rates, or low power from the small sample sizes may be influencing results[47,65,82]. When examining revision rates, length of follow up differed significantly between studies (in Liu et al[48], follow-up ranged from 3 months to 18 years[48]), again making comparisons difficult. Many studies have only defined BMI categorically (BMI above 30 kg/m^2 compared to BMI below 30 kg/m^2), or used different BMI cut-offs to define obesity (i.e. BMI of 27, 30, or 35 kg/m^2)[47]. It is recommended that future studies stratify by BMI or treat it as a continuous variable, which may help clarify the incidence and relationship with perioperative risk[44,65,74,82]. Most importantly, studies have not always reported or sub-classified subjects by comorbidities such as diabetes, hypertension, cardiac disease, or sleep apnea, each of which independently impacts surgical infection and complication rates[65,74]. For example, diabetes may double the infection risk independent of obesity[81,83]. This inability to account for comorbidities is identified as a limitation in several of the systematic reviews[44,46,47,75].

Summary of key knowledge synthesis points for osteoarthritis patients with obesity

Non-surgical treatment (conservative management)

- Evidence for treatment interventions that combine diet and physical activity.
- Limited evidence of specific physical activities recommended for patients with osteoarthritis and obesity.
- Recommendations of weight loss of greater or equivalent to 5-10% of body weight to impact osteoarthritis related symptoms, however weight loss and maintenance of weight loss is challenging, particularly in those with mobility limitations.
- Limited evidence to recommend bariatric surgery as a treatment for osteoarthritis-related pain and function.

Surgical treatment

- Evidence of increased infection rates in TKA with BMI greater than 30 kg/m^2, with even higher rates when BMI is greater than 40 kg/m^2.
- Some evidence of increased infection and dislocation rates in THA with BMI greater than 30 kg/m^2.*
- Conflicting evidence on increased revision rates.
- While surgical risk is higher when BMI is above 30 kg/m^2, there is little support for using an absolute value of BMI as a TJA-eligibility cut-off. The lack of support is related to limitations and conflicting results in underlying research, and clear evidence that patients with obesity benefit from this procedure.
- Limited evidence that weight loss in the year prior to TJA reduces the risk of infection; weight loss greater than 5% of body weight may either have no impact, or may increase the risk of deep surgical infection or 90-day hospital readmission after surgery.

Both surgical and non-surgical

- Weight loss can result in the loss of skeletal muscle in addition to fat, and this wouldn't be apparent by looking at change in BMI. Adults with osteoarthritis are already at risk of having lower skeletal muscle and strength due to aging and pain-related reduced physical activity. Weight loss could increase the risk of mobility limitations and sarcopenic obesity by further reducing skeletal muscle. Body composition may be a more important clinical measure than BMI.

* Although not included in this synthesis due to later publication date, clinical guidelines published March 2017 report that patient satisfaction, functional improvement and pain reduction after THA is similar in patients with and without obesity, with limited evidence on increased infection and dislocation rates[84].

Knowledge gaps

The results of this knowledge synthesis indicate that there are several issues and knowledge gaps regarding treatment recommendations for adults with osteoarthritis and obesity. In addition to lack of knowledge, the generally low/poor quality of evidence in this area makes it difficult to draw definitive conclusions that would be useful for decision making at the patient, clinician and system levels. More research is needed to clearly delineate the aspects of increased surgical risk in patients with obesity. The literature is also lacking in specific recommendations for non-surgical management, and information from the perspective of patients who have both osteoarthritis and obesity, which is imperative when making recommendations to change and improve clinical practice.

Considerations for moving forward in Alberta

The BJH SCN recommends workshop stakeholders consider the following issues when determining strategies for moving forward in the treatment of osteoarthritis in patients with obesity in Alberta:

- Clinical practice guidelines recommend health care practitioners provide weight loss advice for patients with overweight or obesity, yet many practitioners may not have training in evidence-based weight management treatment recommendations. Improving access to education for practitioners or increasing access and referrals to weight management services may be needed.
- Development of integrated models of care that treat osteoarthritis and obesity concurrently may be beneficial. As diet and physical activity are the cornerstones of both obesity and osteoarthritis treatment recommendations, provision of interventions or services that address both conditions together may be more efficient.
- Prior to recommending weight loss, practitioners should consider the challenges of long term weight loss and maintenance and whether losing weight could be harmful for a patient (i.e. older individuals, or those at risk of having low muscle mass or muscle weakness). Additionally, providers should consider the patients previous attempts at weight management before making recommendations.
- Consideration of the patients' perspective on preferred weight loss treatments must be incorporated, as patients may not be preferential to having a surgical intervention (bariatric surgery) in preparation for another surgical intervention (arthroplasty).
- There is a lack of follow-up information on the health trajectory of patients who are not considered appropriate for TJA due to obesity severity or associated comorbidities. Consideration of appropriate treatment strategies for patients who are unable to have surgery may be crucial to prevent further deterioration of health.
- Development and utilization of evidence-based surgical risk and readiness assessment measures may help reduce the use of BMI as an independent measure of surgical risk.

Additionally, the use of obesity-related health assessment tools may provide a better indication of the adiposity-related health risk in the patient.

- Awareness and education around weight bias should be provided, as it can create inequities in healthcare.
- Engagement with patients who have both osteoarthritis and obesity is important to gain their perspective and involve them in advocating for changes in osteoarthritis care.
- Promoting healthcare provider and patient collaboration pre and post care is needed to ensure care that recognizes shared responsibility for improving treatment outcomes.
- Greater understanding of the inter-connection between mental health, osteoarthritis and obesity is needed, including strategies to optimize treatment in patients where long term joint pain may be influencing symptoms of depression or anxiety.

Post Workshop: Outputs and Next Steps

The following is a summary of the discussions, keynote talks, and short talks that took place at the AHS BJH SCN OA & Obesity Workshop on June 13 & 14, 2017 in Leduc, Alberta.

On their own, osteoarthritis and obesity are recognized as complex and chronic health care conditions for which we do not have a cure, and both require long term management to enable a good quality of life. When combined – both existing in one individual – the complexity is further enhanced and many patients struggle to navigate the health care system in an effective manner. Given our tendency to function in medical silos, an integrated approach to the patient is often not available or implemented. Our fundamental knowledge base regarding these conditions are also incomplete, and there is recognition that we are lacking an understanding of the various ways that the underlying pathophysiology of the two conditions influence each other and impact the life of an individual. Further the interplay with mental health was recognized and requires more attention in such discussions.

