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REVIEW ARTICLE

Epidemiology and Population Health

Obesity does not adversely impact the outcome of unicompartmental knee arthroplasty for osteoarthritis: a meta-analysis of 80,798 subjects

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Abstract

Background Patients with end-stage single compartment osteoarthritis benefit from the less invasive unicompartmental knee arthroplasty (UKA). With increasing financial restraints, some healthcare services have set specific BMI cut-offs when determining patient eligibility for knee arthroplasty due to perceived obesity-related complications. The aim of this systematic review is to determine the effect obesity has on outcomes following UKA, and thus elucidate whether obesity should be a contraindication for UKA.

Methods A PRISMA systematic review was conducted using five databases (MEDLINE, EMBASE, Cochrane, PubMed and Web of Science) to identify all clinical studies that examined the effect of obesity on outcomes following UKA. Quantitative meta-analysis was carried out using RevMan 5.3 software. Quality assessment was carried out using the Critical Appraisal Skills Programme (CASP) checklist.

Results Thirty studies, including a total of 80 798 patients were analysed. The mean follow- up duration was 5.42 years. Subgroup meta-analyses showed no statistically significant difference following UKA between patients cohorts with and without obesity in overall complication rates (95% CI, $P = 0.52$), infection rates (95% CI, $P = 0.81$), and revision surgeries (95% CI, $P = 0.06$). When further analysing complications, no differences were identified in minor (95% CI, $P = 0.23$) and major complications (95% CI, $P = 0.68$), or venous thromboembolism rates (95% CI, $P = 0.06$). When further analysing revision surgeries, no differences were identified for revisions specifically for infection (95% CI, $P = 0.71$) or aseptic loosening (95% CI, $P = 0.75$).

Conclusions This meta-analysis shows that obesity does not result in poorer post-operative outcomes following UKA and should not be considered a contraindication for UKA. Future studies, including long-term follow-up RCTs and registry-level analyses, should examine factors associated with obesity and consider stratifying obesity to better delineate any potential differences in outcomes.

Introduction

Obesity is a state of excessive fat accumulation and is defined as a body mass index (BMI) of 30 kg/m^2 or greater [1]. Although BMI as a measure has its limitations, it is the most frequently cited quantifiable measure to grade obesity [2]. The number of people classified as overweight or obese is on the rise. The World Health Organisation (WHO) report that the number of adults with obesity has nearly tripled since 1975 [3]. In 2016, there were more than 1.9 billion adults who were overweight, and of these more than 650 million were obese [3]. A projection model of obesity rates suggests that prevalence may be as high as 1.12 billion adults worldwide by 2030 [4].

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Obesity is a significant risk factor for osteoarthritis (OA), particularly in the knee joint [5–7]. Evidence shows that the risk of knee OA increases with increasing BMI [8]. This, in combination with the projected rise in obesity rates, suggests the burden of patients that have obesity with knee OA will also increase in the future.

Knee OA is ranked as the 11th highest contributor to disability globally [9]. The knee is divided into three compartments: medial tibiofemoral, lateral tibiofemoral, and patellofemoral. Knee OA can involve any or all three of these compartments. End-stage symptomatic disease is usually treated with joint arthroplasty [10]. In a proportion of cases, only one compartment is affected. In these patients unicompartmental knee arthroplasty (UKA) may be performed, where only the affected part of the knee is replaced. The perceived advantage of UKA over total knee arthroplasty (TKA) is that there is less bone resection, shorter intra-operative times and less blood loss [11]. There is also preservation of bone and articular soft tissues of the unaffected compartment [12]. Moreover, there are reduced rates of complications and mortality, along with faster recovery in UKA [13–15]. In a time where the global disease burden of OA is increasing, quicker recovery times and better outcomes are desirable for financially restrained healthcare services. Despite the advantages, UKA is associated with higher revision rates than with TKA [16]. It is therefore important to delineate risk factors for revision to facilitate patient selection and clinical decision making.

