**Weight and Activity Change in Overweight and Obese
Patients after Primary Total Knee Arthroplasty**

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Abstract

Obesity is associated with osteoarthritis of the knee. It is anticipated that after successful total knee arthroplasty, patient activity should increase and body weight should decrease. There are little prospective data on the effect of primary total knee arthroplasty on the weight and activity level of overweight and obese patients in the United States.

We conducted a prospective study of changes in patient weight, body mass index (BMI), and activity level over two years in 219 consecutive patients, 188 (86%) of whom were overweight or obese (BMI ≥ 25). Weight and BMI were assessed preoperatively and at one and two years. Physical activity level was evaluated using the Lower Extremity Activity Scale (LEAS), a self-assessment instrument. Multiple linear regression was used to examine the relationship between preoperative LEAS score and weight/BMI at two years of follow-up.

At two years postoperatively, weight and BMI data were available for 152 patients (81%) with BMI ≥ 25 . No mean weight change was found ($p=0.80$), but mean BMI increased significantly by 0.46 kg/m² ($p=0.049$). Mean LEAS score for 96 patients increased significantly from preoperative to two years ($p<0.001$). At two years follow-up, 17% of patients had lost $\geq 5\%$ of body weight, 23% had gained $\geq 5\%$ of weight, and 60% had $<5\%$ change in weight. Preoperative LEAS score was not associated with weight ($p=0.13$) or BMI ($p=0.08$) at two years.

After primary total knee arthroplasty, mean patient weight did not change and BMI increased at two years, despite an apparent increase in activity level. These findings have important implications for patient expectations and preoperative counseling.

Table of Contents

Manuscript	5
Introduction	5
Methods.....	7
Results.....	13
Discussion.....	20
Introduction Addendum.....	24
<i>Background</i>	
Overweight and Obesity in the United States.....	24
Osteoarthritis of the Knee.....	25
Obesity and Osteoarthritis of the Knee.....	26
Outcomes of Total Knee Arthroplasty in Obese Patients.....	29
<i>Systematic Review of the Studies on Weight/Body Mass Index Change after Total Joint Arthroplasty</i>	
Selection of Articles.....	34
Appraisal of the Literature.....	35
Tables of Studies in Systematic Review.....	Appendix
Discussion Addendum.....	44
Research in Context.....	44
Critical Appraisal of Study.....	44
Implications for Clinical Practice.....	47
Perspectives for Future Research.....	49
References.....	50

Introduction

The prevalence of overweight and obesity among adults in the general population is increasing, and in 2003-2004, 66.3% of adults 20 years of age or older were overweight or obese (Body Mass Index (BMI) > 25 kg/m²).¹ This rise has also occurred within the age-groups that most frequently have total knee arthroplasty as 71.0% of adults $\geq$ 60 years are overweight or obese.^{1, 2} The prevalence of overweight and obesity among adults may even be higher among patients having total knee arthroplasty because increased weight is a risk factor for osteoarthritis of the knee.³ Overweight and obese patients with symptomatic knee arthritis commonly undergo total knee arthroplasty for severe pain and disability. Patients anticipate pain relief after arthroplasty, hopefully leading to an increase in activity level and a decrease in weight.

Total knee arthroplasty relieves pain and improves function in patients with a variety of arthritic disorders for as long as fifteen years following surgery.^{4, 5} Several studies have shown that even obese patients can have a successful outcome with only a slightly increased risk of complications.⁶⁻¹¹ However, high preoperative weight and BMI have been reported to be a risk factor for surgical complications and adverse postoperative outcomes.¹¹⁻¹³

Less is known about whether patients' weight or BMI change following arthroplasty. The preoperative weight of these patients is of interest because some surgeons recommend preoperative weight loss to

facilitate the procedure and to decrease complications.⁶ We, like others, have found that overweight and obese patients often claim they are unable to lose weight because pain from severe arthritis of the knee limits their activity and thus their ability to expend calories.¹⁴ The patients often believe that total knee arthroplasty will permit an increase in their physical activity and enable them to lose weight postoperatively.

