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KNEE ARTHROPLASTY

The outcomes of total knee arthroplasty in morbidly obese patients: a systematic review of the literature

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Abstract

Introduction The increasing prevalence of obesity has led to an increase in total knee arthroplasties (TKAs) being undertaken in patients with a higher body mass index (BMI). TKA in morbidly obese patients can be technically challenging due to numerous anatomical factors and patient co-morbidities. The long-term outcomes in this patient group are unclear. This systematic review aims to compare the long-term revision rates, functional outcomes and complication rates of TKAs in morbidly obese versus non-obese patients.

Methods A search of PubMed, EMBASE and PubMed Central was conducted to identify studies that reported revision rates in a cohort of morbidly obese patients (BMI $\geq$ 40 kg/m^2) that underwent primary TKA, compared to non-obese patients (BMI $\leq$ 30 kg/m^2). Secondary outcomes included Knee Society Objective Scores (KSOS), Knee Society Functional Scores (KSFS), and complication rates between the two groups. The difference in revision rates was assessed using the Chi-squared test. The Wilcoxon signed-rank test was used to compare pre-operative and post-operative functional scores for each group. KSOS and KSFS for morbidly obese and non-obese patients were compared using the Mann–Whitney test. Statistical significance was defined as $p \leq 0.05$.

Results Nine studies were included in this review. There were 624 TKAs in morbidly obese patients and 9,449 TKAs in non-obese patients, average BMI values were 45.0 kg/m^2 (range 40–66 kg/m^2) and 26.5 kg/m^2 (range 11–30 kg/m^2) respectively. The average follow-up time was 4.8 years (range 0.5–14.1) and 5.2 years (range 0.5–13.2) respectively, with a revision rate of 7% and 2% ($p < 0.001$) respectively. All functional scores improved after TKA ($p < 0.001$). Pre- and post-operative KSOS and KSFS were poorer in morbidly obese patients, however, mean improvement in KSOS was the same in both groups and comparable between groups for KSFS ($p = 0.78$). Overall complication rates, including infection, were higher in morbidly obese patients.

Conclusions This review suggests an increased mid to long-term revision rate following primary TKA in morbidly obese patients, however, these patients have a functional recovery which is comparable to non-obese individuals. There is also an increased risk of perioperative complications, such as superficial wound infection. Morbidly obese patients should be fully informed of these issues prior to undergoing primary TKA.

Keywords Total knee arthroplasty · TKA · Total knee replacement · TKR · Morbid obesity · Obesity · Non-obese · Revision rate · Knee Society Objective scores · KSOS · Knee Society Functional scores · KSFS · Complications · Complication rates · Infection · Infection rates · Prosthetic infection · Superficial wound infection · Wound healing problems · Wound healing delay · Quality of life · Functional outcome

Introduction

Total knee arthroplasty (TKA) is one of the most commonly performed orthopaedic procedures in the UK with 108,713 TKAs carried out in 2016 [1]. This number is expected to rise to 118,666 by 2035 [2]. The prevalence of obesity is also increasing, with UK trends predicting a rise from 26%

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in 2008 to 41–48% in men and 35–43% in women by 2035 [3]. As obesity is a risk factor for osteoarthritis (OA), especially in the knee [4], the increase in prevalence has led to an increased number of TKAs being performed on obese patients [5]. In the UK, obese patients comprised 56% of primary TKAs in the 2016 [1]. Whilst the exact mechanism is not known, excessive joint loading in obese patients is thought to alter gait and movement strategies, resulting in joint malalignment and cartilage degeneration [6]. In addition, obesity-related dyslipidaemia has been shown to induce joint damage through the actions of pro-inflammatory adipokines and cytokines [7].

The long-term outcome of TKA in obese patients remains a debated issue. Whilst some studies have shown favourable results [8, 9], others have not [10, 11]. Studies attempting to compare the outcome of primary TKA in obese versus non-obese patients have also shown mixed results [10, 12–16]. Some studies reported increased revision rates, lower functional scores and increased complication rates, including infection [10, 12, 15], whilst others failed to demonstrate any significant difference [13, 14, 16]. This lack of evidence has influenced recent policy-making within the National Health Service (NHS) in the United Kingdom, with some Clinical Commissioning Groups (CCGs) imposing restrictions on offering TKA to obese patients [17].