Orthopaedic surgeons are dealing with an increasing number of end-stage knee OA cases in patients with obesity. There is controversy surrounding the effect obesity has on complication rates and the longevity of arthroplasty prostheses including UKA. Some studies have shown obesity is associated with increased revision rates and complications [17–19], while others have shown obesity has no effect on any outcomes following UKA [20, 21]. Despite the growing evidence that patients with obesity benefit substantially from arthroplasty, some healthcare services have set specific BMI cut-offs when determining patient eligibility for knee arthroplasty [22–24]. It is important for decision making in high BMI cohorts to be informed by robust evidence. The aim of this study is to determine the overall risk of obesity on complications, infections and revision surgery following UKA based on existing literature.

Materials and methods

Database and inclusion criteria

The systematic review was carried out based on the guidelines produced by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis checklist [25]. Inclusion and exclusion criteria for the studies was determined using the PICOS model [26]. Studies which were randomised control trials (RCTs), case control, cohort or cross-sectional studies were included. On the other hand, any reviews and editorials were excluded. Studies which could not be accessed were also excluded. In addition, studies with a sample size fewer than 30 were excluded to avoid over-estimation of the effects of individual studies in the meta-analyses. Only studies which included UKA as an intervention were included. In addition, all studies had to include obese subjects. Consequently, any study which did not include either UKA or patients with obesity were excluded. All included studies were reverse reference-searched for additional studies.

A literature search was carried out by two reviewers (N.A. and K.T.) independently. Five databases were searched for studies which were relevant to this systematic review: Medline (1946 to Week 2 May 2020), EMBASE (1974–14 May 2020), Cochrane library (1946–May 2020), Web of Science (1900–2020) and PubMed (1996–2020).

Using the structural guidelines given by the Cochrane Highly Sensitive Search Strategy, a search strategy was developed [27]. This comprised of but was not limited to the following terms: ‘Arthroplasty, Replacement, Knee’, or ‘Knee Prosthesis’ and ‘Obesity’ and ‘Reoperation’ or ‘Postoperative Complications’ or ‘Prosthesis Failure’. During the search, restrictions were applied on language to only English, and to include only studies conducted on humans. There is a possibility that language restriction can be a source of bias. However, there is no indication that restriction to only the English language has a significant effect on the end results produced in systematic reviews [28]. The overall results of the comprehensive search are shown in Fig. 1.

Quality assessment

Each included study was independently appraised by three reviewers (N.A., K.T., B.Z.) to ensure accurate evaluation. This was conducted using the Critical Appraisal Skills Programme (CASP) checklist for cohort studies [29]. Any disagreements were resolved by discussion.

Data extraction and statistical analysis

Key characteristics were extracted for each study including the study design, the number of patients included in the study, percentage of patients which were female, mean BMI, and mean follow-up duration. In addition, the number of patients who had the following outcomes during or following UKA were also extracted: any complications, minor and major complications, intra-operative fracture, nerve injury, tendon/ligament injury or rupture, venous thromboembolism (VTE), infection of any kind,

