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Mid- to long-term complications and outcome for morbidly obese patients after total knee arthroplasty: a systematic review and meta-analysis

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- *Purpose:* Due to substantial increase in obesity, the demand for total knee arthroplasty (TKA) in obese and morbidly obese patients is higher than ever. This review aims to investigate mid- to long-term complications, revision rates, and outcome for morbidly obese, compared with non-obese after TKA.
- *Methods:* A systematic search was conducted in May 2021. Included studies reported revision rates for morbidly obese and non-obese with a mean follow-up of at least 2 years. Reported knee society score (KSS) has been used to compare the functional outcome. PRISMA protocol was followed, and PROSPERO registered (ID: CRD42021254119).
- *Results:* From 12 studies that met the inclusion criteria, a total of 1031 cases of morbidly obese and 9797 cases of non-obese controls were included. The risk ratio for revision was 1.48 for the morbidly obese, compared with non-obese (95% CI: 0.98 to 2.24; $P=0.06$). Regarding aseptic and septic revision, the risk ratio was 1.44 (95% CI: 0.64 to 3.25; $P=0.37$) and 2.22 (95% CI: 0.89 to 5.57; $P=0.09$), respectively. The morbidly obese scored lower in Objective Knee Society Score (OKSS) and Functional Knee Society Score (FKSS) both preoperatively and postoperatively, compared with the non-obese; however, the two groups improved equally in function scores OKSS ($P=0.967$) and FKSS ($P=0.834$). Overall risk ratio for complications was 1.56 (95% CI: 0.98 to 2.48; $P=0.06$).
- *Conclusions:* The gained benefit in functional outcome surpasses the increase in risk of revision and complications for the morbidly obese in TKA surgery.

Keywords

- morbidly obese
- total knee arthroplasty
- total knee replacement
- revision rate
- Knee Society Score
- functional outcome
- complication rate

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Introduction

Total knee arthroplasty (TKA) is a safe, popular, and reliable surgical treatment of pain and disability from degenerative knee arthrosis. Obesity is a growing problem worldwide, and WHO reports that rates of obesity continue to grow and that 650 million people were found obese in 2016 (1). BMI has increased 0.4 and 0.5 kg/m^2 each decade for men and women, respectively, from 1980 to 2008 (2). Normal weight is defined as 18.5–24.9 kg/m^2, overweight: 25–29.9 kg/m^2, obesity: $\geq$ 30 kg/m^2, and obesity class III, which this study will be investigating, $\geq$ 40 kg/m^2 (3). Obesity class III is also known as morbidly obese. A consequence of obesity is a greater load on weight-bearing joints. Obesity correlates to osteoarthritis (OA) and is known to disproportionally increase and accelerate knee arthrosis (4, 5, 6, 7). Aging as well is correlated with OA (8, 9, 10), and since the world's population is getting older, this further increases the demand for arthroplasty independently of obesity. Although there is a high demand for TKA in obese and morbidly obese at present, the demand is expected to increase even further in the future (11).

Several studies have found increased short-term complications in obese and morbidly obese patients after TKA (12, 13, 14, 15, 16). Studies investigating mid- to long-term complications and outcome in morbidly obese have been more ambiguous due to smaller sample sizes and low event rates (7). One review has found an increased long-term revision rate in morbidly obese (17), another only found increased septic revision (18), and a third failed to conclude anything with certainty (19). This review aims to investigate mid- to long-term complications and outcome for morbidly obese, compared with non-obese after TKA – taken the latest studies in the field into consideration. The outcome will be measured as revision rate and functional outcome. Reported complications will be compared.

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Methods

Search strategy

This review was conducted in accordance with Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) (20, 21) and registered on PROSPERO (ID: CRD42021254119). A systematic search was conducted in May 2021 in relevant databases (PubMed and Embase from 1985 to May 2021). To correctly identify the relevant studies, the terminologies total knee replacement as well as total knee arthroplasty were used. In order to conduct one united search where all suffixes of the words obese and morbid are included, the symbol '*' has been used as a part of the search.

The following search string has been used: '(total knee replacement OR total knee arthroplasty) AND morbid* obes*'. A total of 555 results were found, 282 results from PubMed and 273 results from Embase. After the removal of 175 duplicates, the 380 remaining results were screened (Fig. 1).

Eligibility criteria

To clearly investigate the difference in complications and the outcome for morbidly obese, compared with non-obese after TKA, the following inclusion criteria were chosen: The studies must report revision rate for morbidly obese (BMI: $\geq$ 40 kg/m^2) and non-obese (BMI: $\leq$ 30 kg/m^2) after TKA. Studies comparing morbidly obese with normal weight (BMI: 18.5–25 kg/m^2) will also be included. Only studies with a mean of at least 2 years of follow-up were included. Studies must be published in English. JT has screened the 380 studies found in the search and screened relevant reference lists for additional inclusion. If possible, eligibility could not be determined by title or abstract screening, full articles were assessed. Before final inclusion, full article texts were assessed against eligibility criteria by MA and JT together to confirm consensus on final inclusion.

