texas orthopaedic journal®

ORIGINAL RESEARCH

The Relationship Between Patient BMI and Component Size in Total Knee Arthroplasty: A Retrospective Study

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ABSTRACT

Introduction: Evidence links obesity to degenerative joint disease and total knee arthroplasty (TKA). The extent to which individual patient body mass index (BMI) correlates with TKA component size has not been studied. We therefore determined whether patient BMI is related to TKA component size, and if so, what is the nature of this relationship.
Methods: Medical records of patients treated with primary TKA at our institution were retrospectively reviewed. Patients who received elective, primary TKA with Smith & Nephew components for inflammatory or degenerative arthritis were included. Patients with revision TKA, history of prior knee infection or trauma, congenital knee deformity, or dissimilar implant system were excluded. Demographic data collected included patient age, sex, knee laterality, height, weight, and BMI. TKA femoral and tibial component sizes were recorded for each patient.
Results: No significant relationship was found between component size and patient BMI. Patient age and BMI were directly proportional (p=0.022, pp=0.050). In patients older than 75 years, there was a direct relationship between higher BMI and larger femoral and tibial implants. In patients younger than 55 years, there was a marginally significant inverse association between increasing BMI and femoral and tibial component size.
Discussion: Higher BMI is directly associated with larger TKA component sizes in patients older than 75 years of age. However, in patients younger than 55 years of age, there was a tendency toward requiring smaller TKA components as BMI increased.
Level of Evidence: IV; Retrospective study.
Keywords: Body mass index; Total knee arthroplasty; Knee prosthesis sizing.

INTRODUCTION

The prevalence of obesity in the United States continues to rise [1]. Obesity is a considerable current public health problem that is responsible for increased rates of morbidity and mortality [2]. Approximately 1 out of every 3 Americans is considered obese [3]. Presently, there is evidence linking obesity to degenerative joint disease [4-7], as well as observations that a high percentage of total knee arthroplasty (TKA) candidates are overweight [8-10]. Therefore, there is growing interest in the effects of excess body weight on TKA.

Obesity is typically determined by

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body mass index (BMI). At long-term follow-up, obese TKA patients have demonstrated higher failure rates than their non-obese counterparts [11]. Morbidly obese patients, or those with a BMI greater than 40 kg/m^2, have shown significantly lower implant survivorship compared to non-obese patients [12]. Previous work suggests that high BMI increases stress at the cement-bone interface, a condition that can potentially lead to mechanical loosening and subsequent failure [13]. In addition to the additive effect of increased body weight on knee joint loads during gait, obesity has been reported to cause movement adaptations that may also adversely affect the loading environment within the joint, increasing the potential for injury [14]. Several authors have described broken TKA components in obese patients and, in addition to patient weight, the basis for this catastrophic failure has been attributed to component thinness and smaller component size [15-21].

To date, the extent to which individual patient weight correlates with TKA component size has not been studied. The purpose of this study was to determine if a relationship exists between patient BMI and TKA component size. Our hypothesis is that an inverse relationship exists between patient BMI and TKA implant size.

MATERIALS & METHODS

The study was approved by the Institutional Review Board. The medical records of all patients treated with a total knee arthroplasty at our institution over a 3-year period (January 4, 2010 through June 19, 2013) were retrospectively reviewed. The inclusion criteria consisted of patients who received elective, primary TKA with Smith and Nephew (London, UK) components for inflammatory or degenerative arthritis. The exclusion criteria consisted of revision TKA, a history of prior knee infection or trauma, a congenital knee deformity, or a dissimilar implant system. Demographic data collected included patient age, sex, knee laterality, height, weight, and BMI. TKA femoral and tibial component sizes were recorded for each patient.