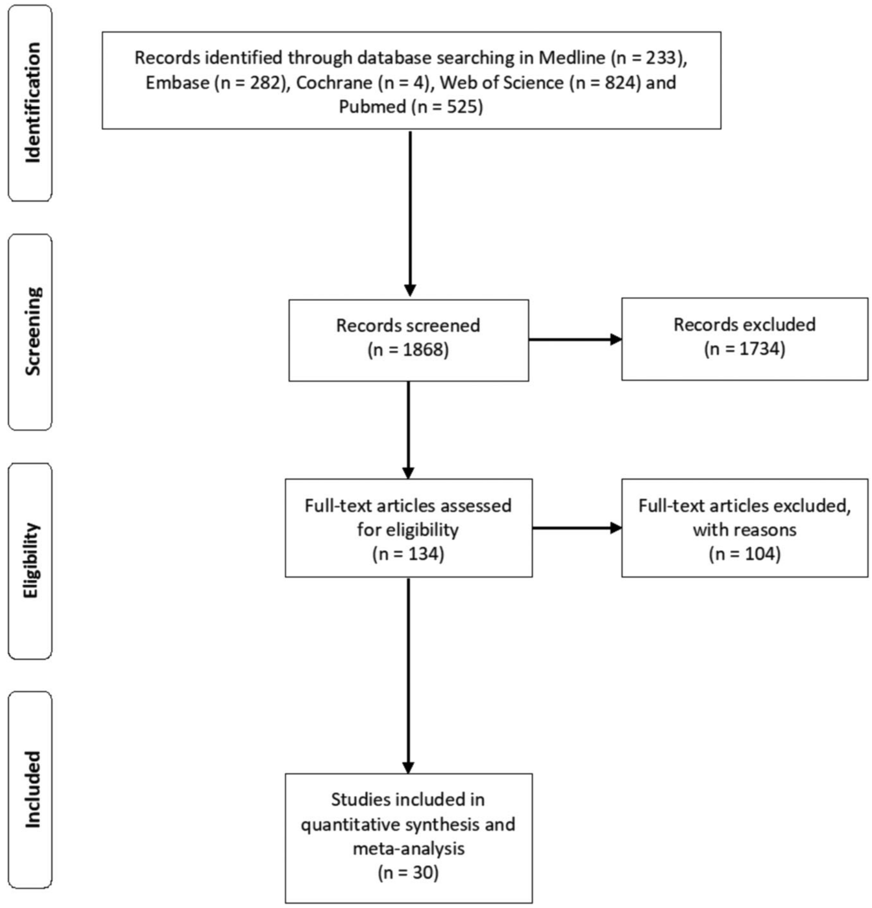

Fig. 1 Overview of the screening and selection process of studies for the systematic review. PRISMA flow diagram showing the screening and selection process.

revision for any reason, revision specifically for infection, revision specifically for aseptic loosening. All available data on patients with and without obesity, with and without each event were compiled. Odds ratios were then calculated for each of these. Forest plots were created for non-specific post-operative outcomes such as overall complication rates. Specific post-operative outcomes such as minor complications were compiled in a table. All data analysis was conducted via the RevMan 5.3 software. The tau-squared, chi squared and I^2 tests were used to test for heterogeneity. All outcomes that had moderate or high degree of heterogeneity ($I^2 > 50\%$) were analysed under a random effect model in the meta-analyses. Outcomes that reported a low degree of heterogeneity ($I^2 < 50\%$) were analysed under a fixed effect model. The overall effects were calculated for all outcomes with a 95% confidence interval, and a P value of < 0.05 was regarded as statistically significant.

Results

Table 1 summaries the main characteristics of the studies included in the systematic review.

Subgroup analyses of the non-specific post-operative outcomes following UKA were conducted through forest plots (Fig. 2).

A subgroup meta-analysis was performed for ten studies, which specifically reported patients with and without obesity who encountered any complication following UKA [17, 21, 30–37] (Fig. 2a). Two studies showed a statistically significant increase in complication rates in patients with obesity [17, 30] while the remaining eight studies showed no statistical difference [21, 31–37]. The pooled odds ratio was 1.36 [95% CI 0.54–3.43] suggesting no statistically significant difference in the complication rates between patients with and without obesity following UKA ($Z = 0.65$, $P = 0.52$).

Nine studies which documented patients with and without obesity who developed infection of any kind following UKA were meta-analysed (Fig. 2b) [17, 30–34, 36, 38, 39]. One study found a statistically significant increased rate of infection in patients without obesity [17]. Seven studies showed no statistical difference [30, 31, 33, 34, 36, 38, 39], and for the last study the odds ratio could not be estimated [32]. The pooled odds ratio was 1.09 [95% CI 0.54–2.17] suggesting no statistically significant difference in the infection rate between patients with and without obesity following UKA ($Z = 0.23$, $P = 0.81$).

Table 1 Characteristics of the studies included in the systematic review, $n = 30$.

Characteristics	Retrospective cohort studies	Prospective cohort studies	Case series	Total
Number of studies	20	7	3	30
Patient sample size	26 271	53 239	1 288	80 798
Mean BMI (range)	32.23 (27.08–43)	28.98 (27.38–30)	29 (28.8–29.2)	31.2 (27.08–43)
% Female (range)	60.16 (38–82.7)	58.82 (45–89.7)	42.1	59.1 (38–89.7)
Mean follow-up duration in months (range)	59.24 (1–139.2)	81.07 (1–122.4)	62.8 (54–67.2)	65.08 (1–139.2)