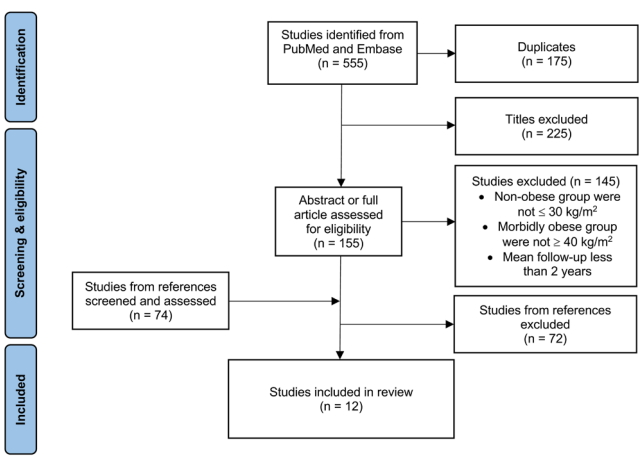

Figure 1
Flowchart of identification, screening, eligibility, and inclusion of studies.

Risk of bias assessment

All included studies are retrospective, there were no available RCTs which met the eligibility criteria, and we, therefore, did not find risk and bias regarding allocation or blinding. The risk of selection bias was not considered significant as all studies included reported all cases operated within a given time frame selected by their BMI grouping. Only studies reporting revision rates have been included. The exclusion of studies omitting revision rates have been chosen to reduce the potential risk of reporting bias.

Data items

Data from the included studies have been extracted into a data sheet. If a study has multiple BMI groups within the inclusion criteria, the groups have been merged into one single group. Several studies reported revision rate and complications in percentage and not in actual events. To create a forest plot, percentages have been calculated back to actual events. When necessary, means and range will be approximated from the figures in the report. Data extracted are the following: number of patients and TKAs, revision rates, BMI, patients' mean age, follow-up time, pre- and postoperative objective and functional Knee Society Scores, overall complications rate, prosthetic loosening, superficial wound infection, and thromboembolic events. Other data regarding complications will be extracted if considered important.

Statistical analysis

The risk ratios for revision have been quantitatively pooled using a random effect model. The results were reported using a forest plot, including individual and pooled point estimates along with 95% CIs. Heterogeneity was calculated using the I^2 statistic.

A Welch t-test has been used to compare Knee Society Score improvements. To compare Knee Society Score preoperative and postoperative a paired t-test has been used. Data analysis was performed using RevMan 5.4 (Cochrane Collaboration) and R 3.6.1. Significance was defined as $P \leq 0.05$.

Results

Search results

In this study, 555 results were identified on PubMed and Embase, in which 175 results were duplicates. All

remaining titles were screened of which 155 studies were further assessed for abstract or full article. Ten passed the inclusion criteria. In total, 74 studies from reference lists were screened and assessed for eligibility. From these, two further studies were included. The flowchart of identification to inclusion is presented in Fig. 1. In total, 12 studies were included in this review (22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33).

Cohort demographics

Studies from 1996 to 2019 matched the reviews criteria. The BMI range of the morbidly obese group is from 40 to 68.2 kg/m^2, compared with 18 to 30 kg/m^2 in the non-obese group. A total of 1031 TKAs were performed in the morbidly obese group and 9797 were performed in the non-obese group. Hakim *et al.* (25) and Bordini *et al.* (32) did not report age differences between their BMI groups but reported the mean age of all patients to be 64.3 years (48–83 years) and 72 years (71.8–72.1), respectively. Both studies claim no age differences to be seen in the two groups. When comparing the other 10 studies, the morbidly obese group is an average of 6.7 years younger than patients in the non-obese group. In Table 1, the reported BMI and patient-age of each study are shown. All studies have a mean follow-up of at least 2 years, with a range of 0.5–17 years. Seven out of the 12 studies reported mean follow-up for both groups. When comparing these seven studies, an overall of 0.5 years in follow-up difference between the two groups is found. Dewan *et al.* (27) had the biggest follow-up difference, 2 years of difference between the two groups. The six other studies showed a range of 0–0.5 years of follow-up difference. Bordini *et al.* (32) only reported mean follow-up for all patients (3.1 years). Naziri *et al.* (22) did not give any mean follow-up independently for the two groups but reported that patients were matched within 4 months. Hakim *et al.* (25) had a follow-up period with a mean of 10.8 years (4–17 years) and reported no difference in follow-up between the two groups. All follow-up information is presented in Table 2.

