Effect of body mass index on postoperative mechanical alignment and long-term outcomes after total knee arthroplasty: a retrospective cohort study of 671 knees

Ya-Hao Lai, Jian Cao, Ze-Xi Li, Wei Feng, Hong Xu, Zong-Ke Zhou

Department of Orthopedics, West China Hospital of Sichuan University, Chengdu, China

Contributions: (I) Conception and design: YH Lai, ZK Zhou; (II) Administrative support: J Cao; (III) Provision of study materials or patients: ZX Li; (IV) Collection and assembly of data: ZX Li, W Feng; (V) Data analysis and interpretation: YH Lai, H Xu; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

*These authors contributed equally to this work.

Background: A high body mass index (BMI) is associated with increased rates of complications after total knee arthroplasty (TKA). However, no study has examined the effect of BMI on lower limb alignment using the World Health Organization’s (WHO) BMI classification. We believe that the WHO’s BMI classification allows a uniform standard worldwide. We sought to investigate the potential association between a high BMI and the incidence of postoperative misalignment. We also evaluated whether a higher BMI is associated with worse clinical function.

Methods: We retrospectively reviewed the data of 671 patients who underwent primary TKA for varus osteoarthritis between January 2010 and December 2015. The patients were divided into the following 5 groups based on their BMI: normal weight (<25.0 kg/m²), overweight (25.0–29.9 kg/m²), class I obese (30.0–34.9 kg/m²), class II obese (35.0–39.9 kg/m²), and class III obese (>40 kg/m²). Both weight and height were measured by nurses on admission. Patients’ preoperative HKA, gender, age, and side of surgery were collected as baseline. All the patients underwent standing, weight-bearing, full-length radiography before and after surgery to measure the mechanical hip-knee-ankle angle (HKA). We followed up patients by telephone. Among the BMI subgroups, we compared the knee function scores, including the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, Knee Society-Knee Score (KS-KS), Knee Society-Function Score (KS-FS), Forgotten Joint Score (FJS), and range of motion (ROM). A multivariate linear regression analysis and a logistic regression was conducted to examine the outcomes.

Results: The study had a mean follow-up period of 8.16 years. The multivariate and logistic regression analyses revealed that preoperative alignment (P=0.002) and a higher BMI (P=0.015) were associated with a higher risk of postoperative misalignment. The WOMAC scores were higher in the normal and overweight groups than the other groups (P=0.022). The FJS and KS-KS gradually decreased as BMI increased.

Conclusions: A higher BMI is associated with a greater risk of misalignment and worse long-term clinical outcome after TKA. When treating patients with high BMI, we should pay more attention to the adjustment of lower limb alignment intraoperatively.

Keywords: Total knee arthroplasty (TKA); obesity; body mass index (BMI); varus knee; alignment

Submitted Jun 02, 2022. Accepted for publication Jul 05, 2022.
doi: 10.21037/atm-22-3212

View this article at: https://dx.doi.org/10.21037/atm-22-3212

© Annals of Translational Medicine. All rights reserved.
Introduction

The increase in the prevalence of obesity since the early 1980s represents a significant health burden worldwide (1). Obesity contributes to a higher risk of osteoarthritis and ultimately, to an increased demand for total knee arthroplasty (TKA) (2). It has been predicted that the demand for primary TKA will reach nearly 3.5 million cases by the year 2030 (3). Given the increasing prevalence of obesity and the demand for TKA, there will be an inevitable increase in the proportion of TKA patients who are obese.

Knee alignment within 3° of neutrality has historically been defined as “neutral alignment” and considered “safe” (4). Misalignment beyond this “safe zone” may increase the load on the prosthetic implant, which in turn may increase the amount of wear (5). Obesity has been associated with the suboptimal overall mechanical alignment of knee components (6,7). A high body mass index (BMI) increases the stress on the underlying bone and implant material, which adversely affects prosthetic longevity and functional gain (8).