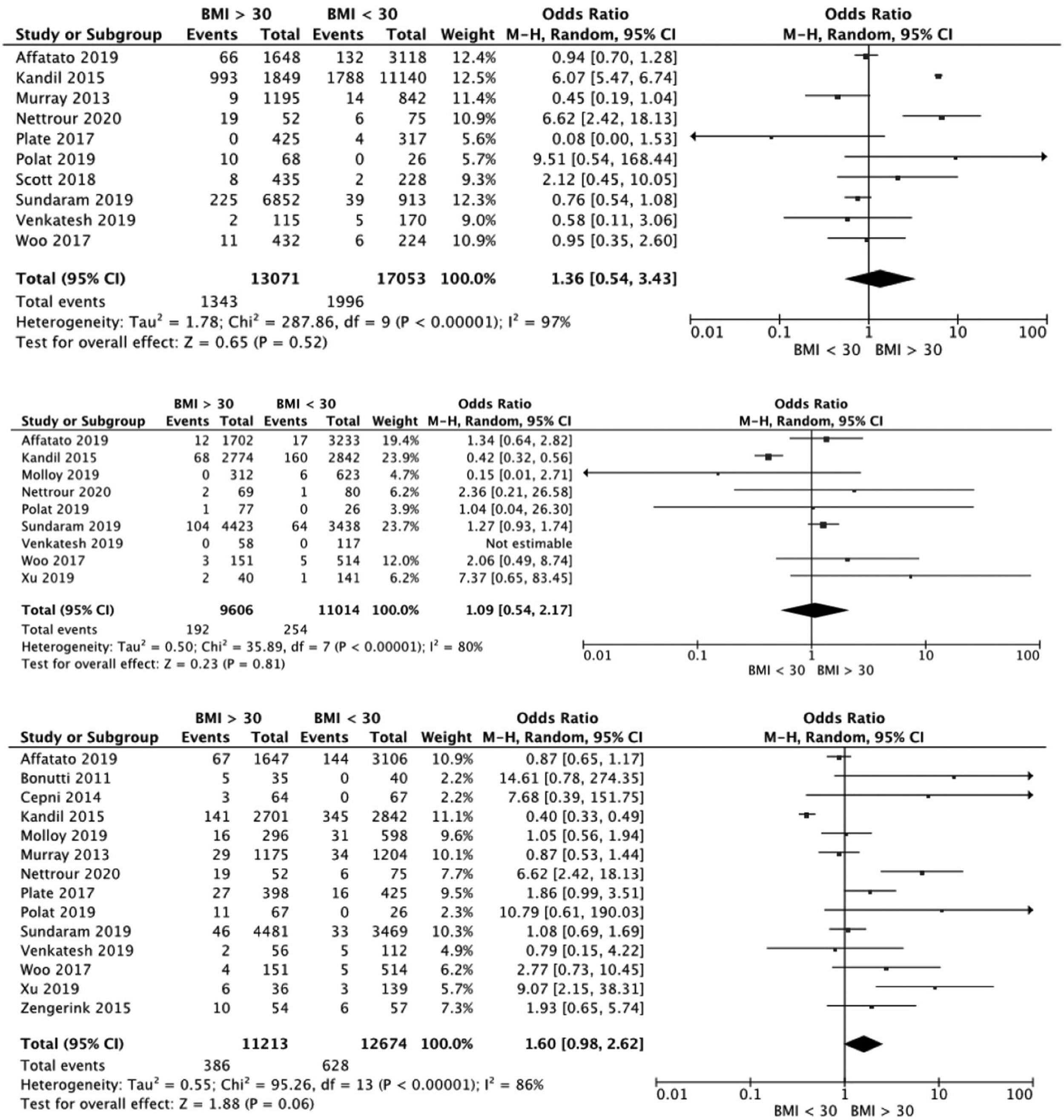

Fig. 2 Forest plot analyses of the non-specific post-operative outcomes following UKA. Forest plots showing the effects of obesity in patients with any complications following UKA (**a**), patients with infections of any kind following UKA (**b**) and patients who underwent revision surgery following UKA for any reason (**c**) (M–H = Mantel–Haenszel, CI = confidence interval, df = degrees of freedom).