Outcome

Revision rates

Two studies reported significantly higher revision rates for morbid obese, compared with non-obese (29, 33). Amin *et al.* (29) found the biggest difference between the two groups, 26% morbidly obese revisions, compared with 0% ($P = 0.01$) in non-obese. Three studies did not find significant difference (22, 27, 28). The rest of the studies did not report statistical testing of the difference between the groups. Table 2 presents all revision rates reported. All together the morbidly obese group had a mean revision rate of 6.6%, compared with 2.3% in the non-obese group. A forest plot of overall revision rates is presented in Fig. 2. The risk ratio for revision is 1.48 for the morbidly obese, compared with the non-obese (95% CI: 0.98 to 2.24; $P = 0.06$). The 95% CIs from all studies overlap which suggest low heterogeneity. The I^2 equals 2%, this likewise indicate homogeneity across all studies. Due to the high number of patients in both groups and the narrow CI, Ponnusamy *et al.* (30) weighted highest, 34.7%. Ponnusamy *et al.* (30) did not find a higher revision rate for morbidly obese patients. However, their super obese subgroup (BMI: 50+ kg/m^2) had significantly higher septic revisions than all the other subgroups with BMI less than 40 kg/m^2 ($P = 0.03$).

Six studies reported aseptic revision (22, 24, 25, 29, 30, 32), and seven studies reported septic revision (22, 24, 25, 26, 29, 30, 32). The risk ratio for aseptic revision is 1.44 for morbidly obese, compared with non-obese (95% CI: 0.64 to 3.25; $P = 0.37$), and the risk ratio for septic revision is 2.22 for morbidly obese, compared with non-obese

Table 1 Demographic information of the included studies. Showing year of publication, mean BMI in kg/m^2 in the morbidly obese and non-obese group, and mean age in years in the morbidly obese and non-obese group.

Study	Year	Mean BMI (range)		Mean age (range)	
		Morbidly obese	Non-obese	Morbidly obese	Non-obese
Amin *et al.* (29)	2006	43 (40–61)	27 (23–30)	62 (40–80)	63 (42–80)
Bordini *et al.* (32)	2009	NR (>40)	NR (<30)	NR (NR)	NR (NR)
Chen *et al.* (28)	2016	NR (>40)	NR (<25)	61 (NR)	68 (NR)
Dewan *et al.* (27)	2009	44 (>40)	25 (20–29)	58 (NR)	66 (NR)
Ersozlu *et al.* (26)	2007	42 (40–45)	27 (24–30)	60 (NR)	67 (NR)
Foran *et al.* (33)	2004	43 (40–47)	26 (18–30)	65 (32–84)	70 (42–84)
Hakim *et al.* (25)	2019	46 (40–68.2)	NR (21–29.99)	NR (NR)	NR (NR)
Krushell *et al.* (24)	2007	44 (40–53)	26 (20–29)	67 (48–81)	69 (39–82)
Mont *et al.* (31)	1996	NR (>40)	NR (<30)	61 (30-70)	58 (30-76)
Naziri *et al.* (22)	2013	54 (50–66)	28 (25–30)	60 (43–74)	59 (45–75)
Ponnusamy *et al.* (30)	2018	47 (NR)	25 (NR)	61 (NR)	70 (NR)
Spicer *et al.* (23)	2001	NR (>40)	NR (<30)	63 (41–78)	70 (35–83)

NR, not reported.

Table 2 Number of cases and mean follow-up in the morbidly obese groups (MO) and non-obese groups (NO) from all the studies. Follow-up and range are reported in years, revision rate in %. *P* value presents a revision rate difference between the two BMI groups.

Study	Year	Patients (knees)		Follow-up, years (range)		Revision, %		*P* value
		MO	NO	MO	NO	MO	NO	
Amin *et al.* (29)	2006	38 (41)	38 (41)	3.2 (0.5–5.5)	3.7 (0.5–5.6)	26	0	0.01
Bordini *et al.* (32)	2009	NR (172)	NR (6532)	NR (1.5–6)	NR (1.5–6)	2	2	NR
Chen *et al.* (28)	2016	117 (117)	2108 (2108)	NR (2-10)	NR (2-10)	2	1	0.703
Dewan *et al.* (27)	2009	31 (41)	67 (85)	4 (NR)	6 (NR)	7	5	0.816
Ersozlu *et al.* (26)	2007	21 (42)	20 (40)	2.7 (2–3.3)	2.7 (2–3.3)	0	0	NR
Foran *et al.* (33)	2004	11 (12)	68 (78)	6.6 (5–8.9)	6.9 (5–10.3)	8	0	0.02
Hakim *et al.* (25)	2019	127 (162)	37 (38)	10.1 (4–NR)	NR (4–NR)	2	3	NR
Krushell *et al.* (24)	2007	NR (39)	NR (39)	7.5 (5.2–14.1)	7.5 (5–13.2)	5	0	NR
Mont *et al.* (31)	1996	45 (50)	45 (50)	5.4 (2–12)	5.2 (2–11.3)	8	4	NR
Naziri *et al.* (22)	2013	95 (101)	95 (101)	5.2 (3–7.1)	NR	7	3	0.28
Ponnusamy *et al.* (30)	2018	195 (195)	260 (260)	NR (3–NR)	NR (3–NR)	7	7	NR
Spicer *et al.* (23)	2001	NR (59)	371 (425)	6.1 (4–12)	6.3 (4–12)	5	3	NR