This systematic review aims to compare the long-term outcomes of TKA in morbidly obese versus non-obese patients. The primary outcome measure was the revision rate and secondary measures included the functional outcome and incidence of complications.

Method

Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed [18]. An electronic database search of PubMed, EMBASE and PubMed Central was conducted, to search for studies reporting revision rates of TKAs in morbidly obese patients. The following search string was used: "(total knee replacement OR total knee arthroplasty) AND morbid obesity". This search returned relevant studies published between the time of inception of the databases to June 2017.

Eligibility criteria

The inclusion criterion was agreed upon by authors LB, AP and SH prior to the identification phase. Studies were included that reported revision rate in morbidly obese patients (BMI > 40 kg/m^2) who had undergone primary TKA versus a non-obese group. Studies with a mean follow-up period of less than 2 years and those not published in English were excluded. Studies that did not directly report revision rates were included if they provided sufficient data from which revision rate could be calculated.

Data extraction

Screening was performed in three phases to identify relevant titles, abstracts and full texts. Two reviewers (LB, AP) extracted the data through a standardized data collection form. Three reviewers (LB, AP, SH) checked the data for accuracy and any inconsistent results were handled by discussion. The following data: number of patients, number of knees, revision rates, overall complication rates, rates of superficial wound infection, prosthetic joint infection and wound healing problems, mean pre- and postoperative Knee Society scores (KSS) and the mean and range for BMI, age and follow-up were extracted.

Statistical analysis

Non-parametric tests were used for statistical analyses. The significance of the difference between revision rates in the morbidly obese and non-obese groups was calculated using the Chi-squared test. The Wilcoxon signed-rank test was used to compare pre-operative and post-operative functional scores for each group separately. The Mann–Whitney test was used to compare pre-operative morbidly obese and non-obese functional scores and post-operative morbidly obese and non-obese functional scores. Statistical significance was defined as $p \leq 0.05$.

Results

Search results

The PRISMA flowchart for study selection is shown in Fig. 1. The initial PubMed search returned 110 abstracts which were screened for eligibility. After removal of duplicates, and studies that did not fit our eligibility criteria, nine studies were included for review [15, 19–26].

Cohort characteristics

Patient demographics for each study are summarised in Table 1. The total reported number of knees in the morbidly obese and non-obese groups across all studies was 624 and 9449, respectively. The mean BMI for morbidly obese patients was 45.0 kg/m^2 (range 40–66 kg/m^2) and 26.5 kg/m^2 (range 11–30 kg/m^2) for non-obese patients. The average morbidly obese patient underwent their TKA at a younger age (62.9 years) than the average non-obese