A meta-analysis was conducted of fourteen studies which recorded patients with and without obesity who underwent revision surgery following UKA for any reason [17, 21, 30–34, 36–42] (Fig. 2c). Two studies showed a statistically significant increase in revision rates in patients with obesity [30, 38], one study showed an increase in patients without obesity [17], while eleven studies showed no difference between the groups [21, 31–34, 36, 37, 39–42]. The pooled odds ratio was 1.60 [95% CI 0.98 to 2.62] suggesting no statistically significant difference in the revision rate between patients with and without following UKA ($Z = 1.88$, $P = 0.06$).

Additional subgroup analyses of specific post-operative outcomes were performed to look at a breakdown of complications and revision surgery (Table 2).

Of the three studies that looked at minor complications following UKA, one found a statistically significant increase in minor complications in patients with obesity [17], whereas two studies showed no difference [17, 33, 35]. Of the two studies that looked at major complications following UKA [17, 33], one study found a statistically significant increase in major complications in patients with obesity [33], while the other study found no difference [17]. Of the four studies that looked at VTE rates following UKA [17, 33, 36, 41], one study showed a statistically significant increase in patients with obesity [17] while the other three studies showed no difference [33, 36, 41]. The pooled odds ratios showed no statistically significant difference in minor and major complications or VTE between the cohorts of patients with and without obesity following UKA.

None of the nine studies that looked at revision surgery specifically for infection [30–32, 34, 36–39, 42], nor the nine studies that looked at revision surgery specifically for aseptic loosening [30–32, 34, 36–40] showed any statistically significant difference between patients with and without obesity.

To assess study heterogeneity, a funnel plot of the studies included in the meta-analysis of all complications was made. Significant heterogeneity was detected on visual inspection, This demonstrates significant asymmetry in the distribution of studies, suggesting bias towards lower odds ratio values revealing an inclination towards more negative odds ratios (Fig. 3). A random-effects model was used for analysis as a fixed effect model, taken into context with an I^2 value of >50% was deemed inappropriate.

A detailed breakdown of the characteristics of each study including study design, number of patients, mean follow-up duration, proportion of female subjects and mean BMI, can be found in Table 3 in the Appendix. As previously mentioned CASP analysis was conducted on all studies included in the systematic review. A table showing the individual analysis of each study can be found in Table 4 in the Appendix.

Discussion

The use of UKA for single compartment end-stage OA has increased significantly over the last couple of decades [43]. Studies have shown that this procedure generally has good functional outcomes, and offers several advantages over TKA [44–47]. The incidence of knee OA is on the rise, which is reflective of the elderly population [48, 49]. However, it is also indicative of the increased number of overweight and persons with obesity worldwide [3]. It is known that obesity accelerates the rate of OA, especially in the knee [50]. Some healthcare services have set specific BMI cut-offs when determining patient eligibility for knee arthroplasty in view of a perceived risk of poorer outcomes in this group. This systematic review and meta-analysis examined studies which investigated post-operative outcomes in patients with and without obesity following UKA.

18 of the 30 studies found that BMI had no effect on outcomes following UKA [12, 20, 21, 32, 34, 36, 37, 39–41, 51–58]. The remaining 12 studies determined that UKA in patients with obesity led to poorer outcomes [17, 19, 30, 31, 33, 35, 38, 42, 59–62]. The most common post-operative outcomes measured in studies included in this review were overall complications following UKA and the need for revision surgery following UKA for any reason. The other post-operative outcomes measured were minor and major complications, infections of any kind, VTE, revision specifically for infection and revision specifically for aseptic loosening following UKA. In addition, during the data extraction phase of the review other intra and post-operative outcomes were sought. These include intra-operative fracture, nerve injury and tendon/ligament injury or rupture. No studies documented nerve injury or tendon/ligament injury or rupture. This may be due to lack of thoroughness of the studies or simply because none of these complications occurred. One study did report rates of intra-operative fractures in their study, but did not compare this to a non-obese cohort [31]. The subgroup meta-analyses conducted on the various post-operative outcomes mentioned above, revealed no statistical significance between patients with and without obesity in any of the outcomes measured.

Subject recruitment can play a large role in the external validity of the included studies, with a wide range of mean BMIs between the studies. Although our meta-analysis found no difference in complications, infection and revision rates between patients with and without obesity, the limited number of studies available did not allow a comparison of different classes of obesity. A study by Giori et al. suggested that the risk of complications for patients with a BMI over 30 kg/m^2 is lower than that in the super-obese (BMI over 40 kg/m^2) [63]. Another study conducted by Adhikary et al. which analysed BMI as a continuous variable,

Table 2 Specific post-operative outcomes in obese and non-obese patient cohorts.