The workshop talks were presented on a range of topics that highlight this complexity, as well as areas of clinical and basic investigative work being done to inform our understanding of the conditions and ultimately, improve patient care in the health care system. These talks included topics such as: the underlying mechanisms of inflammatory processes; adaptations to the digestive process (metabolic syndrome, nutrition); muscle depletion and fatty infiltration of muscle tissue (sarcopenic obesity); limitations of using Body Mass Index (BMI) as a meaningful clinical determinant; weight loss and weight management; determinations regarding readiness for and appropriateness of arthroplasty for patients with obesity; considerations regarding higher rates/incidence of potential anesthesia complications; economic considerations related to providing arthroplasty to patients with obesity; and why poor outcomes and adverse events occur in such patient populations.

The stark reality communicated by the speakers was that pathophysiological changes that occur via obesity are difficult to influence long term or reverse; that there are number of factors

impacting both obesity and OA and the subsequent interface of these two conditions; and that sustained weight loss is incredibly challenging and very uncommon in individuals classified as morbidly obese (less than ~10% are successful). Thus a need for effective obesity prevention strategies became very clear and a shift from the perception that joint replacement surgery as a primary goal for the patient is needed long term. It was also apparent from the discussions that even when arthroplasty is a treatment option, there is a lack of clear guidance on how to determine appropriateness of patients who present with both advanced OA and obesity.

And yet glimmers of hope and potential also emerged from the discussions. These include the opportunity to more effectively partner with primary care in preparing patients for surgery and managing patients up-stream when they have mild to moderate OA; more effective strategies and approaches in working with individuals with obesity (considerations of weight bias, using indicators other than BMI to make treatment recommendations) to develop patient-specific programs with shared responsibilities; the effective implementation of existing prevention interventions, continuing the work to determine criteria for arthroplasty. Further, the patients who were present at the workshop, although perhaps not representative of the "average" patient, certainly showcased the potential for success, the influence of effective motivation, and the importance of patients being engaged in their own care. Lastly, given that we continue to struggle with how to treat and manage patients with OA and obesity, we may need to explore different ways of looking at or understanding these health issues.

Bringing together the expertise of the short talk presenters and the knowledge and personal experience of the workshop participants, a number of themes emerged through round table discussions. Those identified by the group as most salient or pertinent were then further discussed in a world café format. The latter were focused on "solving problems or roadblocks", and identifying ways that the issues could be addressed in Alberta. The primary issues identified were as follows:

Day 1 – Management and prevention of OA and obesity

- How to better support Albertans living with both OA and obesity
- What programs or strategies to prevent obesity and OA can be implemented across Alberta (and how)
- What provincial level approaches can be used to evaluate quality improvement initiatives focused on OA and obesity across the life span
- What knowledge translation opportunities should be exploited

Day 2 – Arthroplasty for patients with OA and obesity

- What are the options and/or pathways for patients to reach their healthiest self prior to considering surgery
- Communication strategies to effectively disseminate the information from the workshop

- What strategies can be used to shift perceptions regarding arthroplasty (surgery) as being the ultimate goal for all patients

In addition to the above, two dedicated breakout sessions were held that provided an opportunity for participants to provide constructive input and feedback on two initiatives currently under development in Alberta and directly applicable for the Albertan with OA and obesity:

- Readiness of Patients with Obesity for Arthroplasty Checklist – developed in collaboration with the DON SCN – its purpose is to provide a comprehensive tool which could be used by health care professionals to consider the various factors that impact determination of appropriateness for a patient with OA and obesity for arthroplasty
- OA Care Framework – being developed by the BJH SCN, it applies a stepped-care approach in addressing how Albertans with OA manage living with OA and how they may access the health care system to support their care needs. The goal of this session was to explore if the framework requires further modification and adaption to specifically consider the Albertan with OA and obesity.

Next steps

White paper **–**

The white paper will now be finalized and posted on the BJH SCN website, where it can be publicly accessed

We will be working with Kristine Godziuk to publish the knowledge synthesis and a meeting report.

Action teams -

The BJH SCN led the initiation of this multi-stakeholder discussion on how we address the challenges faced by Albertans living with OA and obesity and the health care system which aims to provide high quality care. The role of the BJH SCN going forward from the workshop is to facilitate action around key topics identified through workshop discussions. It is imperative that the momentum generated at the workshop be maintained, to ensure that there is productive and proactive action on the issues raised. Therefore, we recognize it is our responsibility for enabling the movement forward. Given our provincial leadership role, the BJH SCN is well positioned to enable and facilitate intra-provincial collaborations with essential stakeholders to move the agenda forward.

Based on a review and analysis of priorities emanating from the world cafés on Day 1 and Day 2 and input from the facilitators of the two break-out sessions, the following priority areas of work emerged:

1. Identify ways to modify or adapt exercise programs (e.g. GLA:D, Joint Effort) to enable participation of individuals with morbid obesity
2. Develop an OA Care Pathway sub-stream that considers the challenges and complications of those with obesity
3. Develop a thinking hub for innovative and out of the box thinking to drive or inform future research questions on OA and obesity
4. Development of a provincial guidance statement regarding risk and appropriateness related to arthroplasty for Albertans with obesity
5. Implementation of evidence-based osteoarthritis prevention programs across Alberta
6. Identify approaches for provincial level data capture and evaluation of quality improvement initiatives
7. Initiate perception change regarding the role of surgery in the treatment of chronic conditions, and implement the stepped care approach to management

These priority areas will be addressed by "Action Teams" which will be formed by volunteers from the workshop or the broader community (based on expressed interest). Each will be tasked with identifying specific recommendations and engaging in the required activities to advance the work in that area within a 12 to18 month period. Deliverables may include, but are not limited to, one or more of the following:

- Guidelines for Primary Care and Surgeons, as well as patients
- Outcomes database development
- Knowledge synthesis/literature reviews
- Progress reports (biannual)
- Presentations to appropriate SCN Core Committees
- Peer reviewed publications
- Research project grants proposals/applications

Our goal is to initiate up to three Action Teams by end of October 2017.

The Scientific Director (DH) and Assistant Scientific Director (AKR) of the BJH SCN will provide oversight. The Action Teams will report directly to the BJH SCN Scientific Office.