The direct and indirect effects of obesity imply that patients with a higher BMI should have worse postoperative alignment after TKA, resulting in worse long-term function and lower prosthetic survival rates (6,9). However, there is no definitive BMI cutoff that accurately separates high-risk patients from low-risk patients. The threshold of 30 kg/m² remains controversial, and studies in which patients were categorized using BMI cutoff values of 35 and 40 kg/m² were able to identify more differences in overall complication rates or implant survival (10,11). We believe that because the authors aimed to magnify the gap in post TKA outcomes between obese and nonobese patients, the cut-off was set at 35 or 40 kg/m². However, this may make the results too idealized to have an instructive role in clinical work. Previous studies (7,12-14) investigating the relationship between obesity and poor postoperative alignment after TKA have yielded conflicting results. However, these studies stratified patients using a BMI threshold of 35 kg/m², which does not reflect the World Health Organization’s (WHO’s) recommendations.

Conversely, a prospective, matched case-control study (12) found no difference in the overall alignment of components between morbidly obese patients (BMI >40 kg/m²) and non-obese patients (BMI <30 kg/m²), but that study did not specify whether full-length hip-ankle radiography was performed, nor did it report the incidence of misalignment. Similarly, another study (14) reported no difference in the alignment of femoral or tibial components in the coronal or sagittal plane between obese patients (BMI ≥30 kg/m²) and non-obese (BMI <30 kg/m²), but again that study did not report quantitative data on misalignment. Another study (15) reported no difference in the mean tibial coronal alignment between obese and non-obese patients when an extramedullary guide was used during primary TKA.

The discrepancy among these studies may at least partly be due to the use of short knee radiography, small samples, and other methodological problems. Only 2 studies (6,15) have used standing, full-length, hip-to-ankle radiography to measure HKA, which is thought to provide accurate information on limb alignment and component alignment with respect to the weight-bearing mechanical axis (6,16). Additionally, studies on the relationship between BMI and TKA have now largely focused on the incidence of postoperative infection and prosthetic survival times but have ignored the effect of BMI on joint function.

The relationship between BMI and the percentage of body fat is age and sex dependent and varies among racial groups (17). Differences in BMI cutoffs may occur across ethnicities. The WHO standards for BMI classification of Chinese population are as follows: normal (18.5–23.9 kg/m²), overweight (24–27.9 kg/m²), obesity (≥28 kg/m²). However, ethnic-specific cut-off points for BMI were thought to increase confusion in health promotion, and disease prevention and management in the increasingly multicultural societies (18). We believe that adoption of the WHO uniform international standards for BMI could reduce this confusion. This could facilitate advances in research on the effects of BMI on lower extremity alignment.

Thus, the present study sought to investigate whether a higher BMI is associated with an increased incidence of postoperative misalignment and worse clinical function after TKA according to WHO grading for BMI. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-3212/rc).

Methods

Patients

In our retrospective cohort study, we performed a retrospective review of all patients undergoing primary TKA from January 2010 to December 2015 at our hospital. During this period, 820 cemented TKAs were performed. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of West
China Hospital of Sichuan University (No. 2012-268). Written informed consent was obtained from each patient. The number of cases at our hospital during the study period determined the sample size. To be eligible for inclusion in the study, patients had to meet the following inclusion criteria: (I) have primary TKA due to primary knee osteoarthritis (diagnosed by an experienced orthopedic surgeon); (II) have undergone surgery, which was performed by 1 surgeon; (III) have complete full-length pre- and postoperative hip-ankle X-ray imaging available; and (IV) have complete clinical and demographic data and contact information available. Patients with valgus alignment, stemmed components, a history of hip arthroplasty or extra-articular deformity that could affect ipsilateral limb alignment, unclear full-length X-ray imaging, no BMI data, and excessive changes in BMI were excluded from the study (Figure 1). There was no significant difference in the preoperative clinical and radiographic measurements between each group.

The patients were divided into the following 5 groups: normal weight (<25.0 kg/m²), overweight (25.0–29.9 kg/m²), class I obese (30.0–34.9 kg/m²), class II obese (35–39.9 kg/m²), and class III obese (>40 kg/m²) (19).

**Surgical technique**

The same surgical technique was used for all patients. All the operations were performed by the same surgeon using a Sigma fixed or rotating plant posterior-stabilized total knee prosthesis (PFC, Johnson & Johnson/DePuy, Warsaw, IN, USA). A midline skin incision was performed, and a medial parapatellar approach was adopted. After retracting the patella, the surgeon completely resected the anterior cruciate ligaments and meniscus. Osteotomy was performed using an intramedullary jig for the distal femur and an extramedullary jig for the proximal tibia, and the valgus angle during osteotomy was determined according to the preoperative full-length radiographs to achieve neutral alignment.

