Published in final edited form as:
J Arthroplasty. 2010 October ; 25(7): 1104–1109. doi:10.1016/j.arth.2009.08.009.

Impact of Body Mass Index on Functional Performance After Total Knee Arthroplasty

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Abstract

The purpose of this investigation was to determine whether functional performance and self-report outcomes are related to body mass index (BMI) after total knee arthroplasty (TKA). We hypothesized that higher BMIs would negatively affect functional performance as assessed by the timed up-and-go test, stair climbing test, 6-minute walk test, and self-report questionnaires. A total of 140 patients with BMIs ranging from 21.2 to 40.0 kg/m^2 were followed over the first 6 months after unilateral TKA. Hierarchical linear regression was used to evaluate the impact of BMI on functional performance at 1, 3, and 6 months after TKA, while taking into account preoperative functional performance. There were no meaningful relationships between BMI and functional performance in the subacute (1 and 3 months) and intermediate (6-month) stages of recovery.

Keywords

total knee arthroplasty; body mass index; obesity; functional performance

Total knee arthroplasty (TKA) is one of the most common elective surgical procedures to alleviate pain and disability associated with knee osteoarthritis (OA) [1]. The number of TKAs performed in the United States increased by 53% between 2000 to 2004 amounting to more than 400 000 each year in the United States [2]. Future projections indicate that by the year 2030, more than 3.48 million of these procedures will be performed each year [1].

Increasing body weight is a risk factor for developing OA of the knee, possibly because of increased mechanical loading at the joint [3–5]. In fact, for every pound of weight loss in patients with OA, there is a 4-fold reduction in the load exerted on the knee with daily activities [6]. In addition, obesity is associated with a variety of metabolic disturbances that could result in systemic risk factors for OA [5].

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No benefits or funds were received in support of the study.

This study was approved by the University of Delaware Institutional Review Board.

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Regardless of the exact cause of OA, the relationship between OA and obesity poses a rising concern [3]. The prevalence of obesity has more than doubled since 1970 [7]. Nearly 65% of adults in the United States are overweight and 30.4% are obese [8]. Obesity is often classified using the body mass index (BMI), which has been shown to relate well with total body fat and potential health risks [9,10]. Body mass index is calculated as weight in kilograms divided by height in meters squared. The World Health Organization has devised a classification system for adults based on BMI as follows: 30 to 34.9 kg/m^2 = obese class I; 35 to 39.9 kg/m^2 = obese class II; 40 kg/m^2 and greater = obese class III [11].

Although obesity has been linked to the development of knee OA, the potential impact of obesity on postoperative outcomes after TKA is less clear [12–20]. Many previous investigations have focused on the rate of prosthesis failure in overweight patients or the risk of complications (ie, incision healing and infection) [18,19]. However, no studies have systematically documented the influence of obesity on measurable physical performance measures after TKA. Functional performance has commonly been assessed using health status questionnaires [12–16]. Yet, performance-based assessments, such as speed on a timed stair climbing test (SCT) and 6-minute walk (6MW) distance, more closely match patients' actual functional abilities. Changes in selfreport questionnaires, on the other hand, tend to be more strongly correlated to patients' pain relief [21,22]. Therefore, examining how BMI relates to functional performance measures after TKA is necessary to better evaluate any potential deleterious effects of BMI on postoperative TKA outcomes.

The purpose of this investigation was to evaluate the impact of BMI on functional performance and self-report outcomes after TKA. We hypothesized that higher BMI would negatively affect functional performance as assessed by the timed up-and-go (TUG) test, SCT, 6MW, and self-report questionnaires.

Materials and Methods

A total of 140 patients (75 women, 65 men) were followed over the first 6 months after unilateral TKA for primary OA by 1 of 3 experienced surgeons from a local orthopedic practice (mean age, 65.3 ± 9.2 years). Most patients received posterior stabilizing prostheses using a medial parapatellar surgical approach. Participants were enrolled in a clinical trial for which there was no effect of intervention [23]. Exclusion criteria for the clinical trial included (1) uncontrolled hypertension; (2) uncontrolled diabetes; (3) symptomatic OA in the contralateral knee (defined as self-reported knee pain greater than 4 on a 10-point verbal analog scale); (4) other lower extremity orthopedic problems that limited function; or (5) neurologic impairment and (6) BMI of more than 40 kg/m^2. The average BMI was 30.8 ± 5.2 kg/m^2 (range, 21.2–40.0 kg/ m^2). The study was approved by the human subject review board at the University of Delaware. All participants provided written informed consent before participation.