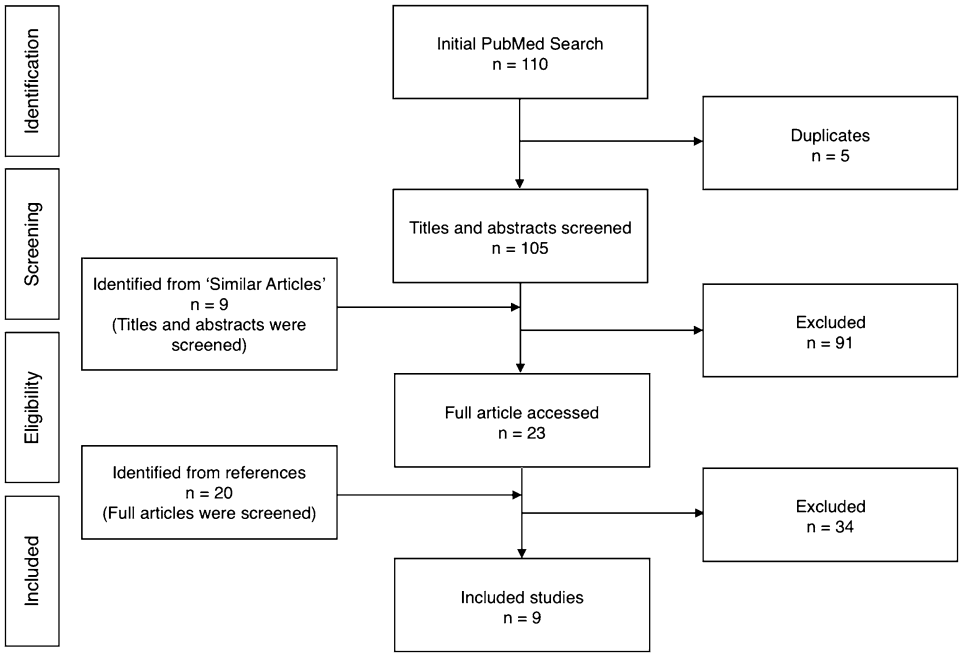

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart for showing the identification of the included studies

Table 1 Mean BMI (and range) and mean age (and range) for morbidly obese (MO) and non-obese (NO) patients in each study

Study	Year	Mean BMI, kg/m^2 (range)		Mean age, years (range)	
		MO	NO	MO	NO
Spicer et al. [24]	2001	NR (> 40)	NR (< 30)	63 (41–78)	70 (35–83)
Foran et al. [21]	2004	43 (40–47)	26 (18–30)	65 (32–84)	70 (42–84)
Amin et al. [14]	2006	43 (40–61)	27 (23–30)	62 (40–80)	63 (42–80)
Ersozlu et al. [20]	2007	42 (40–45)	27 (24–30)	60 (NR)	67 (NR)
Krushell et al. [22]	2007	44 (40–53)	26 (20–29)	67 (48–81)	69 (39–82)
Bordini et al. [18]	2009	NR (> 40)	NR (< 30)	72 (71.8–72.1)	72 (71.8–72.1)
Dewan et al. [25]	2009	44 (> 40)	25 (20–29)	58 (NR)	66 (NR)
Naziri et al. [23]	2013	54 (50–66)	28 (25–30)	60 (43–74)	59 (45–75)
Chen et al. [19]	2016	NR (> 40)	NR (< 30)	61 (NR)	68 (NR)

NR not reported

patient (66.2 years). Bordini et al. only provided a mean age for all patients (72 years) [19]. The most common indication for surgery was osteoarthritis. The average follow-up time was 4.8 years (range 0.5–14.1 years) in the morbidly obese and 5.2 years (range 0.5–13.2 years) in non-obese patients (Table 2). Naziri et al. did not report mean follow-up time in the control group but stated that the follow-up times were matched with the morbidly obese patients within four months [24]. Bordini et al. only provided a mean follow-up time for all patients (3.1 years) [19].

Outcome analysis

Revision rate

The mean revision rates were 7% in the morbidly obese and 2% in non-obese patients ($p < 0.001$) (Table 2). Two studies reported revision rates directly [21, 26], while in eight studies [15, 19, 20, 22–24] the rates were calculated as the percentage of knees that underwent revision during follow-up.

Functional scores

Knee Society Objective Scores (KSOS) are shown in Table 3 and Knee Society Function scores (KSFS) in Table 4. Seven studies reported KSOS and KSFS [15, 20, 21, 23–26]. All functional scores showed a significant

Table 2 Number of patients, number of knees, mean follow-up time (and range) and revision rate for morbidly obese (MO) and non-obese (NO) patients in each study

Study	Year	Patients (knees)		Mean follow-up, years (range)		Revision rate, %		*p* value
		MO	NO	MO	NO	MO	NO	
Spicer et al. [24]	2001	NR (59)	371 (425)	6.1 (4–12)	6.3 (4–12)	5	3	NR
Foran et al. [21]	2004	11 (12)	68 (78)	6.6 (5–8.9)	6.9 (5–10.3)	8	0	0.02
Amin et al. [14]	2006	38 (41)	38 (41)	3.2 (0.5–5.5)	3.7 (0.5–5.6)	26	0	0.01
Ersozlu et al. [20]	2007	21 (42)	20 (40)	2.7 (2–3.3)	2.7 (2–3.3)	0	0	NR
Krushell et al. [22]	2007	NR (39)	NR (39)	7.5 (5.2–14.1)	7.5 (5–13.2)	5	0	NR
Bordini et al. [18]	2009	NR (172)	NR (6532)	3.1 (1.5–6)	3.1 (1.5–6)	2	2	NR
Dewan et al. [25]	2009	31 (41)	67 (85)	4 (NR)	6 (NR)	7	5	0.816
Naziri et al. [23]	2013	95 (101)	95 (101)	5.2 (3–7.1)	NR	7	3	0.28
Chen et al. [19]	2016	117 (117)	2108 (2108)	NR (2–10)	NR (2–10)	2	1	0.703