NR, not reported.

(95% CI: 0.89 to 5.57; $P = 0.09$). Forest plots of aseptic and septic revisions is shown in Figs 3 and 4.

Knee Society Scores

Ten of the studies report Objective Knee Society Score (OKSS) and eight of the studies report Functional Knee Society Score (FKSS) (Table 3). The morbidly obese group and the non-obese group scored significantly higher in OKSS and FKSS at follow-up, compared with before TKA ($P < 0.001$). The morbidly obese improved from a mean of 43 (range: 0–78) to 87 (range: 32–100) in OKSS, compared with a mean of 46 (range: 0–83) to 90 (range: 45–100) in the non-obese group. In FKSS, the morbidly obese scored a mean of 40 (range: 0–85) preoperative and improved to 68 (range: 0–100) postoperative, compared with 46 (range: 0–97) to 76 (range: 20–100) in the non-obese group. The morbidly obese improved a mean of 47.3 in OKSS, compared to 47.0 in the non-obese group ($P = 0.967$). In FKSS, the morbidly obese improved a mean of 29.4, compared to 30.4 in the non-obese group ($P = 0.834$).

Complications

Out of the included studies, six reported more frequent complication rates in the morbidly obese (22, 24, 27, 28, 29, 31). In four studies, the complication rates are fairly close (25, 26, 30, 32). Two studies did not report complications (23, 33). Six studies reported overall complication rate (22, 25, 26, 27, 29, 32), and six studies reported superficial wound infection rate (22, 25, 26, 29, 30, 31). Overall complication rate was 19.5% in the morbidly obese, compared with 10.0% in the non-obese. The risk ratio for overall complications for morbidly obese, compared with non-obese was 1.56 (95% CI: 0.98 to 2.48; $P = 0.06$) (Fig. 5). When comparing superficial wound infection rates an increased rate was seen in the morbidly obese with a

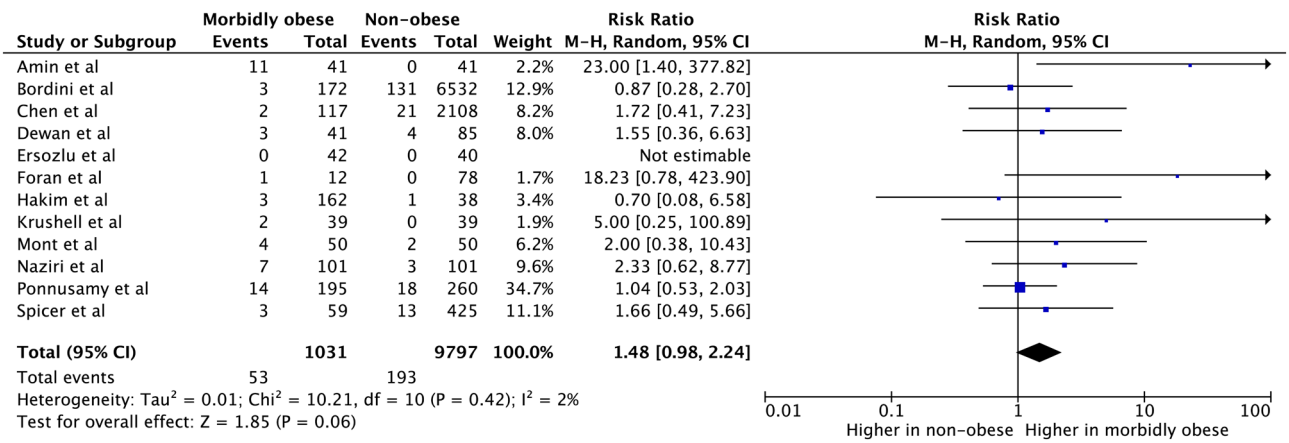

Figure 2

Forest plot of risk ratios for revision among TKA performed in morbidly obese and non-obese patients. Events refer to the number of revisions for each group, and the total indicates the number of knees operated in each group. M–H, Mantel–Haenszel; df, degrees of freedom.