Body mass index was used for this analysis because it is often used to estimate obesity and correlates well with the total amount of body fat [9,10]. Functional testing and self-reported questionnaires were administered preoperatively and 1, 3, and 6 months after TKA (Table 1). Six months of follow-up has been shown to be adequate for capturing long-term changes in functional performance after TKA [24,25]. Subjects completed functional and health questionnaires before functional testing.

Functional Measures

The TUG test, SCT, and 6MW were used to assess functional performance. The TUG test measures the time to rise from a seated position in an armed chair (seat height, 46 cm), walk 3 meters, turn around, and return to a seated position in the chair [26]. The SCT measures the time to ascend and descend 12 steps of 20.1 cm height [21]. For both the TUG test and SCT, the average of 2 trials was analyzed. The 6MW measures the distance a person can walk in 6 minutes [27]. Participants were allowed the use of an assistive device and were instructed to move as quickly as they felt safe and comfortable. The 6MW was not part of the initial protocol; therefore, not all patients completed this test compared to the other outcome measures (n = 118).

Self-Assessment Questionnaires

The Medical Outcomes Survey Short Form-36 (SF-36) [28] and the Activities of Daily Living Scale of the Knee Outcome Survey (KOS-ADLS) [29] were administered to measure perceived functional ability. Both the mental and physical component scores (MCS and PCS, respectively) of the SF-36 were computed.

Rehabilitation

After surgery, patients received inpatient rehabilitation and home physical therapy during the first 3 to 4 weeks after TKA. After home physical therapy, patients participated in a progressive outpatient rehabilitation program 2 to 3 times a week for 6 weeks. A minimum of 12 outpatient therapy visits (mean, 17 visits) was required over the 6-week period at the University of Delaware Physical Therapy Clinic. The rehabilitation protocol was centered on an impairment-based model described previously [23,30].

Data Analysis

Data were processed using the SPSS statistical software package (version 16.0, SPSS Inc, Chicago, Ill). The ability of the independent variables to predict the dependent variables was analyzed using separate hierarchical linear regressions. The first model included only the preoperative outcome measure of interest because preoperative scores have been shown to predict postoperative scores on questionnaires [31,32]. The second model included the preoperative measure plus BMI to examine how much BMI accounted for any additional variance in outcomes. With the addition of BMI, the significance of the change in resultant R^2 value was analyzed with an F test. The resultant F test comparing the first and second models would show if the inclusion of BMI significantly improves the ability to predict the postoperative outcome measure of interest. The alpha level was set at $P < .05$.

Results

Overall, BMI did not account for the variance in postoperative physical performance measures or self-reported SF-36 measures (Table 2–Table 7). In all cases, the inclusion of the appropriate preoperative measure in each model explained significant amounts of postoperative performance. Adding BMI to the model did not result in additional improvement, except for the KOS-ADLS, for which adding BMI to the model resulted in a statistically significant improvement for both 3 and 6 months (Table 7). Interestingly, compared to the other outcome measures, the preoperative KOS-ADLS score in the first model explained very little of the postoperative KOS-ADLS outcomes. Although not all patients returned for the 3 (14%) and 6 (24%) month follow-ups, loss to follow-up was equally distributed across BMIs. There were no superficial wound infections, deep joint infections, perioperative mortality, or deep vein thromboses during outpatient rehabilitation for any patients.

Discussion

This study is the first to examine relationships between obesity and physical performance measures, in addition to self-reported measures after TKA. Contrary to our hypothesis, BMI did not adversely impact functional performance. The lack of a relationship between functional performance and BMI suggests that functional outcomes are not compromised by moderate obesity in this population; however, further investigation is necessary in individuals with BMIs of more than 40 kg/m^2. The KOS-ADLS was the only outcome measure that appeared to be slightly influenced by BMI at 3 and 6 months. The lack of a strong relationship between preoperative and postoperative KOS-ADLS may have allowed BMI to explain a greater amount of variability than noted for the other outcome measures and therefore, may not be clinically meaningful.