Outcome	Number of patients with obesity	Number of patients without obesity	M–H (95% CI)	I2 for heterogeneity	*P* value for heterogeneity	*Z* for overall effect	*P* value for overall effect
Minor complications	9894	13,555	1.82 [0.69, 4.89]	91%	<0.00001	1.21	0.23
Major complications	9657	13,558	1.36 [0.32, 5.68]	97%	<0.00001	0.42	0.68
VTE	7495	6910	0.77 [0.58, 1.01]	72%	0.03	1.87	0.06
Patients who underwent revision surgery specifically for infection	3681	6007	0.89 [0.49, 1.63]	36%	0.2	0.37	0.71
Patients who underwent revision surgery specifically for aseptic loosening	3590	5881	1.05 [0.79, 1.39]	17%	0.29	0.32	0.75

reported that a BMI greater than 45 kg/m^2 was associated with an increased risk of complications [64]. Although we were not able to determine the effect of various obesity classes on complications, infection, and revision rates, this would be worth investigating once there is sufficient literature to allow a meta-analysis.

Seth et al. determined that at short and medium term, patients with obesity have stable implants [51]. This was backed by Xu et al. who found that obesity has no effect on short to medium term outcomes [38]. However, they also found that at ten years patients with obesity had much lower Knee Society functional scores, Oxford knee scores and physical component scores [38]. In addition, there were much greater revision rates as well [38]. This was supported by Scott et al. They followed up their patients for an average of 11.4 years and found that patients with obesity had significantly poorer implant survival rates [35]. Conversely several studies which had long-term follow-ups did not replicate such findings [12, 20, 39, 56]. Cavaignac et al. specifically investigated this matter and followed up patients for 11.6 years on average [20]. They concluded that obesity did not affect long-term results following UKA [20]. It is difficult to reliably assess the impact of obesity on long-term results, as the operative procedure in this case may allow increased activity that drives a change in BMI over a long time-course, as such this confounding element must be taken into consideration in future studies.

Woo et al. found that patients with obesity had lower pre-operative knee scores and did not find any difference in outcomes between patients with and without obesity [36]. This suggests that patients with obesity gain a greater benefit than patients without obesity do. Murray et al. reached similar conclusions [37]. Whilst it may not be reliable to draw conclusions from these two studies alone, it is conceivable that patients with poorer baseline health may experience a greater relative improvement in health following surgery to relief pain and immobility.

One issue which complicates this topic, is the multitude of knee prothesis designs and models. Indeed, many of the studies included in this review did not use only one prothesis type. Various studies have reported differences between mobile and fixed bearing UKA designs. It is possible that some may confer better outcomes than others in patients with obesity. Some authors believe that use of mobile bearing UKA in obesity patients may reduce revision rates. These prostheses disperse load more effectively [65] and so reduce the risk of loosening [57]. Furthermore, there is controversy surrounding InLay and OnLay patellofemoral replacement designs. InLay designs preserve more tibial bone; however, they also increase the interface stress between the tibial bone and the prosthesis insert [21]. This stress would be further increased in patients with obesity. On the other hand, OnLay designs preserve less bone [21]. However, several studies have shown that OnLay designs may increase implant survival [66–68]. In addition to this, few studies, like Haughom et al., have investigated the effect robotic UKA has on outcomes in patients with obesity [59]. Robotics is gaining more traction in the field of orthopaedic surgery and there is evidence that robotic TKA results in better clinical outcomes [69]. This may translate into better and more acceptable outcomes for UKA in patients with obesity.