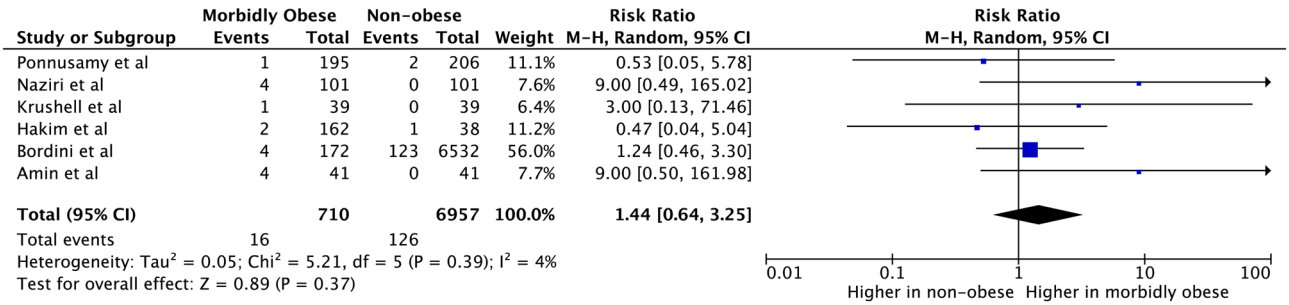

Figure 3

Forest plot of risk ratios for aseptic revision among TKA performed in morbidly obese and non-obese patients. Events refer to the number of aseptic revisions for each group, and total indicates the number of knees operated in each group. M–H, Mantel–Haenszel; df, degrees of freedom.

mean of 7.2%, compared with 1.8% in the non-obese. The risk ratio for superficial wound infection was 2.32 for morbidly obese, compared with non-obese (95% CI: 1.30 to 4.13; $P = 0.005$) (Fig. 6). The largest reported difference between the two groups was in Amin *et al.* (29), with 32% overall complications in morbidly obese, compared with 0% in the non-obese group. Conversely, Hakim *et al.* (25) found a 10.5% overall complication rate in the non-obese, compared with 9.9% in the morbidly obese. However, the non-obese group had only 38 subjects and the study did show significantly higher overall complication rate in the morbidly obese, compared to their obese subgroup (BMI: 30–40 kg/m^2). Mont *et al.* (31) reported 12% of wound healing problems for morbidly obese, compared with 2% in non-obese. However, they did not find significant difference in final outcome between the morbidly obese and the non-obese groups ($P = 0.7$). Other complications found in the included studies are presented in Table 4.

Discussion

This review did not with certainty find morbidly obese to have an increased risk ratio for revision ($P = 0.06$). We found the true risk ratio for revision in morbidly obese, compared with non-obese after TKA to be between 0.98 to 2.24, with a certainty of 95%. The largest impact on our risk ratio for revision was reported by Ponnusamy *et al.*, with a 34.7% weight. Ponnusamy *et al.* did not find any revision rate difference between the morbidly obese and non-obese groups. When calculating the risk ratio for revision excluding this study, a significant difference is found. Studies with a mean follow-up of at least 2 years were included in this review. Including studies with longer mean follow-up periods might better show a potential increased risk of revision in morbidly obese, however, few studies with longer follow-up periods exist. Only studies reporting revision rates have been included. The exclusion of studies omitting revision rates have been chosen to reduce the potential risk of reporting bias. Studies have suggested an increased risk of septic revision for morbidly obese (14, 18, 34, 35). When comparing studies with mid- to long-term follow-up, the risk ratio for septic revision is 2.22 for morbidly obese, compared with non-obese. However, a significant difference could not be found ($P = 0.09$). Nonetheless, this could indicate that morbidly obese have a higher risk ratio for septic revision than aseptic revision, 2.22 compared with 1.44 respectively. In this review,

