RESEARCH ARTICLE

Total Knee Replacement Sizing: Shoe Size Is a Better Predictor for Implant Size than Body Height

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Received: 06 April 2017 *Accepted: 05 August 2017*

Abstract

Background: Various sizes of implants need to be available during surgery. The purpose of this paper is to compare body height and shoe size with implant sizes in patients who underwent total knee replacement surgery to see which biomarker is a better predictor for preoperative planning to determine implant size.

Methods: A total of 100 knees, belonging to 50 females and 50 males, were observed. Participants' body height and shoe size were collected and correlated to implant sizes of a current, frequently used, standard total knee replacement (TKR) implant. The femoral anteroposterior and mediolateral width and the tibial anteroposterior and mediolateral width were correlated with height and shoe size.

Results: The correlation between shoe size and the four knee implant dimensions, femoral AP, ML, and tibial AP and ML were higher than the correlations between height and the same four dimensions.

Conclusion: The results indicated that shoe size is a better predictor of component dimensions than is body height.

Level of evidence: III

Keywords: Biomarkers, Implant size, Preoperative planning, Shoe size, Total knee replacement

Introduction

Predicting component size is an important part of a surgeon's planning prior to total knee arthroplasty (TKA), and sometimes - specifically in very small females or large males - extra small or extra large components must be ordered to be available during surgery. Further, correct component sizes promote proper knee kinematics after replacement and may decrease pain and need for revision. Components that are too large may result in overhang and may irritate surrounding soft tissue, which reduces motion and causes pain (1). Components that are too small, on the other hand, may leave spongy bone exposed, which increases the risk of bleeding and eventual bone loss. Accurate preoperative prediction of component size may also help to decrease the number of different implant sizes that must be stocked in the operating room, and also to reduce the number of size trials needed intra-operatively. This would in turn decrease surgical time and increase efficiency.

There are many current methods for predicting TKA component size preoperatively. Traditionally, radiographic templating using acetate was used (2, 3). More currently, digital methods of templating have been developed, which have shown to be just as accurate as the older acetate modeling (4–6). These methods predict tibial and femoral component size correctly 50–60% of the time, and within 1 size 90–95% of the time. Both of these methods require specific x-rays and can be time-

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intensive for surgeons. Other methods of component size prediction using patient characteristics such as height, age, gender, and weight have been explored. Height has generally been found to be the most predictive factor thus far, though models have varied in overall accuracy.

In an effort to improve component size prediction methods for TKA, additional patient characteristics were considered. Previous studies have shown that a patient's shoe size can be useful in predicting sizes of the femoral component of unicompartmental knee replacements (7). However, no known studies to date have examined the efficacy of using shoe size to predict the size of TKA components. We wanted to be able to use a biomarker that was universally accessible, especially for use in places where advanced imaging technology might not be available. Accordingly, a model using shoe size to predict TKA component size was created and compared to other models to determine which was most accurate.

Materials and Methods

A retrospective chart review identified patients who had undergone primary total knee arthroplasty (TKA) using an implant manufactured by DePuy. All patients received an implant from the DePuy PFC Sigma or DePuy Attune systems. Each operation was performed by the same surgeon at one of three operative sites between 2007 and 2015. A total of 100 knees were included in analysis: 50 from 37 unique female patients and 50 from 39 unique male patients. Each patient's shoe size, according to the standard US sizing scale, was recorded from their medical chart. If patients gave multiple sizes, the average of the reported sizes was used. Female shoe sizes were converted to their male equivalents by subtracting two from the given size. Implant model and sizes of the femoral and tibial components implanted during TKA were recorded from the operative note. DePuy product sizing guides were used to determine the anterior-posterior and medial-lateral lengths of each component, femoral and tibial, in millimeters. These four components - femoral anteroposterior (FAP), femoral mediolateral (FML), tibial anteroposterior (TAP) and tibial mediolateral (TML) - were recorded and used in analysis. Each patient's height in inches at the time of surgery was also recorded from his or her chart. The protocol was submitted to the Brigham and Women's Hospital IRB and found to be exempt due to lack of patients' identifiers. For such a study, formal consent is not required.