Few studies have investigated weight change or BMI change after primary total knee arthroplasty.¹⁵⁻¹⁷ Previous studies examining weight and BMI change after total knee or total hip arthroplasty have found mixed results, but, overall, they suggest that lower extremity arthroplasty does not facilitate weight loss. Three studies in the United Kingdom and one in the United States found that total hip arthroplasty patients gained weight^{14, 16, 17} or increased BMI¹⁸ postoperatively. Woodruff and Stone¹⁶ and Heisel et al.¹⁷ found that patients undergoing total knee arthroplasty had an increase in mean body weight, but the results were not statistically significant. Pritchett and Bortel found that morbidly obese women, who were advised by a physician to lose weight and were counseled by a dietician, had no sustained weight loss and 24% gained weight following total knee arthroplasty.¹⁵

Previous studies of weight change in total knee arthroplasty patients are limited by small sample sizes and the lack of data on change in activity level and change in BMI. The present study prospectively examined whether overweight or obese American patients lose weight

after primary total knee arthroplasty. Our hypothesis was that, although patient activity level would generally increase after total knee arthroplasty, weight and BMI would not change. We also investigated whether preoperative activity level was associated with weight/BMI change in these patients after arthroplasty.

Methods

Participants

We prospectively followed 219 consecutive patients after they underwent primary total knee arthroplasty performed by one surgeon at an American university medical center between May 1998 and December 2003. All patients with BMI less than 25 kg/m² (n = 31) were excluded from the analysis since it would be undesirable for normal weight or underweight patients to lose weight after total knee arthroplasty. If a patient with staged bilateral arthroplasties had both operations during the five year period, only data collected from the time of the second operation were analyzed. All charts were reviewed and data were collected by one investigator (AL). The research protocol was reviewed and approved by the Institutional Review Board of the University of North Carolina.

Procedures and Data Collection

Outcome variables

Patient height and weight, with clothing and shoes, were recorded preoperatively and at one year and two year follow-up visits by one of two nursing personnel using one scale (Scale-tronix 6002, Scale-tronic, Wheaton, Illinois) accurate to one-tenth of a pound. Weight and height were converted to BMI as defined by the ratio of body weight in kilograms divided by the height in meters squared (kg/m^2).¹³ Patients were classified by preoperative BMI as normal weight ($\text{BMI} < 25 \text{ kg/m}^2$), overweight ($25.0 - 29.9 \text{ kg/m}^2$), obese class I ($30.0 - 34.9 \text{ kg/m}^2$), obese class II ($35.0 - 39.9 \text{ kg/m}^2$), and morbidly obese ($\text{BMI} \geq 40 \text{ kg/m}^2$).¹⁹

Independent Variables

Several patient characteristics and demographic variables were collected preoperatively, including age, gender, and orthopedic diagnosis. Preoperatively and at one and two years of follow-up, data were also collected on arthritic co-morbidities and typical activity level.

Co-morbidities potentially affecting mobility were assessed preoperatively and at one year and two year follow-up visits using the three patient classifications described by Charnley,²⁰ which we modified for knees (Supplementary Table 1). Class A patients had unilateral knee arthroplasty and no other problems limiting ambulation. Class B patients had bilateral knee arthroplasty or unilateral knee arthroplasty and arthritis

in the contralateral knee severe enough to limit ambulation. Class C patients had unilateral or bilateral knee arthroplasty and multiple arthritic problems or other conditions directly impeding ambulation, such as rheumatoid arthritis, neurological conditions, or lumbosacral arthritis. The Charnley patient classification was originally designed for use in patients undergoing total hip arthroplasty but has been modified for use in knee arthroplasty patients in several publications.^{17, 21-23} Although the Charnley classification scheme has never been systematically validated, it has been used by convention for over two decades to describe ambulatory function in lower extremity arthroplasty patients.

Supplementary Table 1: Description of Modified Charnley Scale

Class A	Unilateral knee arthroplasty and no other problems limiting ambulation
Class B	Bilateral knee arthroplasty or unilateral knee arthroplasty and arthritis in the contra-lateral knee severe enough to limit ambulation
Class C	Unilateral or bilateral knee arthroplasty and multiple arthritis problems or other conditions directly impeding ambulation

Patient activity level was assessed preoperatively and at one year and two year follow-up visits with the Lower extremity Activity Scale (LEAS),²⁴ used prospectively since September 1998 (Supplementary Figure 1). This self-administered scale reflects an individual's typical daily activity, including frequency and intensity. The LEAS is well-suited to measure activity change in total hip or knee arthroplasty patients because while other commonly used activity instruments measure maximum capability, the LEAS describes actual activity.²⁴ The LEAS is a linear, 12

item scale scored from 1-18 with a score of 1 being “I am confined to bed all day,” 9 being “I am up and about at will in my house and can go out and walk as much as I like with no restrictions (weather permitting),” and 18 being “I am up and about at will in my house and outside. I also participate in vigorous physical activity such as competitive level sports daily.” This instrument has recently been validated to measure physical activity in patients with revision total knee arthroplasty.²⁴ However, the LEAS has also been tested in patients undergoing primary total knee arthroplasty as well as total hip arthroplasty.²⁵

Lower Extremity Activity Scale*

Please read through each description given below, pick the **ONE** description that best describes your regular daily activity and put a check in that box (Check only one box).