NR not reported

Table 3 Mean pre- and postoperative Knee Society Objective scores (KSOS) and improvement in KSOS for morbidly obese (MO) and non-obese (NO) patients in each study

Study	Year	Mean preoperative KSOS (range)		*p* value	Mean postoperative KSOS (range)		*p* value	Mean improvement in KSOS		*p* value
		MO	NO		MO			MO	NO	
Spicer et al. [24]	2001	45 (NR)	48 (NR)	NR	86 (NR)	91 (NR)	NR	41	43	NR
Amin et al. [14]	2006	28 (0–57)	30 (0–56)	0.5	86 (32–97)	91 (45–100)	0.08	58	61	NR
Ersozlu et al. [20]	2007	61 (42–76)	70 (61–83)	NR	87 (57–94)	91 (64–97)	NR	26	21	NR
Krushell et al. [22]	2007	30 (14–65)	34 (13–70)	NR	91 (50–100)	94 (50–100)	NR	61	60	NR
Dewan et al. [25]	2009	53 (NR)	55 (NR)	0.737	85 (NR)	89 (NR)	0.244	32	34	NR
Naziri et al. [23]	2013	53 (23–78)	50 (35–69)	0.0899	91 (58–100)	94 (66–100)	0.1161	42	44	NR
Chen et al. [19]	2016	33 (30–36)	40 (39–40)	< 0.001	83 (81–85)	85 (84–85)	0.013	50	45	0.003

NR not reported

Table 4 Mean pre- and postoperative Knee Society Function scores (KSFS) and improvement in KSFS for morbidly obese (MO) and non-obese (NO) patients in each study

Study	Year	Mean preoperative KSFS (range)		*p* value	Mean postoperative KSFS (range)		*p* value	Mean improvement in KSFS		*p* value
		MO	NO		MO			MO	NO	
Spicer et al. [24]	2001	20 (NR)	30 (NR)	0.003	60 (NR)	68 (NR)	NR	40	38	NR
Amin et al. [14]	2006	51 (0–75)	52 (10–80)	0.5	76 (30–100)	83 (35–100)	0.01	25	31	NR
Ersozlu et al. [20]	2007	46 (39–74)	56 (64–97)	NR	80 (55–83)	86 (60–100)	NR	46	30	NR
Krushell et al. [22]	2007	31 (0–50)	38 (0–80)	NR	44 (0–90)	64 (20–100)	< 0.005	13	26	NR
Dewan et al. [25]	2009	42 (NR)	46 (NR)	0.119	68 (NR)	66 (NR)	0.313	26	20	NR
Naziri et al. [23]	2013	52 (0–85)	54 (35–70)	0.1589	82 (30–100)	90 (64–100)	0.004	30	36	NR
Chen et al. [19]	2016	39 (36–42)	53 (52–54)	< 0.001	58 (55–62)	74 (73–75)	< 0.001	19	21	0.736

NR not reported

improvement after TKA ($p < 0.001$). Mean preoperative KSOS were 43 (range 0–78) and 47 (range 0–83) ($p = 0.65$) and mean postoperative KSOS were 87 (range 32–100) and 91 (range 45–100) ($p = 0.04$) in morbidly and non-obese patients, respectively. Mean improvement in KSOS was 44 in both morbidly and non-obese groups. Mean preoperative KSFS were 40 (range 0–85) and 47 (range 0–97) ($p = 0.20$), mean postoperative KSFS were 67 (range 0–100) and 76 (range 20–100) ($p = 0.20$) and

mean improvement in scores were 27 and 29 ($p = 0.78$) in morbidly and non-obese patients, respectively.