Intramedullary guides were positioned on the femoral side using Whiteside’s line and the anatomical trans-condylar axis as landmarks, while extramedullary guides were positioned on the tibial side using the center of the tibial intercondylar eminence and the center of the ankle. The tibia was cut, the posterior cruciate ligament was resected, and soft tissue was released according to the degree of preoperative flexion contraction. Depending on the patient’s degree of varus, polyethylene spacers of varying thickness were inserted, or additional soft tissue was released. All patients received a cemented total knee prosthesis and underwent patelloplasty without patellar resurfacing.

**Radiographic assessment**

Mechanical HKA was measured in all patients before and after TKA based on full-length radiography, which was conducted while patients were standing, and the patella was facing forward. X-ray images were taken postoperatively at 1 and 6 months, 1 year, and every 2–3 years thereafter. HKA was defined according to the criteria established by Cooke et al. (20) (Figure 2). Preoperatively, the center of the knee was defined as the intersection of the midline between the tibial spines and the midline between the femoral condyles and the tip of the tibia. The ankle center was taken as the middle of the talus roll at the level of the joint.
gap (21). HKA was expressed as the deviation from 180°, with positive values indicating valgus and negative values indicating varus alignment. Based on the postoperative HKA, knee alignment was classified as valgus (HKA > 3°), neutral (−3° ≤ HKA ≤ 3°), and varus (HKA < −3°).

Radiolucent lines progressing beyond 2 mm and the gross shifting of the implant components causing subsidence or tilting were defined as aseptic loosening (22). Mechanical failures, including aseptic loosening, polyethylene wear, and instability requiring revision surgery were considered the endpoints when analyzing implant survival (23).

Follow-up and outcome assessment

A total of 142 of the patients were lost to follow-up; thus, the final analysis contained 529 knees. We compared the knee function of the subgroups after stratifying by BMI. The included patients had the same BMI groupings at follow-up as the initial groupings.

All patients were followed up by telephone and questionnaire forms. At follow-up, we measured the functional score of patients, including the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, Knee Society Knee (KSS) score, Knee Society-Function Score (KS-FS), Forgotten Joint Score (FJS), and range of motion (ROM). All patients were functionally scored in the form of a questionnaire. We believe that the selected rating scales are adequate to comprehensively reflect the degree of joint prosthesis function in patients’ daily life.

The WOMAC comprises 24 items that cover 3 dimensions (i.e., pain, stiffness, and function) to measure dysfunction and pain associated. Higher scores indicate worse knee function. This self-assessment multidimensional instrument has been well studied, and many of its psychometric properties are known (24), and is also considered suitable to predict postoperative outcomes (25).

The KSS, a joint-specific outcome, is divided into 2 parts (i.e., the KS-KS and KS-FS) and helps exclude knee deterioration due simply to natural aging (26). KSS is a validated scoring systems to reflect the functional ability of the joints. Specific parameters assessed by the knee score section were pain (50 points), range of motion (25 points), and stability (25 points), with deduction of flexion contractures, extensor lag, and malalignment. Higher KSS scores indicate better knee function.

The FJS-12 is a 12-item questionnaire assessing patients’ awareness of the joint during different activities of daily living (27). It measures patients’ ability to forget the artificial joint in everyday life, and thus this index may be associated with patient satisfaction (27). The ability to forget artificial joints in everyday life can be regarded as the goal of arthroplasty, thereby satisfying the patient as much as possible. Higher FJS scores indicate a better ability to forget the artificial knee joint.

Statistical analysis

All the analyses were performed in SPSS 26.0 (IBM, Armonk, NY, USA). The normally distributed data are expressed as the mean ± standard deviation (SD), otherwise the data are expressed as the median (25th percentile, 75th percentile). A multivariate linear regression analysis was performed to examine the potential effects of sex, knee side, BMI, and preoperative HKA on postoperative HKA (6). A logistic regression was conducted to examine the contribution of these risk factors to the risk of misalignment in this patient population.