- ☐ 1. I am confined to bed all day. (1)
- ☐ 2. I am confined to bed most of the day except for minimal transfer activities (going to the bathroom, etc.) (2)
- ☐ 3. I am either in bed or sitting in a chair most of the day. (3)
- ☐ 4. I sit most of the day, except for minimal transfer activities, no walking or standing. (4)
- ☐ 5. I sit most of the day, but I stand occasionally and walk a minimal amount in my house. (I may rarely leave the house for an appointment and may require the use of a wheelchair or scooter for transportation.) (5)
- ☐ 6. I walk around my house to a moderate degree but I don't leave the house on a regular basis. I may leave the house occasionally for an appointment. (6)
- ☐ 7. I walk around my house and go outside at will, walking one or two blocks at a time. (7)
- ☐ 8. I walk around my house, go outside at will and walk several blocks at a time without any assistance (weather permitting). (8)
- ☐ 9. I am up and about at will in my house and can go out and walk as much as I would like with no restrictions (weather permitting). (9)
- 10. I am up and about at will in my house and outside. I also work outside the house in a:
 - ☐ minimally (10)
 - ☐ moderately (11)
 - ☐ extremely active job (12)
 (Please check the best description of your work level.)
- 11. I am up and about at will in my house and outside. I also participate in relaxed physical activity such as jogging, dancing, cycling, swimming:
 - ☐ occasionally (2-3 times per month) (13)
 - ☐ 2-3 times per week (14)
 - ☐ daily (15)
 (Please check the best description of how often you participate in this activity.)
- 12. I am up and about at will in my house and outside. I also participate in vigorous physical activity such as competitive level sports
 - ☐ occasionally (2-3 times per month) (16)
 - ☐ 2-3 times per week (17)
 - ☐ daily (18)
 (Please check the best description of how often you participate in this activity.)

* actual score obtained is specified in parentheses at end of whichever statement is chosen

Supplementary Figure 1. Lower Extremity Activity Scale²⁴ Reprinted with permission from The Journal of Bone and Joint Surgery, Inc.

Statistical Analysis

Univariate statistics were used to describe all study variables and examine the distribution of continuous variables for all overweight and

obese patients. The preoperative characteristics of patients who were included in the analyses were compared to those of patients who had incomplete data at one or two years of follow-up using 2-Sample t-tests for continuous variables and Pearson's chi-squared tests for categorical variables.

The percentages of patients who gained, lost, or had no change in weight from preoperative to two years of follow-up were calculated. The United States Food and Drug Administration considers a five percent reduction in weight to be clinically significant weight loss.²⁶ Therefore, patients whose weight decreased by 5% or more were considered to have lost weight, while patients whose weight increased by 5% or more were considered to have gained weight. All other patients were classified as having no significant weight change.

The difference in mean change in weight and BMI from preoperative to one and two years of follow-up was analyzed using a Paired t-test. We examined mean changes for the entire sample as well as the subgroups when the sample was stratified by gender and by pre-operative BMI as either overweight ($25 \leq \text{BMI} < 30$) or obese ($\text{BMI} \geq 30$).

Bivariate analyses were performed to determine associations between weight/BMI at two years and all other study variables, to examine the unadjusted associations between preoperative LEAS score and patient characteristics, and to test for collinearity. 2-Sample t-test was used for variables in two categories, one-way analysis of variance for

variables with more than two categories, and Pearson's Correlation for continuous variables as appropriate. Analyses for BMI were repeated using the Wilcoxon Rank-sum test for variables in two categories, the Kruskal-Wallis test for variables with more than two categories, and Spearman's Correlation for continuous variables.

Multiple linear regression was used to examine the relationship between preoperative LEAS score and weight/BMI at two years of follow-up. The primary outcomes, weight and BMI, and the exposure, preoperative LEAS score, were all treated as continuous variables. Pre-operative weight/BMI, age, gender, pre-operative Charnley class were included in the regression models.

All P values were two-sided, and $p < 0.05$ was considered statistically significant. Stata Statistical Software version 9.0²⁷ was used for all analyses.