The current findings may be surprising considering that many orthopedic surgeons hesitate to operate on obese patients because they suspect a greater risk of complications, component failure, and worse outcomes [16,20,33,34]. However, these operative concerns may be warranted. Total knee arthroplasty in morbidly obese patients (ie, BMI >40 kg/m^2) has been associated with an increased rate of perioperative complications, including problems with wound healing, infection, and avulsion of the MCL [12,16,19,35]. Also, higher peak stresses and the effects of cyclic loading, as a result of higher body weight, may contribute to a higher incidence of aseptic loosening or material failure of the prosthetic component [35,36].

The current study findings are consistent with the findings of previous investigations using self-report questionnaires. A BMI of less than 40 kg/m^2 appears to have a minimal effect on physical function after TKA and minimal complications [3,13,37]. However, there are more disparities in outcomes in persons with BMIs greater than 40 kg/m^2 that appear to be related to greater body mass [3,12,14–16,37,38].

Winiarsky et al [16] retrospectively examined patients with an average BMI of 44.0 kg/m^2 (range, 40.3–56.2 kg/m^2) almost 5 years after TKA. They found significant differences between morbidly obese patients and control patients receiving TKAs using the Knee Society rating system [16]. Morbidly obese patients who were 5 years post-TKA had a mean knee score of 84 compared to a control group with a score of 92 (higher scores are preferable). In addition, morbidly obese patients who were 5 years post-TKA had a postoperative functional score of 53 points compared to controls with a score of 67. Despite lower postoperative scores for obese patients, when preoperative scores were taken into account, obese patients demonstrated similar amounts of improvement in knee and functional scores. Although the results of Winiarsky at el were limited to self-report measures of function, and not performance-based measures, these results suggest that patients with BMIs greater than 40 kg/m^2 have compromised physical function largely because of lower preoperative scores.

Amin et al [12] compared patients with BMIs of more than 40 kg/m^2 and those with BMIs less than 30 kg/m^2. They found that 4 years after TKA, morbidly obese patients had inferior Knee Society scores, a higher incidence of radiolucent lines (density changes in the cement-bone interface) on postoperative radiographs, a higher rate of complications, and more pain and more revisions. In contrast, the same authors later reported that when 370 patients with TKA were divided onto groups of BMI less than 30 kg/m^2 and BMI more than 30 kg/m^2, there were no differences in Knee Society scores between subgroups. Although it was not clear what the average BMI was for each group and how many patients had BMIs >30 kg/m^2, these results further suggest that TKA outcomes in patients with BMIs between 30 and 40 kg/m^2 are comparable with those of the nonobese patients.

Hawker et al [17] examined patients with BMIs similar to those of the present study (BMI <40 kg/m^2) and found that a greater BMI was associated with worse self-reported physical function but was not a significant predictor of pain or the need for a subsequent revision as long as 7 years after TKA. These results further illustrate the lack of consensus in the literature regarding the impact of obesity on TKA outcomes. However, these results suggest that although outcomes for obese patients may not be as good as for nonobese patients, a replacement does provide relief of pain for obese patients who have advanced OA of the knee. Additional investigations have found no relationship between obesity and revision rates, complications, or decreased self-report physical performance [33,36,37].

Regardless of conflicting evidence for BMIs greater than 40 kg/m^2 influencing TKA outcomes, there are clear relationships between morbid obesity and other health problems, such as cardiac disease and diabetes, that warrant counseling for weight reduction for overall health benefits [3]. In this population, it can be extremely difficult for obese patients to lose weight before surgery, as their level of activity is compromised not only by the obesity but also by the arthritis in their knees [36]. Therefore, overweight patients are still at an increased risk of developing serious and sometimes life-threatening illnesses and should be appropriately counseled to lose weight after TKA surgery even if obesity does not compromise functional performance after TKA.