Differences in continuous data, such as age, follow-up duration, HKA, ROM, WOMAC, KSS, and FJS, among different BMI subgroups were assessed for significance.
using an analysis of variance or the Kruskal-Wallis test as appropriate. Differences in categorical data, such as the incidence of misalignment and sex, were compared using the chi-squared test. Differences with two-sided P values <0.05 were considered significant.

**Bias**

The inclusion of patients with too much BMI change preoperatively versus at the follow-up may have led to bias; thus, we excluded patients whose BMI grouping changed at the time of follow-up. Additionally, to avoid bias, the researchers responsible for collecting data were blinded to the group allocation.

**Results**

**Clinical and demographic characteristics of patients**

In total, 671 knees were included in our study. The patients were divided into 5 groups according to their BMI, such that 40.8% of the knees belonged to patients with normal weight, 35.9% to overweight patients, 17.1% to class I obese patients, 5.6% to class II obese patients, and 0.6% to class III obese patients. The preoperative baseline clinical and demographic characteristics of the patients grouped by BMI, and the distribution of patient alignment based on BMI are detailed in Table 1. We followed-up the knee function of the included patients. A total of 142 patients were lost to follow-up because they could not be contacted when investigating patient knee function. Because we censored out the lost to follow-up population before inclusion in the analysis of knee function when comparing knee function across BMI subgroups, this did not affect our results. Thus, the final analysis contained 529 knees. The mean follow-up time was 8.16 years (±1.45 years).

**Association between BMI and postoperative alignment**

Patients’ postoperative alignments are set out in Table 2. We separately compared the postoperative alignment of each BMI subgroup to the normal group. Neither the overweight (P=0.472) nor class III obese (P=0.091) groups differed from the normal group. There were significant differences between the class I obese (P=0.001), class II obese (P=0.008), and normal groups. Of the 671 knees included in the study, 492 knees (73.3%) were corrected to neutral alignment and 179 (26.7%) were unable to be corrected to neutral alignment. Of the 179 uncorrected to neutral knees, 4 (2.2%) had valgus deviations and 175 (97.8%) had varus deviations. The maximum residual varus was –11.4°, and the maximum valgus was +4.6° (Figure 3).

The Kruskal-Wallis test revealed that there was a strong correlation between an increased incidence of misalignment and a higher BMI (H =7.706; P<0.01). The multivariate regression revealed that postoperative alignment was negatively affected by preoperative alignment and BMI,
but it did not depend on sex or knee side (Table 3). The logistic regression supported these findings, indicating that preoperative alignment and an increasing BMI were associated with an increased risk of post-surgical misalignment.

**Association between BMI and knee function**

As stated above, 142 knees of the 671 knees were lost to follow-up; thus, we compared knee function among the remaining 529 knees. ROM (P=0.688) and KS-FS (P=0.584) were similar among the BMI subgroups, while the WOMAC (P=0.022) score was significantly higher in the normal weight and overweight groups than the obese groups (Table 4). FJS (P=0.032), and KS-KS (P=0.001) gradually decreased as BMI increased.

No mechanical malfunctions occurred among patients in the normal, overweight, or class I obese subgroups. In this study, 2 mechanical malfunctions were observed; 1 in a class II obese patient, and the other in a class III obese patient.

**Discussion**

Our study was the first to adopt the WHO classification criteria to investigate the effect of BMI on lower extremity alignment. We also employed the WOMAC, KS-KS, KS-FS, FJS and ROM to assess the effect of BMI on long-term functioning in patients. To our knowledge, we undertook the most comprehensive examination of scoring to date in this study. We found that higher degrees of obesity stratified according to the WHO BMI grading system led to worse lower limb alignment and worse clinical function after TKA.