Complication rates

Morbidly obese patients had higher overall complication rates, and higher rates of superficial wound infection, prosthetic joint infection, wound healing problems or delay compared to non-obese patients in all studies (Table 5). Four studies reported overall complication rates [15, 21, 24, 26], four studies reported superficial wound infections [15, 19, 21, 24], two studies reported prosthetic joint infections [15, 21], two studies reported wound healing problems or delay [23, 24]. Dewan et al. only reported infection rates [26]. Morbidly obese patients also had higher rates of aseptic and radiographic loosening, and osteolysis or wear (Table 5). Three studies reported aseptic loosening [15, 23, 24], two studies reported radiographic loosening [15, 21], one study reported osteolysis or wear [23].

Discussion

This review has shown that morbidly obese TKA patient have significantly higher revision rates ($p < 0.001$) and greater complication rates, including higher rates of infection and wound healing problems, compared with their non-obese counterparts. However, morbidly obese and non-obese patients experience similar improvements in KSOS and KSFS after TKA. All patients undergoing TKA benefit to the same extent from improvements in knee-related function and quality of life, regardless of BMI.

Global obesity trends predict 20% of the world adult population could be obese by 2030, equating to 1.12 billion individuals. In high-income OECD countries, including the UK, US, France and Germany, 37% of adults are expected to be obese by 2030 [27]. Obesity is a risk factor for osteoarthritis and contributes to the demand for TKA in these patients. These projections indicate that an increasing number of morbidly obese patients will warrant TKA in the future.

Morbid obesity has been widely reported to increase the risk of perioperative complications during TKA, including superficial wound infections and prosthetic joint infections [12, 28, 29]. Whilst the exact mechanism is unclear, this may be partly explained by a weakened immune response in obese patients. The number of monocytes that mature to macrophages was found to be significantly less in obese patients [30]. Impaired release of lymphocyte migration-inhibiting factor has also been found in insulin-resistant, non-ketotic diabetic and non-hyperglycaemic obese patients [31]. Furthermore, obesity is strongly associated with reduced subcutaneous tissue oxygenation, which is in turn linked to higher rates of infection [32]. Our review finds a higher incidence of complications in morbidly obese patients. Amin et al. found the greatest difference in complication rate [15]. No complications were reported in their control group, while 32% of morbidly obese knees

Table 5 Complication rates for morbidly obese (MO) and non-obese (NO) patients in each study

Study	Year	Complication rates	
		MO	NO
Amin et al. [14]	2006	Overall complication rate: 32%	Overall complication rate: 0%
		Superficial wound infections: 17%	Superficial wound infections: 0%
		Prosthetic joint infections: 10%	Prosthetic joint infections: 0%
		Radiographic loosening: 4.9%	Radiographic loosening: 0%
		Aseptic loosening: 9.8%	Aseptic loosening: 0%
Ersozlu et al. [20]	2007	Overall complication rate: 30%	Overall complication rate: 25%
		Superficial wound infections: 19%	Superficial wound infections: 5%
		Prosthetic joint infections: 0%	Prosthetic joint infections: 0%
		Radiographic loosening: 0%	Radiographic loosening: 0%
Krushell et al. [22]	2007	Wound-healing problems: 20.5%	Wound-healing problems: 0%
		Aseptic loosening: 2.6%	Aseptic loosening: 0%
		Osteolysis or wear: 2.6%	Osteolysis or wear: 0%
Bordini et al. [18]	2009	Superficial wound infections: 0%	Superficial wound infections: 0%
Dewan et al. [25]	2009	Overall complication rate: 26%	Overall complication: 15%
		Infection: 7%	Infection: 4%
Naziri et al. [23]	2013	Overall complication rate: 14%	Overall complication rate: 5%
		Superficial wound infection: 1%	Aseptic loosening: 0%
		Delayed wound healing: 1%	
		Aseptic loosening: 4%	

experienced complications; 17% were superficial wound infections, and 5% were prosthetic joint infections [15]. This may in part be due to surgery in morbidly obese patients being more technically demanding, resulting in longer operative time which increases the risk of postoperative infections [33, 34].