Statistical Analysis

Femoral and tibial component sizes were grouped into 3 subcategories: Sizes 1-3 were defined as "small," 4 and 5 were defined as "medium," and 6-8 were defined as "large." Descriptive statistics were reported as percentages for categorical variables and means (standard deviation) for continuous variables. Differences among patients who received the 3 different component sizes were assessed with chi-square test and analysis of variance for categorical and continuous variable, respectively. Ordinal logistic regression analysis was used to explore the relationship between BMI and component size adjusted for other covariates. There was no violation on the assumption of proportional odds in these models. We reported odds ratio with its 95% confidence interval estimated from these models. We also tested the interactions between BMI and age as well as BMI and gender on the component size. All of the tests were 2-sided with an alpha of 0.05 and were performed with the use of SAS 9.3.

RESULTS

A total of 288 patients who underwent TKA during the investigational time period were identified. Among these, 250 patients and a total of 259 TKAs met the inclusion criteria. The average patient age was 64.18 years (range 45-86 years). There were 98 male (37.8%) and 161 (62.2%) female TKA cases. Ninety-eight knees (37.8%), 74 knees (28.6%), 65 knees (25.1%), 20 knees (7.7%) and 2 knees (0.8%) were implanted in patients with a BMI ≥35, 30-34.9, 25-29.9, 18.5-24.9 and <18.5, respectively. Table 1 demonstrates the proportion of patients receiving different component sizes. With respect to femoral components, 33 required small sizes (12.7%), 133 required medium sizes (51.4%), and 93 required large sizes (35.9%). With respect to tibial components, 108 required small sizes (41.7%), 97 required medium sizes (37.5%), and 54 required large sizes (20.8%). Among males, with respect to femoral components, 2.0%, 27.6%, and 70.4% required small, medium, and large sizes, respectively. Among males, with respect to tibial components, 7.1%, 40.8%, and 52.0% required small, medium, and large components, respectively. Among females, with respect to femoral components, 19.3%, 65.8%, and 14.9% required small, medium, and large sizes, respectively. Among females, with respect to tibial components, 62.7%, 35.4%, and 1.9% required small, medium, and large components, respectively. Males were 13.22 times more likely to have a larger femoral component size and 33.82 times more likely to have a larger tibial component size than females.

Table 1. Femoral and Tibial Component Sizes Stratified by Patient Characteristics.

		Femoral				Tibial			
	N (%)	1-3	4,5	6-8	P-value	1-3	4,5	6-8	P-value
Total									
N	259	33	133	93		108	97	54	
%		12.7%	51.4%	35.9%		41.7%	37.5%	20.8%	
Gender									
M	98 (37.8%)	2.0%	27.6%	70.4%	<0.0001*	7.2%	40.8%	52.0%	<0.0001*
F	161 (62.2%)	19.3%	65.8%	14.9%		62.7%	35.4%	1.9%	
Age		66.5	65.0	62.2	0.0076*	65.4	63.8	62.3	0.0407*
Laterality									
Left	133 (51.4%)	13.5%	50.4%	36.1%	0.9103	46.6%	33.8%	19.5%	0.2513
Right	126 (48.6%)	11.9%	52.4%	35.7%		36.5%	41.3%	22.2%	
Diabetes									
No	197 (76.1%)	14.7%	49.2%	36.0%	0.1969	41.6%	38.6%	19.8%	0.6986
Yes	62 (23.9%)	6.5%	58.1%	35.5%		41.9%	33.9%	24.2%	
BMI		32.8	33.0	34.3	0.1573	32.7	34.2	33.6	0.3045

*Statistically significant difference; Chi-square test was used for categorical and ANOVA for continuous variables

Table 2. Odds of Receiving Larger Component Sizes among TKA Patients.