TKA can improve knee function in obese patients; however, concerns exist as to whether such patients face a higher risk of wound healing problems, infections, or long-term failure after the procedure (7,12,28). In all TKA patients, misalignment outside the “safe zone” of the mechanically neutral alignment may place increased shear stress on the polyethylene implant components, which in turn may lead to excessive wear and premature aseptic loosening (5,29). The risk of these outcomes may be even higher among TKA patients who are obese (6). In primary TKA, mechanical extra-medullary guides rely on palpable anatomic landmarks to determine tibial component positioning, which may be more difficult to determine.
Table 4 Functional outcomes after TKA for knees stratified by BMI

| Score or outcome | Normal (n=212) | Overweight (n=195) | Class I obese (n=97) | Class II obese (n=23) | Class III obese (n=2) | P value* |
|------------------|----------------|-------------------|---------------------|----------------------|---------------------|----------|
| Range of motion (°) | 99.50±7.619 | 95.56±15.519 | 94.82±16.898 | 90.00±7.071 | 89.29±13.271 | 0.688 |
| WOMAC score | 11.75±13.049 | 11.95±8.637 | 15.80±10.402 | 16.22±15.772 | 28.50±14.782 | 0.022 |
| KS-KS | 114.31±35.248 | 90.72±19.433 | 84.48±10.297 | 81.60±8.792 | 69.40±24.333 | 0.001 |
| KS-FS | 86.40±8.656 | 73.89±16.055 | 78.92±21.989 | 72.60±12.198 | 66.23±16.784 | 0.584 |
| FJS | 81.25±15.113 | 77.53±21.874 | 72.51±27.260 | 62.40±34.658 | 54.21±31.279 | 0.032 |

Data are presented as mean ± SD. * based on multivariate regression analysis. TKA, total knee arthroplasty; BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; KS-KS, Knee Society-Knee Score; KS-FS, Knee Society-Function Score; FJS, Forgotten Joint Score.

in obese patients with excess soft tissue over the leg and ankle (15). The thick soft tissue envelope in obese patients may make surgical exposure difficult, obscure bony landmarks, and obstruct accurate positioning of cutting guides (30).

Our study found that patients with a higher BMI were more likely to suffer poor lower limb alignment, which led to a larger proportion of patients with postoperative residual varus. Similarly, a previous study (31) showed that a higher BMI makes neutral alignment more difficult to achieve using mechanical, intramedullary femoral guides, and extramedullary tibial guides. We and others use a surgical approach with intramedullary femoral and extramedullary tibial guides. When working with TKA patients who have a high BMI, especially those who are morbidly obese, we suggest that surgeons be prepared to rely on alternative methods for determining limb alignment in the event that adipose tissue obscures the traditional bony landmarks. In recent years, computer-guided TKA has become an alternative method for improving alignment (32). However, it may lead to erroneous measurements in obese patients due to difficulties in registering the femoral head center because of the substantial weight of the leg, and in registering the ankle center due to difficulties in palpating the malleoli. Conversely, a previous study (16) reported that the rate of patients falling outside the “safe zone” was similar between obese and non-obese patients (7.5% vs. 6.2%) in computer-assisted TKA. Thus, while obesity may not be an indication for using computer navigation during TKA, it can help to achieve consistently accurate limb and component alignment in obese patients. However, the issue of registration or the effect of reduced adipose tissue in the silico identification of bony landmarks needs to be addressed.

A second major finding of our study is that functional scores decreased with a higher BMI, which suggests that patients with a higher BMI have worse knee clinical function and are less likely to forget about the artificial knee joint, which may contribute to lower satisfaction. Previous studies on the relationship between BMI and TKA have largely focused on the incidence of postoperative infection and prosthetic survival times and have ignored the effect of BMI on joint function. Maniar et al. (33) suggested comparable knee function between class I obese patients and non-obese patients, but lower long-term knee function in class II obese patients. Conversely, another study (34) found no significant differences in knee function among different BMI groups. Stevens-Lapsley et al. (35) found no relationship between functional recovery and a BMI <40 up to 6 months after TKA. In a retrospective study of 988 patients, Stock et al. (36) confirmed that among patients with low preoperative BMI, the Patient-Reported Outcomes Measurement Information System-Physical Function scores of total hip arthroplasty and TKA patients were significantly improved. To the best of our knowledge, these studies either had a short follow-up period or employed few scoring systems, which may not adequately represent how well patients adapt to the sham knee. A great strength of our study is the adoption of the FJS scoring system. The FJS measures patients’ ability to forget the artificial joint in everyday life, and thus this index may be associated with patient satisfaction (27). We consider this a better response to the patient’s degree of endorsement of the false knee.