Compared to previous studies, strengths of the current investigation include the use of performance-based measures and standardization of a progressive postoperative rehabilitation program. All patients were treated identically with the progressive rehabilitation program to maximize patient outcomes. A limitation of the current investigation was the exclusion criteria (diabetes, uncontrolled hypertension, and BMI <40 kg/m^2), which may limit the generalizability of these results. Therefore, it remains uncertain if patients with higher BMIs and a greater number of comorbid conditions would exhibit some relationship between degree of obesity and functional performance.

As the prevalence of obesity continues to rise [3], understanding the relationship between obesity and TKA outcomes becomes increasingly important. The present study is the first to objectively capture physical performance outcomes in patients with BMIs less than 40 kg/m^2 rather than relying on self-report measures. Despite our hypothesis that higher BMI would negatively impact physical function after TKA, our results suggest there is no meaningful relationship between BMI and functional performance in the subacute (1 and 3 months) and intermediate (6 months) stages of recovery for BMIs less than 40 kg/m^2 in patients meeting the aforementioned exclusion criteria. There is a weak relationship with perceived function (KOS-ADLS). Therefore, BMI alone should not be used as a strong determinant for anticipating performance outcomes or exclusion of surgery in patients who have few comorbidities and BMIs less than 40 kg/m^2. Additional investigation is necessary to determine whether the results of the present study persist even years after TKA and whether these results are similar in individuals with BMIs more than 40 kg/m^2 and a greater number of comorbidities.

Acknowledgments

This study was funded by a National Institutes of Health (NIH) grant (R01-HD041055). Support for investigators was also provided by an NIH training grant (T32HD007490) and the American Physical Therapy Association Foundation (PODS I, II, Mary McMillan scholarships). We wish to acknowledge the expertise of the physical therapists at the University of Delaware Physical Therapy Clinic (Newark, Del) as well as Michael Axe, MD, Alex Bodenstab, MD, William Newcomb, MD, and Leo Rasis, MD at First State Orthopaedics (Newark, Del).

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Table 1

Mean ± SD of Functional Outcome Measures

	Preoperative (n = 140)	1 mo (n = 140)	3 mo (n = 120)	6 mo (n = 106)
BMI (kg/m^2)	30.8 ± 5.2	30.0 ± 4.5	30.5 ± 4.8	30.5 ± 4.6
TUG test (s)	10.0 ± 2.7	11.8 ± 3.8	8.2 ± 1.9	8.0 ± 1.8
SCT (s)	20.3 ± 9.7	26.2 ± 11.7	13.7 ± 4.8	12.8 ± 4.8
6MW* (m)	456 ± 114	400 ± 105	521 ± 111	532 ± 113
SF-36 PCS	32.2 ± 8.5	29.1 ± 6.4	43.1 ± 7.6	45.6 ± 8.7
SF-36 MCS	56.0 ± 8.8	51.0 ± 10.9	56.6 ± 7.9	56.3 ± 6.8
KOS-ADLS	0.53 ± 0.32	0.56 ± 0.13	0.80 ± 0.11	0.85 ± 0.11

*For 6MW, n = 118, 118, 100, and 85 for preoperative, 1, 3, and 6 months, respectively.

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Table 2

Comparison of Regression Models Used to Predict (a) 1-Month TUG (n = 140), (b) 3-Month TUG (n = 120), and (c) 6-Month TUG (n = 106)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo TUG						
Preoperative TUG	0.585	0.338	0.343	71.952	1,138	<0.001
Preoperative TUG + BMI	0.586	0.334	<0.001	0.080	1,137	0.778
(b) Model for 3-mo TUG						
Preoperative TUG	0.756	0.568	0.571	157.220	1,118	<0.001
Preoperative TUG + BMI	0.757	0.566	0.002	0.549	1,117	0.460
(c) Model for 6-mo TUG						
Preoperative TUG	0.738	0.541	0.545	124.535	1,104	<0.001
Preoperative TUG + BMI	0.742	0.542	0.006	0.431	1,103	0.247