BMI related cut offs for UKA was popularised by Kozinn and Scott, in 1989, where they considered patients over 82 kg to be unsuitable for UKA based on biotribology [70]. One would anticipate that increasing loads to a prosthesis, as is the case in patients with obesity, would negatively impact the performance of the prosthesis in the long run. Studies in the past have shown that compared to the native knee, there is increased strain to the tibia following UKA [71, 72]. This in combination with increased load bearing in patients with obesity could result in failure and loosening of the prosthesis. Additionally, obesity increases the risk of several co-morbidities such as hypertension and

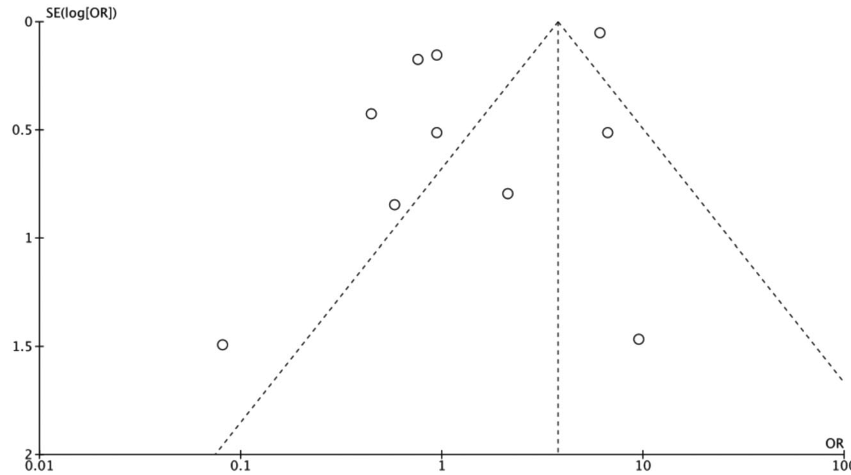

Fig. 3 Funnel plot of all studies included. The funnel plot demonstrates the heterogeneity of the forest plots. The dotted line represents 95% confidence interval for the overall effect under a fixed-effects model.

type 2 diabetes [73–75]. Such co-morbidities increase the risk of infection and complications post operatively.

Despite these theories, several studies, as shown in this review, have found that increased BMI does not increase revision or complication rates. It is not completely understood why this is the case. Kuipers et al. speculated that patients with obesity are less active and therefore will not use their prosthesis as intensively as patients without obesity [53]. Thus, despite an increased load bearing, there is less traumatic force. Sundaram et al. postulated that patients with obesity do not experience increased complications because they are managed more vigorously post-operatively and because they have a stronger physiological reserve [33]. Extensive research needs to be conducted into this field to definitely determine the underlying mechanisms involved.

Our review suggests that the use of BMI as a cut off by healthcare services in determining patient eligibility for knee arthroplasty is inappropriate. Increasing BMI is associated with an increased risk of co-morbidities, which may be the primary reason for increased complications seen in several studies. We recommend the use of a more comprehensive risk assessment in determining patient eligibility for knee arthroplasty looking at multiple risk factors. This should include hypoalbuminaemia, which is associated with complications following joint arthroplasty, and is linked with malnutrition and obesity [76, 77]. This could represent complications previously believed to be associated with obesity [78].

Strengths of this study include the critical appraisal before the studies were included in the final review, and the large number of patients included in the meta-analysis. Our analysis included thirty studies with 80,798 patients with a mean of 5.42 years. Our systematic review is limited by the quality of the studies that were available and their follow-up duration. No RCTs were identified during the comprehensive literature search on multiple databases. Only cohort studies and case series were included in this study which are level two and level four evidence levels, respectively. In that regard, this review has found a gap in the literature, with RCTs needing to be carried out to investigate outcomes in this group of patients. There also may be commercial bias in many of the studies included in our review. One study received support from NHS Research Scotland [35]. An additional nine studies declared a conflict of interest [19, 21, 30, 33, 37, 39, 55–57]. Four studies did not declare whether they had any conflicts [12, 54, 58, 60]. For two studies, the conflict of interest statements could not be accessed [17, 42]. In addition, due to the limited number of studies, this review did not investigate if results differed between patella-femoral, medial tibio-femoral and lateral tibio-femoral replacements. Future reviews can further analyse this effect in obese patients as the number of studies increases.

Conclusion

UKA is known to confer some advantages over TKA. However, its use in patients with obesity has been surrounded by controversy. The evidence from this study shows that obesity does not result in poorer post-operative outcomes and so should not be considered a contra-indication. Future studies, including long-term follow-up RCTs and registry-level analyses, should look at factors associated with obesity and consider stratifying obesity to better delineate any potential differences in outcome.

Compliance with ethical standards

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

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