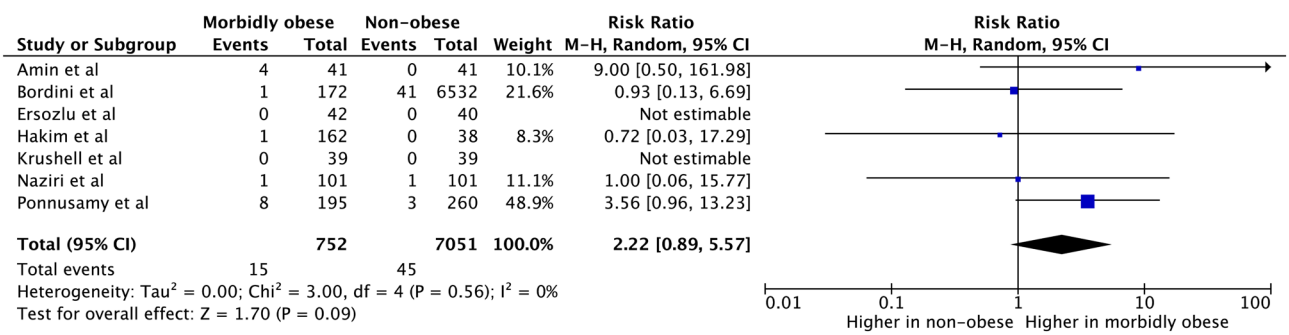

Figure 4

Forest plot of risk ratios for septic revision TKA performed in morbidly obese and non-obese patients. Events refer to the number of septic revisions for each group, and total indicates the number of knees operated in each group. M–H, Mantel–Haenszel; df, degrees of freedom.

Table 3 **Objective and Functional Knee Society Score** (OKSS and FKSS) **for morbidly obese** (MO) **and non-obese** (NO). **Pre- and post-operative scores as well as improvement values are mean.**

Study	Year	Preoperative (range)		Postoperative (range)		Improvement	
		MO	NO	MO	NO	MO	NO
Objective Knee Society Score							
Amin *et al.* (29)	2006	28 (0–57)	30 (0–56)	86 (32–97)	91 (45–100)	58	61
Chen *et al.* (28)	2016	33 (NR)	40 (NR)	83 (NR)	85 (NR)	50	45
Dewan *et al.* (27)	2009	53 (NR)	55 (NR)	85 (NR)	89 (NR)	32	34
Ersozlu *et al.* (26)	2007	61 (42–76)	70 (61–83)	87 (57–94)	91 (64–97)	26	21
Hakim *et al.* (25)	2019	46 (NR)	43 (NR)	84 (NR)	86 (NR)	38	42
Krushell *et al.* (24)	2007	30 (14–65)	34 (13–70)	91 (50–100)	94 (50–100)	61	60
Mont *et al.* (31)	1996	42 (30–52)	NR (NR)	88 (50–100)	91 (NR)	46	NR
Naziri *et al.* (22)	2013	53 (23–78)	50 (35–69)	91 (58–100)	94 (66–100)	42	44
Ponnusamy *et al.* (30)	2018	NR (NR)	NR (NR)	NR (NR)	NR (NR)	79	73
Spicer *et al.* (23)	2001	45 (NR)	48 (NR)	86 (NR)	91 (NR)	41	43
Functional Knee Society Score							
Amin *et al.* (29)	2006	51 (0–75)	52 (10–80)	76 (30–100)	83 (35–100)	25	31
Chen *et al.* (28)	2016	39 (NR)	53 (NR)	58 (NR)	74 (NR)	20	21
Dewan *et al.* (27)	2009	42 (NR)	46 (NR)	68 (NR)	66 (NR)	26	20
Ersozlu *et al.* (26)	2007	46 (39–74)	56 (64–97)	80 (55–83)	86 (60–100)	46	30
Hakim *et al.* (25)	2019	37 (NR)	39 (NR)	72 (NR)	80 (NR)	35	41
Krushell *et al.* (24)	2007	31 (0–50)	38 (0–80)	44 (0–90)	64 (20–100)	13	26
Naziri *et al.* (22)	2013	52 (0–85)	54 (35–70)	82 (30–100)	90 (64–100)	30	36
Spicer *et al.* (23)	2001	20 (NR)	30 (NR)	60 (NR)	68 (NR)	40	38

NR, not reported.

increased revision rate in morbidly obese cannot fully be confirmed. Increased aseptic loosening in morbidly obese has been attributed to higher degrees of mechanical stress (29, 36). Most morbidly obese have lower activity levels, and the overall mechanical stress might not be as big as earlier anticipated (37). Some studies have suggested the use of short-stemmed tibial components to help mitigate the risk of aseptic loosening (38, 39). Garceau *et al.* investigated this further and found significantly less tibial loosening when using short-stemmed tibial components in morbidly obese (40). They suggest that stemmed tibia may be considered in high-risk patients. In this study we did not find an increased risk of aseptic loosening in the morbidly obese using standard primary tibia components.

This review showed lower pre- and postoperative OKSS and FKSS in morbidly obese, compared with non-obese. However, the mean improvement was equivalent between the two groups. The objective and functional outcome such as pain relief, range of motion (ROM), knee alignment, knee stability, walking distance, and stair climbing vastly improve for the morbidly obese as well as for the non-obese. All patients regardless of BMI have great gain in functional outcome after TKA.