Results

Preoperative data were recorded for 219 patients (Figure 1). After excluding 31 underweight or normal weight patients, postoperative data were recorded for 188 overweight/obese patients who were followed for a mean of 21 months. Data were available at one year follow-up for 165 patients (87.8%): 12 patients had no follow-up data and 11 patients had only two year follow-up data. Data were available at two years for 152 patients (80.9%): 12 patients had no follow-up data and 24 patients had

only one year follow-up data. Patients were excluded due to death, untimely follow-up, refusal to return for follow-up, or were lost to follow-up. Overall, 141 patients had preoperative, one-year, and two year follow-up data; 11 had preoperative and two-year data only; 24 had preoperative and one-year data only; and 12 had preoperative data only.

Figure 1. Study flow chart.

Characteristics of All TKA Patients

One hundred and forty-three patients (65%) had a unilateral arthroplasty, 59 (27%) had one-stage bilateral arthroplasty, and 17 (8%) had staged bilateral arthroplasty. One hundred and sixty-one patients (74%) were female and 58 (26%) were male. The mean age was 71.5 years (range 41-94 years). The preoperative diagnosis was osteoarthritis in 185 patients (84%); rheumatoid arthritis in 12 (5%); osteonecrosis in 6 (3%); psoriatic arthritis in 5 (2%); traumatic arthritis in 4 (2%); and a variety of other diagnoses in 6 (4%).

Characteristics of Overweight/Obese Patients

Preoperatively, 188 patients (86%) were classified by BMI as either overweight or obese (Table 1). Of these, 100 patients (53%) were overweight, 52 (28%) were in obesity class I, 32 (17%) were in obesity class II, and 4 (2%) had extreme obesity. Among overweight or obese patients, 123 (65%) patients had a unilateral arthroplasty, 50 (26.5%) had one-stage bilateral arthroplasty, and 16 (8.5%) had staged bilateral arthroplasty. One hundred and forty patients (74%) were female and 48 (26%) were male. The mean age was 71 years (range 41-89). The preoperative orthopaedic diagnosis was osteoarthritis in 160 (85%); rheumatoid arthritis in 10 (5%); psoriatic arthritis in 5 (3%); osteonecrosis in 4 (2%); traumatic arthritis in 4 (2%); and a variety of other diagnoses in 5 (3%). When preoperative characteristics were compared, no significant

differences existed between overweight/obese patients who were included in the analyses and those patients who were not interviewed or lacked LEAS data at two years of follow-up.

Table 1. Preoperative Characteristics of Overweight or Obese Patients (n=188).

Characteristic	Mean (s.d) or percent	range
Mean age	70.9 (8.7)	41-89
% Female	74	
Mean weight (kg)	84.9 (12.6)	54.4-117.0
Mean body mass index (kg/m ²)	30.8 (4.0)	25-42.1
BMI classification		
Overweight (25≤BMI<30)	53	
Obesity class I (30≤BMI<35)	28	
Obesity class II (35≤BMI<40)	17	
Morbidly obese (BMI≥40)	2	
Mean activity level	7.9 (2.7)	2-17
Charnley		
Class A	23	
Class B	42	
Class C	35	
Staging		
Unilateral	65	
One-stage bilateral	26.5	
Staged bilateral	8.5	
Diagnosis		
Osteoarthritis	85	
Rheumatoid arthritis	5	
Other	10	

When the sample was stratified by gender, female patients had significantly lower weight ($p<0.001$), greater BMI ($p=0.03$), and lower activity level ($p=0.002$) than did male patients. Males and females did not differ significantly on other preoperative characteristics (data not shown).

The percent of patients who gained, lost, or had no change in weight from preoperative to two years of follow-up were calculated. At two years of follow-up, 17% of patients had lost weight $\geq 5\%$ of body weight, 23% had gained $\geq 5\%$ of body weight, and 60% had $< 5\%$ change in weight. These percentages did not differ by gender or preoperative obesity status (data not shown).

Table 2: Patient Weight Change at 2 Years Postoperatively.*

	2 Years Postoperatively (n=152)
% Lost Weight	17
% No Weight Change	60
% Gained Weight	23

*Weight change is $\geq 5\%$ or $\leq 5\%$ of weight from preoperative

At two years postoperatively, no significant mean weight loss was found, but mean BMI increased (Table 3). Mean postoperative weight loss was 0.14 kg (95% CI: -1.3-1.0, $p=0.80$). Mean postoperative BMI at two years increased by 0.46 kg/m² (95% CI: 0.00-0.92, $p=0.049$). When patients with preoperative and one year follow-up data were analyzed, no significant weight or BMI changes were detected (data not shown).