Our study had some limitations. First, our BMI subgroups were small; thus, our results need to be verified and extended in larger samples. In particular, our small subgroups meant that we could not reliably assess a number of factors (e.g., whether an increasing BMI was associated with a higher risk of poor alignment). Second, the same surgeon performed all the procedures in our study, which helped reduce confounding bias but may not reflect real clinical situations in which clinician experience may affect outcomes.
Conclusions

Despite its limitations, our study suggests that a higher BMI is associated with a greater risk of misalignment after TKA. In patients with postoperative residnal varus, class II obesity (35–40 kg/m²) and class III obesity (>40 kg/m²) may be associated with worse long-term clinical outcomes. However, long-term prosthetic survival may not depend on BMI.

Acknowledgments

Funding: This work was supported by the 1·3·5 Project for Disciplines of Excellence, West China Hospital of Sichuan University, and the Regional Innovation and Cooperation Program of Science and Technology Department of Sichuan Province (No. 2021YFQ0028). The funding from the 2 programs supported the design of the experiment and data analysis. Neither of the 2 programs gave rise to any bias.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-3212/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-3212/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-3212/coif).

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of West China Hospital of Sichuan University (No. 2012-268). Written informed consent was obtained from each patient.

Open Access Statement: This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: https://creativecommons.org/licenses/by-nc-nd/4.0/.