The association between BMI and the long-term outcome of TKA is unclear. Studies have shown increased revision rates and lower functional scores in obese patients [35–37] whilst other studies have reported similar outcomes regardless of BMI [9, 38, 39]. Gaillard et al. found that obesity did not affect mid-term implant survival, though their results indicated poorer functional outcomes and a risk of postoperative complications in obese patients [40]. This review suggests that revision rates are greater in morbidly obese patients. Amin et al. reported the greatest difference in revision rates between morbidly obese and non-obese patients, where survivorship rates were 26% and 0%, respectively [15]. A common assumption is that overloading of the knee occurs in patients with high BMI, resulting in greater impact loading across the tibial component, therefore, increased component loosening and poorer implant survival [15, 24, 41]. In spite of this, it has been suggested that a more sedentary lifestyle in morbidly obese patients counterbalances the increased rate of prosthesis wear, which may explain the small difference in revision rate reported in the review [15, 42]. Patient-specific guide technology has also been shown to reliably correct mechanical alignment in obese patients without adversely affecting outcomes [43].

Mean pre- and postoperative overall KSOS and KSFS were consistently lower in morbidly obese patients, though, and perhaps more importantly, the mean score improvements were comparable between the two groups. Chen et al. studied the largest number of patients, 117 morbidly obese and 2108 non-obese patients, and found comparable KSFS between the two groups as well as superior improvements in KSOS [20]. The authors of this study suggest sample sizes in other studies are too small to detect true differences in functional scores. Krushell et al. reported the poorest mean improvement in KSFS of 13 in the morbidly obese group versus 26 in the non-obese group [23]. Though this improvement may seem insignificant numerically, it is approximately equivalent to being housebound preoperatively, and able to walk 400 metres postoperatively [44]. These findings suggest TKA offers substantial benefits to morbidly obese patients in terms of pain relief, knee stability, range of movement, walking distance and climbing stairs.

Limitations to this review include the large range in BMI within both study groups and the small sample sizes. Follow-up times ranged from 0.5 to 14.1 years, therefore, making it difficult to compare short, medium and long-term implant survivorship. Other confounding variables included comorbidities, prosthesis type, population heterogeneity, activity level, laterality and surgical technique. Individual ages were not reported in the included studies, therefore, statistical significance could not be calculated. Six studies were retrospective, and therefore, susceptible to selection bias [19–21, 23, 24, 35]. Our statistical analyses were limited to non-parametric methods, because a normal distribution could not be assumed from the reported data. More randomised controlled trials and prospective cohort studies are required to assess long-term outcomes in morbidly obese patients.

Conclusion

This review indicates that revision rate of TKA in morbidly obese individuals is increased compared with non-obese patients [7% vs. 2% ($p < 0.001$)]. There is also an increased risk of perioperative complications, mainly superficial wound infections. Nevertheless, all patients regardless of BMI experience comparable improvements in knee function. In conclusion, obese patients should be counselled regarding the increased risk of failure and inferior functional outcome, and should be encouraged to lose weight prior to undergoing TKA. These patients, however, should not be refused TKA based on their BMI value alone, as the procedure is likely to offer them a significant improvement in functional outcome and quality of life.

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Compliance with ethical standards

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

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Green M, Howard P, Porter M, Wilkinson M, Wishart N, Porteus M et al. (2017) NJR 14th Annual Report. Natl Jt Regist 14th Annu Rep.