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82. Buchbinder R, Richards B, Harris I. Knee osteoarthritis and role for surgical intervention: lessons learned from randomized clinical trials and population-based cohorts. *Curr Opin Rheumatol*. 2014;26(2):138-144. doi:10.1097/BOR.0000000000000022.

83. Rodriguez-merchan EC. Review article : Outcome of total knee arthroplasty in obese patients. *J Orthop Surg*. 2015;23(1):107-110.

84. American Academy of Orthopaedic Surgeons. *Management of Osteoarthritis of the Hip: Evidence-Based Clinical Practice Guideline*.; 2017. doi:10.5435/JAAOS-D-14-00432.

85. Sridhar MS, Xerogeanes JW, Jarrett CD, Xerogeanes JW, Labib S a. Obesity and symptomatic osteoarthritis of the knee. *J Bone Jt Surg*. 2012;94(4):433-440. doi:10.1302/0301-620X.94B4.27648.

86. Berry PA, Wluka AE, Davies-Tuck ML, et al. The relationship between body composition and structural changes at the knee. *Rheumatology*. 2010;49(12):2362-2369. doi:10.1093/rheumatology/keq255.

87. Vincent HK, Heywood K, Connelley J, Hurley RW. Weight loss and obesity in the treatment and prevention of osteoarthritis. *Am Acad Phys Med Rehabil*. 2012;4(50):S59-S67. doi:10.1016/j.pmrj.2012.01.005.Weight.

88. McGrory BJ, Weber KL, Jevsevar DS, Sevarino K. Surgical Management of Osteoarthritis of the Knee: Evidence-based Guideline. *J Am Acad Orthop Surg*. 2016;24(8):e87-93. doi:10.5435/JAAOS-D-16-00159.

89. 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. doi:10.2106/JBJS.15.01311.

Appendix 1. Workshop Program

DAY 1 – JUNE 13, 2017		
TIME	**ACTIVITY**	**SPEAKER**
8:00-9:00	Registration and poster viewing	
9:00-9:20	Welcome and approach to the workshop	David Hart & Ania Kania-Richmond
9:20-9:50	Opening talk	Mary Forhan, PhD, OT
9:50-10:05	Patient perspective	Deb Baranec
10:05-10:15	Q & A	
10:15-10:30	Break & student poster viewing	
10:30-12:30	Short talks: Prevention and Management Topic: Nutrition Topic: Metabolic syndrome & inflammation – relationship to osteoarthritis and obesity Topic: Approaches to treatment of obesity Topic: Sarcopenic obesity Topic: Prevention of osteoarthritis and obesity post injury Q & A	 Carla Prado, PhD, RD David Hart, PhD Arya Sharma, MD, DSc(hon), FRCPC Linda Woodhouse, PhD, PT Jackie Whitaker, PhD, PT
12:30-1:15	Lunch – Round table discussion re: key issues in Alberta	
1:15-1:45	Reporting back and identifying top 3 issues	Facilitated
1:45-2:00	Break	
2:00-3:15	Breakout sessions: Option 1: World Café – next steps to address the top 3 issues emerging from round table discussion Option 2: Development of the BJH SCN Framework for Osteoarthritis	 Facilitated Mel Slomp & Sheila Kelly
3:15-3:30	Closing of Day 1	David Hart & Ania Kania-Richmond
3:30-4:30	Student poster judging	

DAY 2 – JUNE 14, 2017		
TIME	**ACTIVITY**	**SPEAKER**
8:00-9:00	Registration and poster viewing	
9:00-9:20	Welcome and approach to the workshop	David Hart & Ania Kania-Richmond
9:20-9:50	Opening talk	Raul Kuchinad, MD
9:50-10:05	Patient perspective	TBC
10:05-10:15	Q & A	
10:15-10:30	Break & student poster viewing	
10:30-12:30	Short talks: Arthroplasty Topic: Weight loss prior to surgery Topic: BMI and arthroplasty outcomes Topic: Anesthesiology considerations Topic: Optimizing the arthroplasty OR for patients with obesity Topic: Health economics of care for patients with osteoarthritis and obesity Q & A	 Shahebina Walji, MD, CCFP Benham Sharif, PhD, Post-Doctoral Fellow Edward Vasarhelyi, MD, MSc, FRCSC Chris de Gara, MB, MS, FRCS, FACS Edward Vasarhelyi, MD, MSc, FRCSC
12:30-1:15	Lunch – Round table discussion re: key issues in Alberta	
1:15-1:45	Reporting back and identifying top 3 issues	Facilitated
1:45-2:00	Break	
2:00-3:15	Breakout sessions: Option 1: World Café – next steps to address the top 3 issues emerging from round table discussion Option 2: Development of the “Readiness for Surgery Checklist”	 Facilitated Mel Slomp & Petra O’Connell (DON SCN)
3:15-3:30	Closing of Day 2	David Hart & Ania Kania-Richmond

Appendix 2. Knowledge synthesis methodology

A scoping review methodology was used to generate the knowledge synthesis. The focus of this paper was to identify the current status of knowledge and recommendations for treatment of osteoarthritis in adults with obesity, and so the search focused on published review articles (systematic, scoping, comprehensive, or clinical reviews and/or meta-analyses). Review articles were included if they were published between January 2010 and January 2017 in English, with a focus on non-surgical (conservative) and/or surgical treatment of hip and knee osteoarthritis in adults with obesity. Articles were excluded if they were based on animal subjects, were primary studies (not reviews), or were not about osteoarthritis treatment in adults with obesity.

Reviews that met our inclusion criteria were identified through a systematic search of 4 databases: MEDLINE (via Ovid), CINAHL, Web of Science, and Embase. The search was conducted in February 2017 with support from a University of Alberta Master of Library Information Systems (MLIS) librarian. Keywords and medical subject headings (MeSH) used for each database are provided in Appendix 3. In addition, reference lists of included studies were reviewed to identify any articles that may have been missed.