References

1. GBD 2015 Obesity Collaborators; Afshin A, Forouzanfar MH, et al. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N Engl J Med 2017;377:13-27.
2. Workgroup of the American Association of Hip and Knee Surgeons Evidence Based Committee. Obesity and Total Joint Arthroplasty A Literature Based Review. J Arthroplasty 2013;28:714-21.
3. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780-5.
4. Fang DM, Ritter MA, Davis KE. Coronal Alignment in Total Knee Arthroplasty Just How Important is it? J Arthroplasty 2009;24:39-43.
5. D’Lima DD, Hermida JC, Chen PC, et al. Polyethylene wear and variations in knee kinematics. Clin Orthop Relat Res 2001;(392):124-30.
6. Estes CS, Schmidt KJ, McLemore R, et al. Effect of body mass index on limb alignment after total knee arthroplasty. J Arthroplasty 2013;28:101-5.
7. Krushell RJ, Fingeroth RJ. Primary total knee arthroplasty in morbidly obese patients - A 5-to 14-year follow-up study. J Arthroplasty 2007;22:77-80.
8. Ayyar V, Burnett R, Coutts FJ, et al. The Influence of Obesity on Patient Reported Outcomes following Total Knee Replacement. Arthritis 2012;2012:185208.
9. Başdelioğlu K. Effects of body mass index on outcomes of total knee arthroplasty. Eur J Orthop Surg Traumatol 2021;31:595-600.
10. Collins RA, Walmsley PJ, Amin AK, et al. Does obesity influence clinical outcome at nine years following total knee replacement? J Bone Joint Surg Br 2012;94:1351-5.
11. Si HB, Zeng Y, Shen B, et al. The influence of body mass index on the outcomes of primary total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2015;23:1824-32.
12. Amin AK, Clayton RAE, Patton JT, et al. Total knee replacement in morbidly obese patients - Results of a prospective, matched study. J Bone Joint Surg Br 2006;88:1321-6.
13. Järvenpää J, Kettunen J, Kröger H, et al. Obesity may impair the early outcome of total knee arthroplasty. Scand J Surg 2010;99:45-9.
14. Jackson MP, Sexton SA, Walter WL, et al. The impact of
obesity on the mid-term outcome of cementless total knee replacement. J Bone Joint Surg Br 2009;91:1044-8.
15. Compton J, Owens J, Otero J, et al. Extramedullary Guide Alignment Is not Affected by Obesity in Primary Total Knee Arthroplasty. J Knee Surg 2021;34:1076-9.
16. Shetty GM, Mullaji AB, Bhyade S, et al. No effect of obesity on limb and component alignment after computer-assisted total knee arthroplasty. Knee 2014;21:862-5.
17. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157-63.
18. Conroy RM, Pyörälä K, Fitzgerald AP, et al. Estimation of ten-year risk of fatal cardiovascular disease in Europe: the SCORE project. Eur Heart J 2003;24:987-1003.
19. WHO Consultation on Obesity (1999: Geneva, Switzerland) & World Health Organization (2000): Obesity: Preventing and managing the global epidemic - Introduction. Obesity: Preventing and Managing the Global Epidemic: Report of a Who Consultation. WHO Technical Report Series, 2000:1-253.
20. Cooke TD, Sled EA, Scudamore RA. Frontal plane knee alignment: a call for standardized measurement. J Rheumatol 2007;34:1796-801.
21. Nishida K, Matsumoto T, Takayama K, et al. Remaining mild varus limb alignment leads to better clinical outcome in total knee arthroplasty for varus osteoarthritis. Knee Surg Sports Traumatol Arthrosc 2017;25:3488-94.
22. Ewald FC. The knee-society total knee arthroplasty roentgenographic evaluation and scoring system. Clin Orthop Relat Res 1989;(248):9-12.
23. Oh SM, Bin SI, Kim JY, et al. Impact of preoperative varus deformity on postoperative mechanical alignment and long-term results of “mechanical” aligned total knee arthroplasty. Orthop Traumatol Surg Res 2019;105:1061-6.
24. Bellamy N, Kirwan J, Boers M, et al. Recommendations for a core set of outcome measures for future phase III clinical trials in knee, hip, and hand osteoarthritis. Consensus development at OMERACT III. J Rheumatol 1997;24:799-802.
25. Walker LC, Clement ND, Dechan DJ. Predicting the Outcome of Total Knee Arthroplasty Using the WOMAC Score: A Review of the Literature. J Knee Surg 2019;32:736-41.
26. Odum SM, Fehring TK; Knee Society Crosswalk Writing Group. Can Original Knee Society Scores Be Used to Estimate New 2011 Knee Society Scores? Clin Orthop Relat Res 2017;475:160-7.
27. Behrend H, Giesinger K, Giesinger JM, et al. The “Forgotten Joint” as the Ultimate Goal in Joint Arthroplasty Validation of a New Patient-Reported Outcome Measure. J Arthroplasty 2012;27:430-6.
28. Dowsey MM, Liew D, Stoney JD, et al. The impact of pre-operative obesity on weight change and outcome in total knee replacement: a prospective study of 529 consecutive patients. J Bone Joint Surg Br 2010;92:513-20.
29. D’Lima DD, Chen PC, Colwell CW Jr. Polyethylene contact stresses, articular congruity, and knee alignment. Clin Orthop Relat Res 2001;(392):232-8.
30. Winiarsky R, Barth P, Lotke P. Total knee arthroplasty in morbidly obese patients. J Bone Joint Surg Am 1998;80:1770-4.
31. Parratte S, Pagnano MW, Trousdale RT, et al. Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. J Bone Joint Surg Am 2010;92:2143-9.
32. Lang JE, Mannava S, Floyd AJ, et al. Robotic systems in orthopaedic surgery. J Bone Joint Surg Br 2011;93:1296-9.
33. Maniar RN, Maniar PR, Singhi T, et al. WHO Class of Obesity Influences Functional Recovery Post-TKA. Clin Orthop Surg 2018;10:26-32.
34. Daniilidis K, Yao D, Gosheger G, et al. Does BMI influence clinical outcomes after total knee arthroplasty? Technol Health Care 2016;24:367-75.
35. Stevens-Lapsley JE, Petterson SC, Mizner RL, et al. Impact of body mass index on functional performance after total knee arthroplasty. J Arthroplasty 2010;25:1104-9.
36. Stock LA, Brennan JC, Turcotte JJ, et al. Effect of Weight Change on Patient Reported Outcomes Following Total Joint Arthroplasty. J Arthroplasty 2022. [Epub ahead of print]. doi: 10.1016/j.arth.2022.04.029.

Cite this article as: Lai YH, Cao J, Li ZX, Feng W, Xu H, Zhou ZK. Effect of body mass index on postoperative mechanical alignment and long-term outcomes after total knee arthroplasty: a retrospective cohort study of 671 knees. Ann Transl Med 2022;10(15):829. doi: 10.21037/atm-22-3212

(English Language Editor: L. Huleatt)