	Femoral			Tibial		
	OR	95%CI		OR	95%CI	
Gender (M vs F)	13.22	7.22	24.30	33.82	16.11	71.01
Laterality (L vs R)	0.92	0.55	1.56	0.58	0.35	0.96
Diabetis (Y vs N)	1.02	0.55	1.92	0.83	0.45	1.52
BMI vs Age**						
Age 45	0.93	0.85	1.01	0.94	0.86	1.03
Age 45	0.97	0.92	1.03	0.98	0.93	1.04
Age 45	1.02	0.98	1.07	1.03	0.98	1.07
Age 45	1.07	1.01	1.14	1.07	1.00	1.14
Age 45	1.13	1.02	1.24	1.12	1.01	1.24

Odds ratio (OR) was estimated from ordinal logistic regression.
*Significant interaction between BMI and age (p=0.022, pp=0.050).

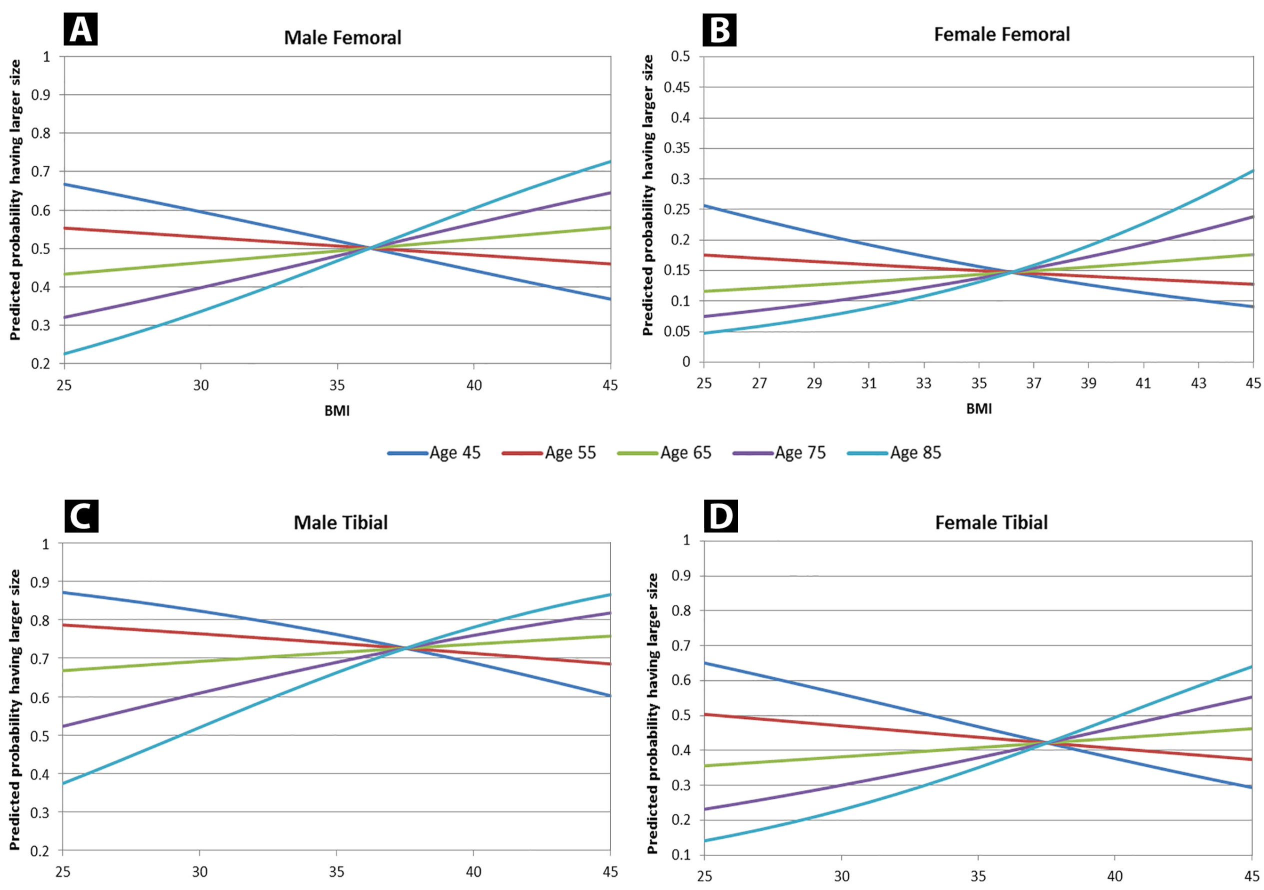

Figure 1. The predicted probability of receiving larger component size over the range of BMI from 25 kg/m^2 to 45 kg/m^2 by age, based on ordinal logistic regression models, stratified by locations of component and gender.

DISCUSSION

The knee joint is exposed to high contact and shear forces during weight-bearing, with compressive loads estimated to be in excess of 3 times body weight during walking and up to 6 times body weight during stair climbing [22]. The objective of our study was to determine if a relationship exists between patient BMI and TKA femoral and tibial component size, and our hypothesis was that an inverse relationship between patient BMI and component size was another explanation, in addition to weight alone, for early TKA failure in these patients.

According to our results, most patients require medium-sized femoral and small-sized tibial components. Right-sided knees were 58% more likely to require larger implants than left-sided knees. Previous studies have shown component asymmetry among left and right total knees to be between 6.7% and 9% without a difference in functional outcomes [23-25]. Our study presents similar findings with a different perspective. A surgeon must therefore approach the sizing of TKA components solely on the basis of individual knee anatomy, not relying on estimates from a contralateral TKA previously performed in the same patient.

In regards to sex, the fact that the males in our study required large-sized components while the females required small-sized components is intuitive, based on the anatomical differences typically encountered between genders. However, our findings suggest that gender may be a better determinant of probable TKA implant size than BMI.

A direct relationship between patient age and BMI was encountered. Moreover, the incidence and severity of osteoarthritis increased with age. In addition, a more sedentary and low-demand lifestyle is seen in patients as they age. These factors likely contribute to an elevation in BMI in older patients that require TKA.