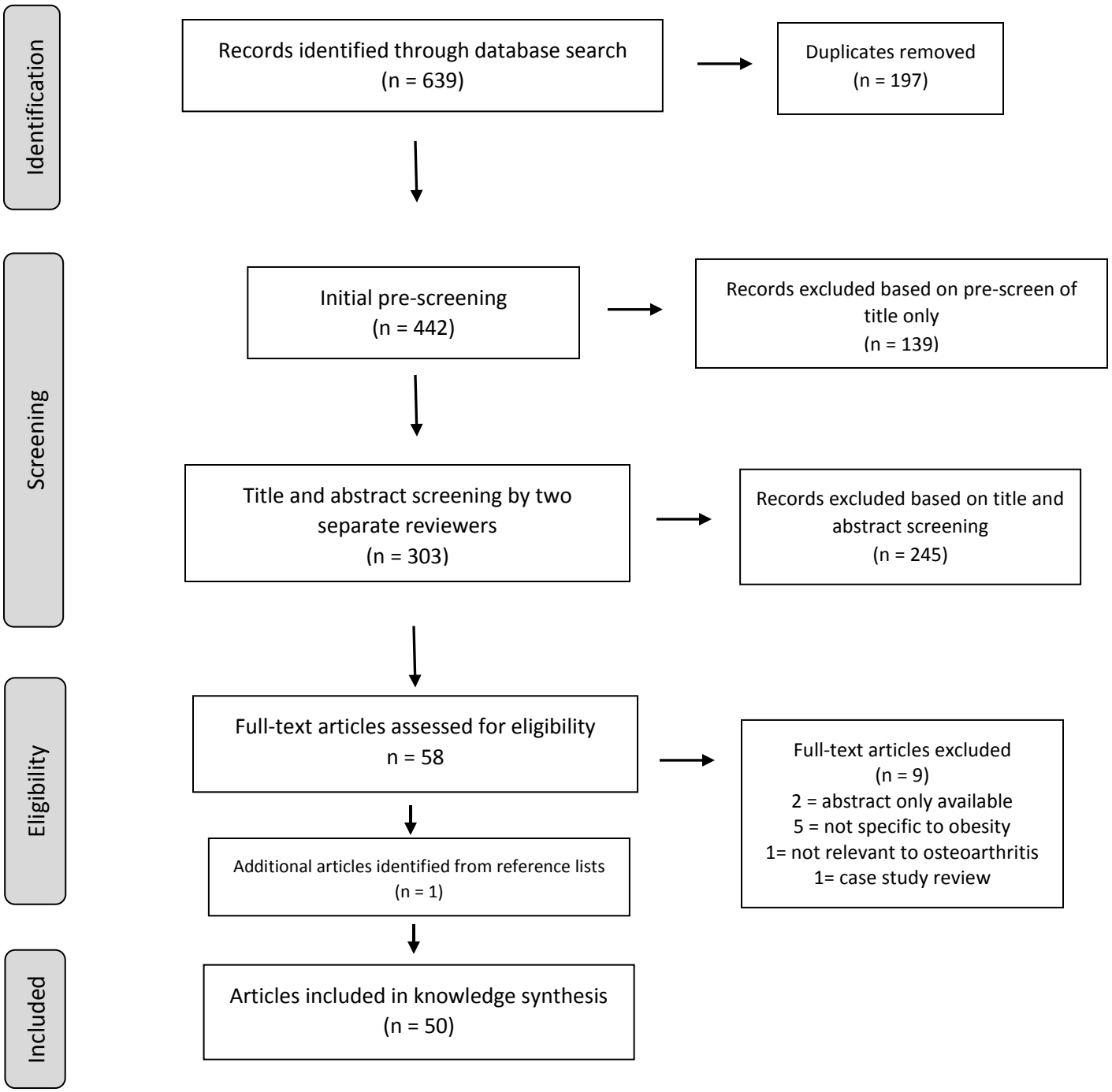
In total, 640 studies were identified from all sources, 197 duplicates were removed, 384 articles were screened and removed based on title and abstract, and 59 full text articles were retrieved and screened. 50 review articles were included in the synthesis. For the synthesis, data extracted from each review article included: year of publication, review methodology, and key findings.

Appendix 3. Search strategy

Search mode: Boolean/phrase
Limiters: January 2010 to January 2017, English language
Search conducted February 1, 2017
Assistance provided from Liz Dennett, MLIS, at the University of Alberta

Database	Keywords	Results
MEDLINE Via Ovid	1. Osteoarthriti*.mp. 2. (hip or hips or knee or knees or "lower limb*" or "lower extremit*").mp. 3. (obes* or superobes* or overweight).mp. 4. Arthroplasty, Replacement, Hip/ or Arthroplasty, Replacement, Knee/ 5. (treatment or intervention* or therapy or management or rehab* or "joint replacement*" or arthroplast* or replacement* or revision or TKA or TJA or THA or surg* or "non-surg*" or "non surg*" or physiotherap* or "physical therap*" or exercise).mp. 6. (review or (systematic* adj3 review*) or "meta-analy*" or metaanaly* or overview).mp,pt. 7. 1 and 2 and 3 and (4 or 5) and 6	116
CINAHL	Osteoarthriti* AND (hip or hips or knee or knees or "lower limb*" or "lower extremit*") AND (obes* or superobes* or overweight) AND ((MH "Arthroplasty, Replacement, Knee") OR (MH "Arthroplasty, Replacement, Hip") OR treatment or intervention* or therapy or management or rehab* or "joint replacement*" or arthroplast* or replacement* or revision or TKA or TJA or THA or surg* or "non-surg*" or "non surg*" or physiotherap* or "physical therap*" or exercise) AND (review or (systematic* n3 review*) or "meta-analy*" or metaanaly* or overview)	43
WEB OF SCIENCE	TS=Osteoarthriti* AND TS=(hip or hips or knee or knees or "lower limb*" or "lower extremit*") AND TS=(obes* or superobes* or overweight) AND TS=(treatment or intervention* or therapy or management or rehab* or "joint replacement*" or arthroplast* or replacement* or revision or TKA or TJA or THA or surg* or "non-surg*" or "non surg*" or physiotherap* or "physical therap*" or exercise) AND TS=(review or "systematic* review*" or "meta-analy*" or metaanaly* or overview)	199
Embase	1. Osteoarthriti*.mp. 2. (hip or hips or knee or knees or "lower limb*" or "lower extremit*").mp. 3. (obes* or superobes* or overweight).mp 4. total knee arthroplasty/ or knee replacement/ or total arthroplasty/ or hip prosthesis/ or total hip prosthesis/ 5. (treatment or intervention* or therapy or management or rehab* or "joint replacement*" or arthroplast* or replacement* or revision or TKA or TJA or THA or surg* or "non-surg*" or "non surg*" or physiotherap* or "physical therap*" or exercise).mp. 6. (review or (systematic* adj3 review*) or "meta-analy*" or metaanaly* or overview).mp,pt. 7. 1 and 2 and 3 and (4 or 5) and 6	281
TOTAL		**639**