Ten out of 12 included studies reported mean age in their weight groups. All together the morbidly obese were a mean of 6.7 years younger than the non-obese. This indicates that morbidly obese are likely to develop severe arthrosis of the knee at an earlier age than non-obese, confirming the results of earlier studies (4, 5, 6, 7).

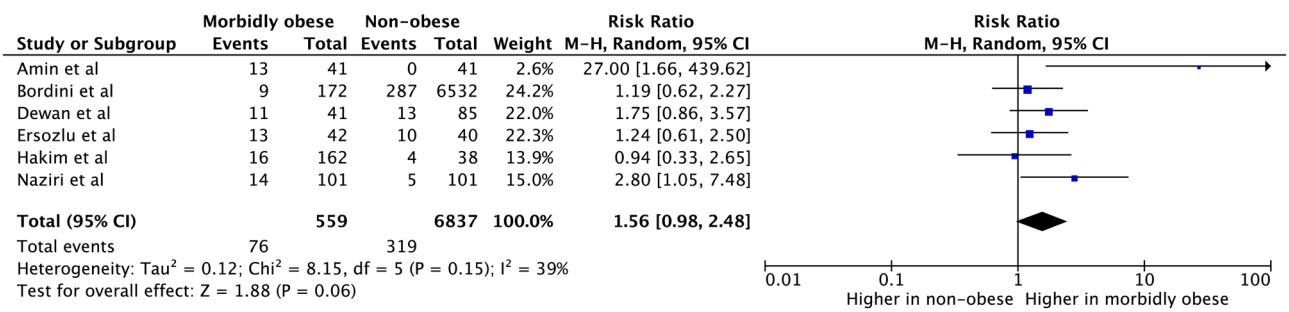

Figure 5

Forest plot of risk ratio for overall complications in morbidly obese compared with non-obese patients. Events refer to the number of complications in each group, and total indicates the number of knees operated in each group. M–H, Mantel–Haenszel; df, degrees of freedom.

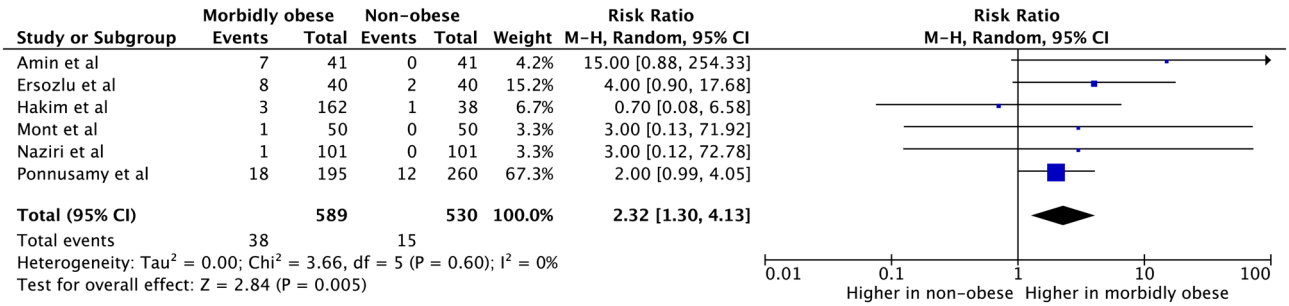

Figure 6

Forest plot of risk ratio for superficial wound infection in morbidly obese compared with non-obese patients. Events refer to the number of superficial wound infections in each group, and total indicates the number of knees operated in each group. M–H, Mantel–Haenszel; df, degrees of freedom.

Moreover, the age difference between the groups with almost 7 years younger average age in the morbidly obese group, means that this group is inherently more likely to fail earlier as young age itself is also an independent risk factor for early revision (41). If the morbidly obese and the non-obese groups had been stratified for age, more complications might have been found in the morbidly obese group.

A statistical analysis included all studies has not been possible because of the several different complications, which have been reported. However, most studies reported increased complication rates in morbidly obese. Six studies reported overall complications and the morbidly obese had a risk ratio of 1.56 for overall complications, compared with the non-obese (95% CI: 0.98 to 2.48; $P = 0.06$). Noticeably Amin *et al.* found an overall complication

Table 4 Complications found in all studies.