2. Culliford D, Maskell J, Judge A, Cooper C, Prieto-Alhambra D, Arden NK (2015) Future projections of total hip and knee arthroplasty in the UK: results from the UK Clinical Practice Research Datalink. Osteoarthr Cartil 23(4):594–600
3. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M (2011) Health and economic burden of the projected obesity trends in the USA and the UK. Lancet 378(9793):815–825
4. Singer SP, Dammerer D, Krismer M, Liebensteiner MC (2018) Maximum lifetime body mass index is the appropriate predictor of knee and hip osteoarthritis. Arch Orthop Trauma Surg 138(1):99–103
5. Powell A, Teichtahl AJ, Wluka AE, Cicuttini FM. Obesity (2005) A preventable risk factor for large joint osteoarthritis which may act through biomechanical factors. Br J Sports Med 39:4–5
6. Runhaar J, Koes BW, Clockaerts S, Bierma-Zeinstra SMA (2011) A systematic review on changed biomechanics of lower extremities in obese individuals: a possible role in development of osteoarthritis. Obes Rev 12(12):1071–1082
7. Thijssen E, Van Caam A, Van Der Kraan PM (2014) Obesity and osteoarthritis, more than just wear and tear: pivotal roles for inflamed adipose tissue and dyslipidaemia in obesity-induced osteoarthritis. Rheumatology (United Kingdom) 54:588–600
8. Cushnaghan J, Bennett J, Reading I, Croft P, Byng P, Cox K et al (2009) Long-term outcome following total knee arthroplasty: a controlled longitudinal study. Ann Rheum Dis 68(5):642–647
9. Hamoui N, Kantor S, Vince K, Crookes PF (2006) Long-term outcome of total knee replacement: does obesity matter? Obes Surg 16(1):35–38
10. Järvenpää J, Kettunen J, Kröger H, Miettinen H (2010) Obesity may impair the early outcome of total knee arthroplasty. A prospective study of 100 patients. Scand J Surg 99:45–49
11. Núñez M, Lozano L, Núñez E, Segur JM, Sastre S, Maculé F et al (2009) Total knee replacement and health-related quality of life: factors influencing long-term outcomes. Arthritis Rheum 61(8):1062–1069
12. Malinzak RA, Ritter MA, Berend ME, Meding JB, Olberding EM, Davis KE (2009) Morbidly obese, diabetic, younger, and unilateral joint arthroplasty patients have elevated total joint arthroplasty infection rates. J Arthroplasty 24(6 suppl):84–88
13. Deshmukh RG, Hayes JH, Pinder IM (2002) Does body weight influence outcome after total knee arthroplasty? A 1-year analysis. J Arthroplasty 17(3):315–319
14. Baker P, Petheram T, Jameson S, Reed M, Gregg P, Deehan D (2012) The association between body mass index and the outcomes of total knee arthroplasty. J Bone Jt Surg Am 94(16):1501–1508
15. Amin AK, Clayton RAE, Patton JT, Gaston M, Cook RE, Brenkel IJ (2006) Total knee replacement in morbidly obese patients. Results of a prospective, matched study. J Bone Jt Surg [Br] 8888(10):1321–1326
16. Suleiman L, Ortega G, Ong'uti SK, Gonzalez DO, Tran DD, Onyike A et al (2012) Does BMI affect perioperative complications following total knee and hip arthroplasty? J Surg Res 174(1):7–11
17. Royal College of Surgeons of England (2016) Smokers and overweight patients: soft targets for NHSsavings? Royal College of Surgeons of England Website. https://www.rcseng.ac.uk/library-and-publications/rcs-publications/docs/smokers-soft-targets/. Accessed 13 Feb 2019
18. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 339:b2535–b2535
19. Bordini B, Stea S, Cremonini S, Viceconti M, De Palma R, Toni A (2009) Relationship between obesity and early failure of total knee prostheses. BMC Musculoskelet Disord 10(1):29
20. Chen JY, Lo NN, Chong HC, Bin Abd Razak HR, Pang HN, Tay DK et al (2016) The influence of body mass index on functional outcome and quality of life after total knee arthroplasty. Bone Jt J 98–B(6):780–785
21. Ersozlu S, Akkaya T, Ozgur AF, Sahin O, Senturk I, Tandogan R (2008) Bilateral staged total knee arthroplasty in obese patients. Arch Orthop Trauma Surg 128(2):143–148
22. Foran JRH, Mont M, Etienne G, Jones LC, Hungerford DS (2004) The outcome of total knee arthroplasty in obese patients. J Bone Jt Surg Am 86–A(8):1609–1615