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Table 3

Comparison of Regression Models Used to Predict (a) 1-Month SCT (n = 140), (b) 3-Month SCT (n = 120), and (c) 6-Month SCT (n = 106)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo SCT						
Preoperative SCT	0.588	0.341	0.346	72.409	1,138	<0.001
Preoperative SCT + BMI	0.589	0.338	0.002	0.323	1,137	0.571
(b) Model for 3-mo SCT						
Preoperative SCT	0.664	0.437	0.441	93.266	1,118	<0.001
Preoperative SCT + BMI	0.665	0.432	<0.001	0.031	1,117	0.861
(c) Model for 6-mo SCT						
Preoperative SCT	0.559	0.306	0.312	47.198	1,104	<0.001
Preoperative SCT + BMI	0.560	0.300	0.001	0.152	1,103	0.698

Table 4

Comparison of Regression Models Used to Predict (a) 1-Month 6MW (n = 118), (b) 3-Month 6MW (n = 100), and (c) 6-Month 6MW (n = 85)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo 6MW						
Preoperative 6MW	0.640	0.404	0.409	78.401	1,116	<0.001
Preoperative 6MW + BMI	0.643	0.403	0.004	0.779	1,115	0.366
(b) Model for 3-mo 6MW						
Preoperative 6MW	0.815	0.661	0.665	189.448	1,98	<0.001
Preoperative 6MW + BMI	0.817	0.660	0.002	0.628	1,97	0.421
(c) Model for 6-mo 6MW						
Preoperative 6MW	0.864	0.744	0.747	238.819	1,83	<0.001
Preoperative 6MW + BMI	0.865	0.742	0.001	0.288	1,82	0.603

Table 5

Comparison of Regression Models Used to Predict (a) 1-Month SF-36 PCS (n=140), (b) 3-Month SF-36 PCS (n = 120), and (c) 6-Month SF-36 PCS (n = 106)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo PCS						
Preoperative PCS	0.390	0.146	0.152	24.743	1,138	<0.001
Preoperative PCS + BMI	0.392	0.141	<0.001	0.225	1,137	0.636
(b) Model for 3-mo PCS						
Preoperative PCS	0.487	0.230	0.237	36.933	1,118	<0.001
Preoperative PCS + BMI	0.487	0.224	0.000	0.012	1,117	0.912
(c) Model for 6-mo PCS						
Preoperative PCS	0.452	0.197	0.204	26.713	1,104	<0.001
Preoperative PCS + BMI	0.468	0.203	0.014	1.877	1,103	0.174

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Table 6

Comparison of Regression Models Used to Predict (a) 1-Month SF-36 MCS (n = 140), (b) 3-Month SF-36 MCS (n = 120), and (c) 6-Month SF-36 MCS (n = 106)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo MCS						
Preoperative MCS	0.405	0.158	0.164	27.124	1,138	<0.001
Preoperative MCS + BMI	0.407	0.154	0.002	0.264	1,137	0.608
(b) Model for 3-mo MCS						
Preoperative MCS	0.403	0.156	0.163	23.111	1,118	<0.001
Preoperative MCS + BMI	0.403	0.148	0.000	0.005	1,117	0.941
(c) Model for 6-mo MCS						
Preoperative MCS	0.396	0.149	0.157	19.370	1,104	<0.001
Preoperative MCS + BMI	0.400	0.144	0.003	0.394	1,103	0.531

Table 7

Comparison of Regression Models Used to Predict (a) 1-Month KOS (n = 153), (b) 3-Month KOS (n = 129) and (c) 6-Month KOS (n = 111)

	r	R^2	R^2 Change	F Change	*df*	Significant F Change
(a) Model for 1-mo KOS						
Preoperative KOS	0.178	0.025	0.032	4.520	1,138	0.035
Preoperative KOS + BMI	0.187	0.021	0.003	0.465	1,137	0.496
(b) Model for 3-mo KOS						
Preoperative KOS	0.268	0.064	0.072	9.125	1,118	0.003
Preoperative KOS + BMI	0.366	0.120	0.063	8.450	1,117	0.004
(c) Model for 6-mo KOS						
Preoperative KOS	0.263	0.060	0.069	7.702	1,104	0.007
Preoperative KOS + BMI	0.353	0.108	0.056	6.543	1,103	0.012