Appendix 4. Results of search



Appendix 5. Excluded full text articles (n=9)

Reference	Reason for exclusion
Fransen M, McConnell S, Harmer AR, Van der Esch M, Simic M, Bennell KL (2015). Exercise for osteoarthritis of the knee. Cochrane Database of Systematic Reviews.	No discussion of obesity
Hochberg MC, Altman RD, April KT, Benkhalti M, Guyatt G, McGowan J, et al (2012). American college of rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. Arthritis Care & Research, 64(4), 465-474.	No discussion of obesity, only general recommendation for weight loss in patients who are overweight
Kroon FPB, van der Burg LRA, Buchbinder R, Osborne RH, Johnston RV, Pitt V (2014). Self-management education programmes for osteoarthritis. Cochrane Database of Systematic Reviews.	No discussion of obesity
Loew L, Brosseau L, Wells GA, Tugwell P, et al. (2012) Ottawa panel evidence-based clinical practice guidelines for aerobic walking programs in the management of osteoarthritis. Archives of Physical Medicine and Rehabilitation, 93:1269-1285.	Only included studies in the systematic review where subjects had a BMI <25, so results not relevant to obesity
Nelson AE, Allen KD, Golightly YM, Goode AP, Jordan JM (2014). A systematic review of recommendations and guidelines for the management of osteoarthritis: The chronic osteoarthritis management initiative of the U.S. bone and joint initiative. Seminars in Arthritis & Rheumatism, 43(6), 701-712.	No discussion of obesity, only general recommendation for weight loss in patients who are overweight
Prodromo J, Rackley J, Mulcahey MK (2016). A review of important medical and surgical considerations for obese patients undergoing arthroscopic surgery.	Not relevant for osteoarthritis
Steultjens M, Allan R, Marreiros S, & Smith S (2014). Current evidence for clinical phenotypes in knee osteoarthritis: A systematic review. Osteoarthritis and Cartilage, 22, S219-S220.	Abstract only, full text not available
ToupinApril K, Hochberg M, Tugwell P, Altman R, Benkhalti M, Guyatt G, et al (2010). Development of the 2009 revised ACR recommendations for the management of osteoarthritis. Journal of Rheumatology. 37(6 SUPPL. 2), 1336.	Abstract only, full text not available
Yates AJ Jr, McGrory BJ, Starz TW, Vincent KR, McCardel B, Golightly YM (2014). AAOS appropriate use criteria: Optimizing the non-arthroplasty management of osteoarthritis of the knee. Journal of the American Academy of Orthopaedic Surgeons, 22(4), 261-267.	Case study review

Appendix 6. Included review articles (n= 50)

Category of review	Authors	Year	Title and Journal Reference	Overview and Key Findings Relative to Obesity
Non-specific				
2	Lee R, Kean WF[5].	2012	Obesity and knee osteoarthritis. Inflammopharmacology, 20:53-58.	Research on the unequivocal association between obesity and osteoarthritis development is reviewed, with discussion of recent literature suggesting weight loss as a treatment strategy to improve pain and physical function. Emphasized limitations of current cross-sectional studies and the need for longitudinal and prospective research.
3	Heidari B[63].	2011	Knee osteoarthritis diagnosis, treatment and associated factors of progression: part II. Caspian Journal of Internal Medicine, 2(3):249-255.	Review of knee osteoarthritis diagnosis, progression and treatment and relationship with obesity. Weight loss and maintenance of weight at lower level is recommended.
3	Prajapati PM, Solanki AS[62].	2011	Osteoarthritis and its treatment. International Research Journal of Pharmacy, 2(12):117-119.	Overview of osteoarthritis development and treatment. Weight loss is recommended to reduce strain on joints and improve pain and stiffness.
3	Sridhar MS, Jarrett CD, Xerogeanes JA, Labib SA[85].	2012	Obesity and symptomatic osteoarthritis of the knee. The Journal of Bone and Joint Surgery, 94(4): 433-439.	Overview of osteoarthritis development and treatments, including arthroplasty. Recommends more studies to evaluate impact of weight loss on outcomes.
Conservative management (non-surgical treatment)				
1	Brosseau L, Wells GA, Tugwell P, Egan M, et al[39].	2011	Ottawa panel evidence-based clinical practice guidelines for the management of osteoarthritis in adults who are obese or overweight. Physical Therapy, 91(6):843-861.	Clinical practice guidelines that provides strong recommendations for combination physical activity and diet programs to provide pain relief and functional improvements. Weight loss is unsubstantial with these interventions. Body composition measurement is preferable over BMI or body weight to measure change after intervention.
1	McAlindon TE, Bannuru RR, Sullivan MC, Arden NK, et al[40].	2014	OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis and Cartilage, 22:363-388.	Clinical practice guidelines that recommend weight loss of 5% of body weight within a 20 week period for adults who are overweight. Obesity is considered a comorbidity that can cause physical impairment and should be considered when making activity recommendations.
1/2†	March L, Amatya B, Osborne RH, Brand C[54].	2010	Developing a minimum standard of care for treating people with osteoarthritis of the hip and knee. Best Practice & Research Clinical Rheumatology, 24:121-145.	Consensus paper summarizing 3 international guidelines. Recommends weight loss advice or referral to weight management services be provided for patients who are overweight or obese; barriers include lack of knowledge and tools, lack of integrated care funding and models, and provision of counselling for appropriate weight management. Research is also needed on safety of different exercise modalities and intensities in patients with osteoarthritis and obesity.
2	de Rooij M, Steultjens MPM, Avezaat E, Hakkinen A, et al[56].	2013	Restrictions and contraindications for exercise therapy in patients with hip and knee osteoarthritis and comorbidity. Physical Therapy Reviews, 18(2):101-111.	Summary of exercise recommendations for osteoarthritis and comorbid conditions, including obesity. Obesity is not a contraindication to exercise in osteoarthritis, however restrictions related to increased stress on joints, shortness of breath, and fear of movement should be considered.