Results

R^2 coefficients were calculated between each of the four implant component dimensions and either shoe size or height. For each implant component dimension, we determined the difference in R^2 for shoe size vs. height and used William's t-test to determine if the two correlations - implant dimension and height vs. implant dimension and shoe size - were significantly different (8, 9). For each dimension, the correlation with shoe size was found to be higher than the correlation with height. P-values were calculated to determine if these differences were significant; the results are shown in Table 1. For the TAP and TML dimensions, the difference was found to be significant. For the FAP and FML dimensions, more participants would be needed to reach a level of statistical significance.

Regression equations were generated which related the size of tibial and femoral components in both the Attune and PFC Sigma systems to shoe size. R^2 coefficients were calculated to determine how effectively these equations predicted component size. The results are shown in Table 2. For each equation, the p-value of the correlation component was shown to be statistically significant, indicating that the linear model using shoe size to predict component size was effective. So, if the shoe size is 8 (female) the calculated size y for a PFC tibia is 0.2478x+1.2445 or 0.25 x 8 + 1.2 = 3.2. The calculated tibial size would be a size 3 [Table 3].

The regression equations generated as shown in Table 2, along with equations generated in the same

Table 1. Comparison of R^2 Coefficients of Shoe Size or Height versus the Four Dimensions of Total Knee Implant Measurements

	R^2 Value Using Shoe Size (US Male Equivalent Sizing)	R^2 Value Using Height (Inches)	*P-value*
TAP	0.6601	0.5198	.0114
TML	0.6489	0.5267	.0277
FAP	0.5953	0.5156	.1352
FML	0.6423	0.5533	.0967

Table 2. Regression Equations and R^2 Coefficients using Shoe Size to Predict Total Knee Implant Component Sizes

	Regression Equation Using Shoe Size as a Predictor	R^2	*P-value* of Coefficient
Attune Femoral Component	y=0.401x+2.4189	0.6646	8.09×10^{-10}
Attune Tibial Component	y=0.5993+0.5925	0.7556	3.00×10^{-12}
PFC Sigma Femoral Component	y=0.2678x+1.5914	0.5607	1.70×10^{-12}
PFC Sigma Tibial Component	y=0.2478+12445	0.5960	1.29×10^{-13}

Table 3. Calculated Component sizes for Attune and PFC Sigma tibial implants for men (women's US shoe size is men's minus 2)

Shoe Size (US Women)	Shoe Size (US Men)	Attune Tibial Component	PFC Sigma Tibial Component
2	4	3	2
2.5	4.5	3	2.5
3	5	4	2.5
3.5	5.5	4	2.5
4	6	4	2.5
4.5	6.5	4	3
5.0	7	5	3
5.5	7.5	5	3
6.0	8	5	3
6.5	8.5	6	3
7.0	9	6	3
7.5	9.5	6	4
8.0	10	7	4
8.5	10.5	7	4
9.0	11	7	4
9.5	11.5	7	4
10.0	12	8	4
10.5	12.5	8	4
11.0	13	8	4
11.5	13.5	9	5
12.0	14	9	5
12.5	14.5	9	5
13	15	10	5

Table 4. Percentage of Implant Component Sizes Predicted Accurately or within ±1 Size Using Shoe Size versus Height as a Predictor

	Tibial Components		Femoral Components		Overall Components	
	Predicted Correctly	Predicted ±1 Size	Predicted Correctly	Predicted ±1 Size	Predicted Correctly	Predicted ±1 Size
Shoe Size	63%	96%	56%	99%	60%	98%
Height	58%	92%	56%	98%	57%	95%

way using height as a predictor, were used to compute predicted implant sizes for all study participants. This is seen in Table 3. The predicted component sizes were compared to the actual component sizes to determine if one method was more effective than the other; these results are shown in Table 4.