A significant inverse relationship was noted between patient age and TKA component size. As the age of the patient increased, the component size of the TKA components decreased. This finding was unanticipated and we do not have a reasonable explanation for it. Furthermore, we determined that the probability of requiring larger femoral and tibial components in older patients increases as BMI increases. Interestingly, in patients younger than 55 years, there was a marginally significant trend towards the need for smaller-sized components as BMI increases. Therefore, an inverse association exists between BMI and component size at a younger age, although it was not statistically significant. This finding may be due to the relatively few number of younger patients in this study. A stronger, more significant association could possibly exist with an increased sample size.

The use of proper TKA implant size and morphology is of considerable importance considering its influence on initial component stability and implant longevity [26]. With the increased load a high BMI places on the knee, TKA components must be able to withstand higher contact forces. The observed trend towards younger patients with increased BMIs requiring smaller component sizes could have interesting implications in future implant design.

The limitations of our study include a possible surgeon selection bias in recommending TKA surgery for patients on the basis of their weight. Radiographic parameters that could actually measure individual patient anatomy or the adequacy of implant selection/placement was not assessed. Surgeries were performed by multiple surgeons.

There could have been differences in the parameters used for intraoperative component size selections. As mentioned earlier, a larger sample size may provide additional data that could validate the trend towards younger patients with large BMIs requiring smaller implants.

Our study did have several notable strengths. To our knowledge, despite some anecdotal beliefs regarding this issue, ours is the first study to investigate the relationship between patient BMI and TKA component sizes. Furthermore, as the selection of component sizes in TKA is performed in a manner that seeks the best fit for each patient's anatomy, we present this approach as a novel, albeit indirect, method for appraising individual knee size.

In conclusion, increasing BMI is directly associated with larger TKA component sizes in patients older than 75 years of age. However, patients younger than 55 years of age show a tendency towards requiring smaller TKA components as their BMI increases. Further research is warranted to better understand these observations.

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