2	Khoja SS, Susko AM, Josbeno DA, Piva SR, Fitzgerald GK[61].	2014	Comparing physical activity programs for managing osteoarthritis in overweight or obese patients. Journal of Comparative Effectiveness Research, 3(3):283-299.	Review of evidence on physical activity interventions for osteoarthritis management in adults with obesity. Discussion of strategies to improve adherence to activity. Current evidence is limited by a lack of studies on adults with morbid obesity and moderate to severe osteoarthritis.
3	Eyles J, Lucas BR, Hunter DJ[55].	2013	Tailoring nonsurgical management according to clinical presentation. Rheumatic Disease Clinics of North America, 39:213-233.	Review of evidence on individual characteristics that impact non-surgical treatment. Body mass index was not a predictor of response to non-surgical interventions.
3	Fibel KH, Hillstrom HJ, Halpern BC[59].	2015	State-of-the-art management of knee osteoarthritis. World Journal of Clinical Cases, 3(2):89-101.	Review of relationship between obesity and osteoarthritis, along with current strategies for osteoarthritis management. Weight loss, exercise and muscle strengthening are recommended.
3	Iannone F, Lapadula G[11].	2010	Obesity and inflammation – targets for OA therapy. Current Drug Targets, 11:586-598.	Review of the mechanical load and inflammatory relationship of osteoarthritis development associated with obesity. Adipokines and other inflammatory mediators are discussed as potential pharmacotherapy treatment targets to be used in concern with weight loss.
3	Knittle K, De Gucht V, Maes S[60].	2012	Lifestyle-and behaviour-change interventions in musculoskeletal conditions. Best Practice & Research Clinical Rheumatology, 26:293-304.	Overview of lifestyle and behaviour change strategies and interventions for weight management and physical activity. Recommends a patient centered approach that is less prescriptive, and referral to health care providers that have time to work with patients on behaviour change.
Weight Loss				
1	Garvey WT, Mechanick JI, Brett EM, Garber AJ, et al[42].	2016	American Association of Clinical Endocrinologists and American College of Endocrinology comprehensive clinical practice guidelines for medical care of patients with obesity. Endocrine Practice, 22(3).	Clinical practice guidelines that recommend weight loss of ≥ 10% body weight for osteoarthritis treatment. Combining weight loss and physical activity can help achieve 5-10% loss of body weight. Weight loss before or after TJA is no longer recommended due to evidence gaps.
1	Gill RS, Al-Adra DP, Shi X, Sharma AM, Birch DW, Karmali S[68].	2011	The benefits of bariatric surgery in obese patients with hip and knee osteoarthritis: a systematic review. Obesity Reviews, 12:1083–1089.	Systematic review found that bariatric surgery may improve osteoarthritis-related hip and knee pain in patients with obesity, but the heterogeneity in study outcomes and low quality of evidence prevents definitive conclusions.
1	Groen VA, van de Graaf VA, Scholtes VAB, Sprague S, van Wagensveld BA, et al[50].	2015	Effects of bariatric surgery for knee complaints in (morbidly) obese adult patients: a systematic review. Obesity Reviews, 16:161-170.	Systematic review found that bariatric surgery was likely to improve osteoarthritis-related knee pain in patients with obesity, but the quality of evidence was low so definitive conclusions could not be made.
1	Inacio MCS, Kritz-Silverstein D, Paxton EW, Fithian DC[53].	2012	Do patients lose weight after joint arthroplasty surgery? A systematic review. Clinical Orthopaedics and Related Research, 471:291-298.	Systematic review found no evidence that body weight or body composition changes after TJA (either increases, decreases or remains the same).
1	Lui M, Jones CA, Westby MD[52].	2015	Effect of non-surgical, non-pharmacological weight loss interventions in patients who are obese prior to hip and knee arthroplasty surgery: a rapid review. Systematic Reviews, 4:121.	Systematic review included two cohort studies; patients who lost weight (≥5% of body weight) before TKA had either no difference or increased likelihood 90-day hospital readmission (OR 1.63) and deep surgical infection (OR 3.77) compared to those who didn't lose weight before TJA. There is limited evidence to recommend weight loss before TJA.
1	Smith TO, Aboelmagd T,	2016	Does bariatric surgery prior to total hip or knee	Meta-analysis indicated no difference in risk for infections, revision or

	Hing CB, MacGregor A[51].		arthroplasty reduce post-operative complications and improve clinical outcomes for obese patients? The Bone & Joint Journal, 98B(9):1160-1166.	mortality when patients had bariatric surgery prior to TJA compared to those who did not.
2	Plow MA, Moore S, Husni ME, Kirwan JP[58].	2014	A systematic review of behavioural techniques used in nutrition and weight loss interventions among adults with mobility-impairing neurological and musculoskeletal conditions. Obesity Reviews, 15:945-956.	Systematic review results indicate that weight loss interventions in mobility limiting conditions resulted in mean weight loss of 4.11 kg, however further research is needed. Adults with mobility limitations are at high risk for obesity and low muscle mass, so body composition may be a better outcome measure compared to BMI.
2/3*	Springer BD, Carter JT, McLawhorn AS, Scharf K, et al[73].	2016	Obesity and the role of bariatric surgery in the surgical management of osteoarthritis of the hip and knee: a review of the literature. Surgery for Obesity and Related Diseases.	Evidence to support bariatric surgery before joint arthroplasty is limited. Optimal co-management of lower limb osteoarthritis in patients with a BMI >40 or >35 with comorbidities requires further prospective research.
2/3*	Wluka AE, Lombard CB, Cicuttini FM[86].	2013	Tackling obesity in knee osteoarthritis. Nature Reviews Rheumatology, 9:225-235.	Review of weight management strategies for knee osteoarthritis. RCTs show weight loss of 5% of body weight is achievable, but self-management support and long-term follow up are required for maintenance of weight loss, which can be challenging. Preventing weight gain may be better approach.
3	Bliddal H, Leeds AR, Christensen R[10].	2014	Osteoarthritis, obesity and weight loss: evidence, hypotheses and horizons – a scoping review. Obesity Reviews, 15:578-586.	Recommendations for exercise together with weight loss for osteoarthritis treatment, with a goal of weight loss of 10%, however there is inconclusive evidence for maintenance of weight loss and suitability of exercise when osteoarthritis is severe. Interventions that treat both obesity and osteoarthritis are needed.
3	Kulkarni K, Karssiens T, Kumar V, Pandit H[65].	2016	Obesity and osteoarthritis. Maturitas, 89:22-28.	Review of studies on weight loss and obesity in osteoarthritis, with recommendations that TKA not be denied based on BMI.
3	Messier SP[57].	2010	Diet and exercise for obese adults with knee osteoarthritis. Clinics in Geriatric Medicine, 26:461-477.	Exercise and 10% loss of body weight loss are recommended, however it is acknowledged that interventions to achieve that weight loss are rare, and weight loss is difficult to achieve.
3	Vincent HK, Heywood K, Connelley J, Hurley RW[87].	2012	Weight loss and obesity in the treatment and prevention of osteoarthritis. American Academy of Physical Medicine and Rehabilitation, 4(50):S59-S67.	Review of relationship between obesity and osteoarthritis, and recommendations for weigh loss strategies including medications, exercise and diet, and bariatric surgery. Consideration for pain and kinesiophobia are important.
Total Joint Arthroplasty (hip and knee)				
2	Flego A, Dowsey MM, Choong PFM, Moodie M[77].	2016	Addressing obesity in the management of knee and hip osteoarthritis – weighing in from an economic perspective. BMC Musculoskeletal Disorders, 17:233.	Obesity may be associated with higher hospital based healthcare costs with TJA compared to those without obesity, however data is heterogeneous. Results did not consider improvements in efficiency of clinical pathways and non-hospital costs such as medications, rehabilitation, loss of productivity and personal expenses of the patient.
3	Springer BD, Parvizi J, Austin M, et al[74].	2013	Obesity and total joint arthroplasty: a literature based review (from the Workgroup of the American Association of Hip and Knee Surgeons (AAHKS) Evidence Based Committee). The	Consensus review from the workgroup of American Association of Hip and Knee (AAHKS) surgeons. Review recommends surgeons discuss increased TKA perioperative risk with patients who have obesity, particularly those with a BMI >40 as risk increases substantially. Recommend consideration of