Discussion

The results demonstrate that the correlations between shoe size and two of the four knee implant dimensions - TAP and TML - are higher than the correlations between height and the same dimensions. (Shoe size also corresponded to higher correlations in the FAP and FML dimensions, but the difference was not statistically significant). This result is particularly interesting given that the correlation coefficient between shoe size and height in this study was 0.835. It does seem, therefore, that shoe size is a predictor of tibial component dimensions than is femoral height.

As regards to our calculated linear models, the fact that these values are significant for each of the four dimensions indicates that shoe size can be effectively used to predict both femoral and tibial component size. The regression equations generated can be used in preoperative planning to predict the implant size, as seen in Table 3. For example, if a female patient were to present with a size 9.5 shoe, a doctor could easily determine that she would need an Attune size 7.0 femoral component and an Attune 7.5 tibial component. The results also suggest that shoe size could be used to predict component size effectively in a number of different implant systems. Regression equations would simply need to be generated using each system's unique sizing scale. However, it is important to understand that our series of implants are based on a posterior referencing technique, which allows a more accurate flexion gap balancing. It tends however that the femoral size is always slightly larger compared to the tibia. For this reason we would recommend to rely more on the tibial calculation and recommend to use a femoral component equal or one size larger than the tibia.

Table 4 shows the percentage of implant component sizes that were predicted accurately, or within one size, using regression equations based on either shoe size or height. Shoe size was a better predictor than height, particularly for tibial components, but the differences were not statistically significant. Given that shoe size was found to be more significantly correlated with implant dimensions than was height, significant differences may have been expected in implant size prediction ability as well. However, the lack of significance in this case may reflect the fact that there are a limited number of implant sizes to choose from, and the closest fitting size must therefore be used. Accordingly, a prediction method that is less precise may still yield acceptable sizing results.

The study was limited to a relatively small sample size of only 100 knees. A larger study could show additional significant results, which would further support the use of shoe size to predict TKA component size. This study also only looked at two models of implants, the DePuy Attune and PFC Sigma models. In order for this method to be used by other surgeons, regression equations for different TKA models may need to be generated. The results showed significant correlation between shoe size and all four component dimensions - TAP, TML, FAP, and FML - which indicates that this method would likely translate effectively to other implant models. This information may also be useful to implant manufacturers, as relationships between anatomic dimensions could be incorporated when designing the next generation of TKA components to create the best range of fit options (10).

Another disadvantage of this simple regression equations is the fact that we did not verify this with other imaging such as X-rays or CT scan. Well, this cohort of patients did not get CT scans prior to surgery. This is not our standard of care. Regular X-rays have variable magnifications and might not represent the actual intra-op sizing. We believe that the actual implant sizes from the surgery itself would be a better variable.

One further shortcoming could lie in the fact that the randomly chosen cohort in this study happened to contain a relatively uniform set of shoe sizes. We had very few people whose feet were unusually small or large, and had to use a narrower range of sizes than expected to come up with our equation. If the relationship continues linearly, however, predicting the implant size of an outlier could simply be a matter of plugging in an x-value into the equations in Table 2. We do not, however, make such a guarantee; further research into larger shoe sizes would be necessary. We also were not able to find any other studies for total knee replacements. To our knowledge there is only one study correlating shoe size with femoral component size in partial knee replacements (7).

Overall, using shoe size to predict the size of TKA components has shown to be an effective method which can be implemented preoperatively. Once the regression equations are in place, the method is far less labor intensive than traditional templating, and more accurate overall than using other variables like height as predictors. Using the correct component sizes is vital to ensuring the best potential patient outcomes. Accurate preoperative templating may also help to shorten surgical time, which benefits both provider and patient. The potential combination of improved simplicity and greater benefits certainly makes this a method worth implementing.

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. There is no external funding for this study.

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