23. Krushell RJ, Fingeroth RJ (2007) Primary total knee arthroplasty in morbidly obese patients: a 5- to 14-year follow-up study. J Arthroplast 22(6):77–80
24. Naziri Q, Issa K, Malkani AL, Bonutti PM, Harwin SF, Mont MA (2013) Bariatric orthopaedics: total knee arthroplasty in super-obese patients (BMI> 50 kg/m^2). Survivorship and complications. Clin Orthop Relat Res 471(11):3523–3530
25. Spicer DD, Pomeroy DL, Badenhausen WE, Schaper LA, Curry JI, Suthers KE et al (2001) Body mass index as a predictor of outcome in total knee replacement. Int Orthop 25(4):246–249
26. Dewan A, Bertolusso R, Karastinos A, Conditt M, Noble PC, Parsley BS (2009) Implant durability and knee function after total knee arthroplasty in the morbidly obese patient. J Arthroplasty 24(6):89–94
27. Kelly T, Yang W, Chen C-S, Reynolds K, He J (2008) Global burden of obesity in 2005 and projections to 2030. Int J Obes 32(9):1431–1437
28. Ward DT, Metz LN, Horst PK, Kim HT, Kuo AC (2015) Complications of morbid obesity in total joint arthroplasty: risk stratification based on BMI. J Arthroplast 30(9):42–46
29. Kerkhoffs GMMJ, Servien E, Dunn W, Dahm D, Bramer JAM, Haverkamp D (2012) The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. J Bone Jt Surg Am 94(20):1839–1844
30. Krishnan EC, Trost L, Aarons S, Jewell WR (1982) Study of function and maturation of monocytes in morbidly obese individuals. J Surg Res 33(2):89–97
31. Kolterman OG, Olefsky JM, Kurahara C, Taylor K (1980) A defect in cell-mediated immune function in insulin-resistant diabetic and obese subjects. J Lab Clin Med 96(3):535–543
32. Kabon B, Nagele A, Reddy D, Eagon C, Fleshman JW, Sessler DI et al (2004) Obesity decreases perioperative tissue oxygenation. Anesthesiology 100(2):274–280
33. Gadinsky NE, Manuel JB, Lyman S, Westrich GH (2012) Increased operating room time in patients with obesity during primary total knee arthroplasty: conflicts for scheduling. J Arthroplast 27(6):1171–1176
34. Peersman G, Laskin R, Davis J, Peterson MGE, Richart T (2006) Prolonged operative time correlates with increased infection rate after total knee arthroplasty. HSS J 2(1):70–72
35. Foran JRH, Mont MA, Rajadhyaksha AD, Jones LC, Etienne G, Hungerford DS (2004) Total knee arthroplasty in obese patients: a comparison with a matched control group. J Arthroplast 19(7):817–824
36. Mulhall KJ, Ghomrawi HM, Mihalko W, Cui Q, Saleh KJ (2007) Adverse effects of increased body mass index and weight on survivorship of total knee arthroplasty and subsequent outcomes of revision TKA. J Knee Surg 20(3):199–204
37. Vazquez-Vela Johnson G, Worland RL, Keenan J, Norambuena N (2003) Patient demographics as a predictor of the ten-year survival rate in primary total knee replacement. J Bone Jt Surg 85(1):52–56
38. Amin AK, Patton JT, Cook RE, Brenkel IJ (2006) Does obesity influence the clinical outcome at five years following total knee replacement for osteoarthritis? J Bone Jt Surg Br 88(3):335–340

39. Griffin FM, Scuderi GR, Insall JN, Colizza W. Total knee arthroplasty in patients who were obese with 10 years followup. Clin Orthop Relat Res. 1998;(356):28–33
40. Gaillard R, Gaillard T, Denjean S, Lustig S (2017) No influence of obesity on survival of cementless, posterior-stabilised, rotating-platform implants. Arch Orthop Trauma Surg 137(12):1743–1750
41. Gunst S, Fessy MH (2015) The effect of obesity on mechanical failure after total knee arthroplasty. Ann Transl Med 3(20):310
42. McClung CD, Zahiri C, Higa JK, Amstutz HC, Schmalzried TP (2000) Relationship between body mass index and activity in hip or knee arthroplasty patients. J Orthop Res 18(19):35–39
43. Anwar R, Kini SG, Sait S, Bruce WJM (2016) Early clinical and radiological results of total knee arthroplasty using patient-specific guides in obese patients. Arch Orthop Trauma Surg [Internet] 136(2):265–70. Available from: http://link.springer.com/https://doi.org/10.1007/s00402-015-2399-z
44. Insall JN, Dorr L, Scott R, Scott W (1989) Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res Nov(248):13–14