			Journal of Arthroplasty, 28:714-721.	delay of TJA in those with BMI >40 and significant comorbidity, unless surgery is absolutely indicated. Data for THA is less clear.
3	Dowsey MM,, Gunn J, Choong PFM[33].	2014	Selecting those to refer for joint replacement: who will likely benefit and who will not? Best Practice & Research Clinical Rheumatology, 28:157-171.	Appropriateness for TJA is discussed, recommending consideration of responder criteria and development of evidence based algorithms. Current practice is based on clinical judgement. Response rates in patients with obesity are similar to those without obesity.
3	Vasarhelyi EM, MacDonald SJ[76].	2012	The influence of obesity on total joint arthroplasty. The Journal of Bone and Joint Surgery, 94-B, SupplA:100-102.	Review of relationship between obesity and osteoarthritis. Role of the orthopedic surgeon to encourage weight loss, inform patients of surgical risk, to delay but not deny arthroplasty for patients with obesity.
Total Knee Arthroplasty				
1	Kerkhoffs GMMJ, Servien E, Dunn W, Dahm D, et al[44].	2012	The influence of obesity on the complication rate and outcome of total knee arthroplasty. The Journal of Bone and Joint Surgery, 94:1839-1844.	Meta-analysis indicated increased rates of superficial infection (OR 2.17, CI 1.5-3.1), deep infection (OR 2.4, CI 1.3-4.6) and revision (OR 1.3, CI 1.02-1.7) when BMI >30 compared to <30. There were no differences in venous thromboembolism or pulmonary embolism rates.
1	McGrory BJ, Weber KL, Jevsevar DS, Sevarino K[41,88,89].	2016	Surgical management of osteoarthritis of the knee. Evidence-based guideline. Journal of the American Academy of Orthopaedic Surgeons, 24(8):e87-e93. Summary of American Academy of Orthopaedic Surgeons (AAOS) Guidelines.	Conflicting evidence on complications after TKA in patients with obesity based on BMI, but some evidence that patients with obesity have poorer functional improvement after TKA, so BMI is considered a risk factor for TKA. Moderate evidence that delaying TKA for 8 month to allow weight loss does not worsen outcomes. Research is needed to determine if other factors relative to obesity contribute to increased risk (i.e. malnutrition).
1	Samson AJ, Mercer GE, Campbell DG[45].	2010	Total knee replacement in the morbidly obese: a literature review. ANZ Journal of Surgery, 80:595-599.	BMI >40 had 3.3 – 9 times rates of deep infection compared to BMI <30, but comparable clinical and functional Knee Society Scores after TKA. Increased risk of infection and risk for early revision should be discussed with patients along with encouragement to lose weight before TKA.
1	Si H, Shen B, Yang J, Zhou Z, Kang P, Pei F[46].	2015	The influence of body mass index on the outcomes of primary total knee arthroplasty. Knee Surgery, Sports Traumatology, Arthroscopy, 23:1824-1832.	Meta-analysis indicated higher ≥ 5 year revision rates in BMI>30 versus <30 (OR 1.6, CI 1.1-2.4), along with greater overall infections (OR 1.45, CI 1.1-1.8), superficial infections (OR 1.7, CI 1.2-2.3) and deep vein thrombosis (DVT) (OR 2.7 CI 1.3-5.4). Compared to BMI <30, the BMI >40 group had even higher rates of overall infections (OR 4.0, CI 2.3-7.1), superficial infections (OR 6.8, CI 3.4-13.8), deep infections (OR 2.9, CI 1.4-6.1), and DVT (OR 8.2, CI 1.8-36.4). BMI >40 was not associated with higher revision rates than BMI <30. There were no differences in aseptic loosening with follow-up ≥ 5 years. Confounding factors may not have been adjusted for in included studies.
2	McElroy MJ, Pivec R, Issa K, Harwin SF, Mont MA[75].	2013	The effect of obesity and morbid obesity on outcomes in TKA. The Journal of Knee Surgery, 26(2):83-88.	BMI 40-49.9 had higher implant failure risk (RR 9.7, CI 1.2-78.8) and risk of perioperative complications (RR 2.8, CI 1.2-6.5) compared to BMI 30-39. BMI 40-49.9 had poorer Knee Society Scores than BMI <30. The BMI 30-39 group had outcomes similar to BMI <30. Lack of control for comorbid conditions may have impacted results.
2	Vaishya R, Vijay V, Wamae D, Agarwal AK[72].	2016	Is total knee replacement justified in the morbidly obese? A systematic review. Cureus, 8(9):e804	BMI >40 had higher rates of overall complications and superficial infections than BMI <30, but no difference in deep infection rates, prosthetic survival, and Knee Society Scores.