Study	Year	Morbidly obese	Non-obese
Amin *et al.* (29)	2006	Overall complication rate: 32% Superficial wound infection: 17% Radiographic loosening: 4.9%	Overall complication rate: 0% Superficial wound infection: 0% Radiographic loosening: 0%
Bordini *et al.* (32)	2009	Overall complication rate: 5.2% Thromboembolic events: 0%	Overall complication rate: 4.4% Thromboembolic events: 0.3%
Chen *et al.* (28)	2016	30-day readmission: 6%	30-day readmission: 3%
Dewan *et al.* (27)	2009	Overall complication rate: 26% Infection 7%	Overall complication rate: 15% Infection 4%
Ersozlu *et al.* (26)	2007	Overall complication rate: 30% Superficial wound infection: 19%	Overall complication rate: 25% Superficial wound infection: 5%
Foran *et al.* (33)	2004	NR	NR
Hakim *et al.* (25)	2019	Overall complication rate: 9.9% Superficial wound infection: 2% Late deep infection: 0.6% Skin necrosis: 0.6% Transient peronal palsy: 0.6% Tromboembolic event: 1.9% Patellar clunk syndrome: 1.2%	Overall complication rate: 10.5% Superficial wound infection: 3% Late deep infection: 0% Skin necrosis: 0% Transient peronal palsy: 0.6% Tromboembolic event: 2.6% Patellar clunk syndrome: 2.6%
Krushell *et al.* (24)	2007	Wound healing problems 20.5% Osteolysis or wear: 2.6% Deep vein thrombosis: 2.6%	Wound healing problems 0% Osteolysis or wear: 0% Deep vein thrombosis: 2.6%
Mont *et al.* (31)	1996	Superficial wound infection: 2% Wound healing problems 12% *Chronic knee pain: 8%	Superficial wound infection: 0% Wound healing problems 2%
Naziri *et al.* (22)	2013	Overall complication rate: 14% Superficial wound infection: 1% Wound healing problems 1%	Overall complication rate: 5% Superficial wound infection: 0% Wound healing problems 0%
Ponnusamy *et al.* (30)	2018	Thromboembolic events: 0.5% Superficial wound infection: 9.2% 90 days readmission: 8.7%	Thromboembolic events: 1.9% Superficial wound infection: 4.6% 90 days readmission: 6.2%
Spicer *et al.* (23)	2001	NR	NR

*4% had chronic pain prior to TKA.
NR, not reported.

rate of 32% in the morbidly obese, compared with 0% in the non-obese (29). Comparing the six studies reporting superficial wound infection, a significantly increased risk ratio of 2.32 for morbidly obese, compared with non-obese was found (95% CI, 1.30 to 4.13; $P = 0.005$). Hakim *et al.* found significantly longer surgical incision length in morbidly obese patients, and suggest that this might be a co-factor for superficial infection (25). Other studies with a focus on perioperative and short-term complications in morbidly obese have likewise found a significant superficial infection rate (14, 24, 35, 42, 43), and also found an increased deep infection rate (14, 42). Prolonged operative times during TKA have been found to correlate with an increased infection rate (44, 45, 46). Operation time in obese is prolonged which partly could explain the increased infection rate. Another explanation could be a weakened immune response in obese. Krishnan *et al.* found significantly less macrophages matured from monocytes in obese individuals (47). In general, obese individuals have more comorbidities such as diabetes, which has shown significantly higher infection rates after arthroplasty (16).

It has been suggested that morbidly obese should optimize their condition prior to TKA (48, 49). However, studies investigating preoperative bariatric surgery have shown mixed results, and some studies have even reported the same or worse outcome (50, 51). A possible explanation for worse outcome in bariatric patients is concomitant malnutrition in this population (52). Patients may remain in catabolic state for 2 years after gastric bypass (53). Martin *et al.* investigated this in their review, and would neither encourage nor discourage preoperative bariatric surgery (54). Nelson *et al.* suggest that morbid obesity is not independently correlated with perioperative complications, and found a strong confound between low serum albumin levels and perioperative complications (55).

Conclusions

This review has found that morbidly obese have a 1.48 risk ratio for revision, compared with non-obese patients after TKA (95% CI: 0.98 to 2.24; $P = 0.06$). This could indicate that morbidly obese are more likely to need revision after TKA; however, the correlation between morbid obesity and revision rate may not be as high as earlier studies have concluded. A statistically significant risk of septic revision for morbidly obese, compared with non-obese, could not be found ($P = 0.09$). However, the risk ratio for septic revision in morbidly obese is 2.22, compared with a 1.44 risk ratio for aseptic revision. To better investigate the long-term revision rate, more studies with long-term follow-ups are needed. Morbidly obese patients in average scored lower OKSS and FKSS both prior and after TKA. However, they improve just as much in OKSS and FKSS as non-obese patients after TKA. The morbidly obese had increased risk of superficial wound infection with a risk ratio of 2.32 (95% CI: 1.30 to 4.13; $P = 0.005$) and a 1.56 risk ratio for overall complications (95% CI: 0.98 to 2.48; $P = 0.06$), compared with non-obese patients. We consider the gained benefit for the morbidly obese in functional outcome to surpass the risk in TKA. However, the morbidly obese patient should be encouraged to lose weight before TKA as well as after TKA.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the work reported.

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