2/3*	Rodriguez-Merchan EC[83]	2015	Review article: outcome of total knee arthroplasty in obese patients. Journal of Orthopaedic Surgery, 23(1):107-110	Review of literature on TKA. Obesity may impact outcomes, complications and implant survival, but conflicting results reported. Patients with obesity should not be denied surgery as improvement in pain and function is similar to patients without obesity.
3	Buchbinder R, Richards B, Harris I[82].	2014	Knee osteoarthritis and role for surgical intervention: lessons learned from randomized clinical trials and population-based cohorts. Current Opinion in Rheumatology, 26(2): 138-144.	Review of evidence from randomized controlled trials and cohort studies to inform osteoarthritis treatment. Discussed evidence on risk with TJA and concluded that patients with obesity should be counselled on the increased TJA surgical risk, particularly those with a BMI >40 or >50. Controlled trials and prospective cohort studies are needed to improve evidence-based knowledge for treatment of knee osteoarthritis.
3	Cheatham, SW[78].	2013	Do patient factors and prehabilitation improve outcomes after total knee arthroplasty? Topics in Geriatric Rehabilitation, vol 29, 1:17-24.	Review of patient factors related to TKA outcomes. Strength, age, range of motion, pain and patient expectations have the strongest influence on outcomes, whereas obesity, gender, and timing of surgery have a weaker influence on outcomes. Prehabilitation studies show potential benefit but further research is needed.
3	Choong PFM, Dowsey MM[69].	2011	Update in surgery for osteoarthritis of the knee. International Journal of Rheumatic Diseases, 14:167-174.	Review of surgical procedures for osteoarthritis of the knee, including total knee arthroplasty.
3	Hamilton DF, Howie CR, Burnett R, Simpson AHRW, Patton JT[80].	2015	Dealing with the predicted increase in demand for revision total knee arthroplasty. Challenges, risks and opportunities. The Bone & Joint Journal, 97-B:723-728.	Increased rates of TKA in patients below the age of 55 related to rising obesity will lead to increased needs for revision surgery. Revisions are largely due to infection and aseptic loosening, but limits to prosthetic lifespan is a concern in younger patients. Revisions are associated with greater health care expense and higher surgical risk, although surgeon volume and experience may mitigate this risk.
3	Hamlin BR[66].	2011	Treatment of knee arthrosis in the morbidly obese patient. Orthopedic Clinics of North America, 42(1):107-113.	Review of surgical optimization and considerations when TKA is required in patients who have morbid obesity. Patients must have comorbidities optimized prior to surgery and be aware of increased risk of complications and slower recovery time.
3	Salih S, Sutton P[71].	2013	Obesity, knee osteoarthritis and knee arthroplasty: a review. BMC Sports Science, Medicine, and Rehabilitation, 5:25.	Review of association between osteoarthritis and obesity, and outcomes in arthroplasty. Controversy around increased peri-operative complications in those with obesity, and discussion of early results for revision in this population. Review supports TKA in patients with obesity, but increased risk for complications and revision should be discussed with the patient.
Total Hip Arthroplasty				
1	Haverkamp D, Klinkenbijl MN, Somford MP, Albers GHR, van der Vis HM[47].	2011	Obesity in total hip arthroplasty – does it really matter? Acta Orthopaedica, 82(4): 417-422.	Meta-analyses indicated increased occurrence of aseptic loosening (OR 0.6, CI 0.43-0.96), infection (OR 0.3, CI 0.19-0.49), dislocation (OR 0.5, CI 0.38-0.75) and venous thromboembolism (OR 0.6, CI 0.32-0.98) in those with a BMI <30 compared to BMI >30. No control for comorbidity was included in analyses.
1	Liu W, Wahafu T, Cheng M, Cheng T, Zhang Y, Zhang X[48].	2015	The influence of obesity on primary total hip arthroplasty outcomes: a meta-analysis of prospective cohort studies. Orthopaedics &	Meta-analyses indicated increased rates of overall complications (RR 1.68, CI 1.23-2.30), dislocation (RR 2.1, 1.54-2.81), and deep infections (RR 2.92, 0.74-11.49) in those with obesity compared to non-obese. Additionally, they

			Traumatology, 101:289-296.	had poorer Harris Hip Scores and longer operating times, but no difference in length of stay. Confounding comorbidities had not been adjusted for in included studies.
Rehabilitation after Arthroplasty				
2	Mistry JB, Elmallah RDK, Bhave A, Chughtai M, et al[64].	2016	Rehabilitation guidelines after total knee arthroplasty: a review. The Journal of Knee Surgery, 29(3):201-217.	Review of rehabilitation techniques and modalities after TKA, with discussion on controversy regarding increased risk, complications and revision in patients with obesity. Research is needed to evaluate how rehabilitation modalities can assist with improving outcomes in those with obesity.
3	Stevens M, Reininga IHF, Bulstra SK, Wagenmakers R, van den Akker-Scheek I[79].	2012	Physical activity participation after total hip and knee arthroplasty. Clinics in Geriatric Medicine, 28:509-520.	Review of benefits of physical activity for osteoarthritis, particularly related to TJA. Physical activity after TJA is recommended for patients with obesity to increase energy expenditure and improve body weight, however consideration for type of activity and impact and wear on the prosthesis should be given. Low and moderate impact activities are universally recommended after TJA.
Orthopedic surgery				
1	Hart HF, Barton CJ, Khan KM, Riel H, Crossley KM[43].	2016	Is body mass index associated with patellofemoral pain and patellofemoral osteoarthritis? A systematic review and meta-analysis. British Journal of Sports Medicine, 0:1-11.	Meta-analysis results showed that while a higher BMI is associated with patellofemoral pain, BMI was not associated with intervention outcomes in patellofemoral osteoarthritis treatment.
3	Parratte S, Pesenti S, Argenson JN[81].	2014	Obesity in orthopedics and trauma surgery. Orthopaedics & Traumatology: Surgery & Research, 100:S91-S97.	Special considerations for TJA surgery in patients with obesity, including patient positioning, use of instrumentation and surgical techniques when higher adiposity is present. Diabetes may double the infection rate in patients with obesity, so control is needed before surgery.
3	Sabharwal S, Root MZ[70].	2012	Impact of obesity on orthopaedics. The Journal of Bone and Joint Surgery, 94:1045-1052.	Review of surgical challenges in individuals with obesity, including imaging difficulties, perioperative considerations, and arthroplasty outcomes.

† did not report search strategy, but summarized guidelines from 2008-2009 developed with systematic search strategy and assessment of bias/quality

* utilized a systematic search strategy but did not report the results