Mean changes were also examined with patients stratified by gender and by preoperative BMI as overweight ($25 \leq \text{BMI} < 30$) and obese ($\text{BMI} \geq 30$). When patients were stratified by gender, no significant mean weight loss was found and the increase in BMI was no longer statistically significant (data not shown). When patients were stratified by preoperative BMI, no significant mean weight loss was found, and BMI increased

significantly among overweight patients but not among obese patients (Table 3).

LEAS scores were available preoperatively, at one and at two-years for 87 overweight and obese patients (46%), preoperatively and at one-year for 116 patients (62%), and preoperatively and at two-years for 92 patients (49%). Mean LEAS activity level increased significantly postoperatively (Table 3). Mean activity score increased by 1.8 points (95% CI: 1.3-2.3, $p < 0.001$) from preoperative to year two. Significant changes in mean activity level were also found among patients with one year of follow-up, among female and male patients (data not shown), and among overweight and obese patients (Table 3).

Table 3: Comparison of Mean Weight, BMI, and Activity for Patients with 2 year follow-up data.

All Patients	n	Preoperatively	At 2 years	p-value*
Mean Weight (kg)	152	85.5	85.4	0.80
Mean BMI (kg/m ²)	152	30.9	31.3	0.049
Mean LEAS Score (1-18)	92	8.0	9.9	<0.001
Overweight Patients	n	Preoperatively	At 2 years	p-value
Mean Weight (kg)	78	78.0	78.1	0.85
Mean BMI (kg/m ²)	78	27.7	28.4	0.008
Mean LEAS Score	42	7.9	9.7	<0.001
Obese Patients	n	Preoperatively	At 2 years	p-value
Mean Weight (kg)	74	93.5	93.0	0.67
Mean BMI (kg/m ²)	74	34.2	34.4	0.63
Mean LEAS Score	50	8.0	9.9	<0.001

*Significance test for comparisons based on the Paired T-test.

Several significant associations were detected between patient characteristics and weight, BMI, and preoperative LEAS. Age and pre-operative weight were positively correlated with postoperative weight at

the $p < 0.001$ significance level. Similarly, age and preoperative BMI were positively correlated with postoperative BMI ($p < 0.001$). Males were more likely to have higher weights after two years ($p < 0.001$). Females tended to have higher BMI after two years, but this was not statistically significant when BMI was assumed to have a non-parametric distribution ($p = 0.07$). When patients were stratified by preoperative BMI, obese patients were significantly younger than overweight patients ($p < 0.001$). Preoperative LEAS score was significantly higher among males patients ($p = 0.002$).

Multiple linear regression was also used to identify the relationship between preoperative LEAS score and weight/BMI at two years, adjusted for covariates. The models included preoperative LEAS score, preoperative weight or BMI, age, gender, and preoperative Charnley classification as covariates. Preoperative LEAS score is not associated with weight or BMI at two years postoperatively (Table 4).

Table 4. Adjusted Comparisons Between Preoperative LEAS score[†] and 2 yr Weight (kg) and BMI (kg/m²).

Preoperative LEAS score	n (total 109)	Adjusted* Mean 2 yr Weight	p-value	Adjusted** Mean 2 yr BMI	p-value
3	1	118.4	0.13	30.9	0.078
5	5	99.4		34.4	
7	36	86.3		32.1	
9	2	85.5		26.8	
11	10	89.8		30.9	
13	2	79.9		32.9	
15	2	100.7		33.2	
17	1	104.3		31.7	

[†]Predicted estimates for selected values of LEAS

*Based on the means from the multiple linear regression model, adjusted for preoperative weight, age, gender, and Charnley classification

**Based on the means from the multiple linear regression model, adjusted for preoperative BMI, age, gender, and Charnley classification

Discussion

Two years after primary total knee arthroplasty, this cohort of overweight and obese patients experienced no change in mean weight, but an increase in mean BMI. These findings occurred despite an apparent increase in activity level. Only 17% of patients had lost $\geq 5\%$ of body weight by two years postoperatively. Preoperative LEAS score was not associated with weight or BMI at two years.

Although we were unable to identify which patients were most likely to lose weight after arthroplasty, 17% of patients did lose a notable amount of weight two years after total knee arthroplasty. It is not clear if this is higher or lower than the percentage of all overweight or obese adults aged 41-89 in the general population who experience weight loss over two years. Perhaps total knee arthroplasty does allow some overweight/obese patients to lose weight more easily than they would without arthroplasty. However, this question is beyond the scope of our study.

These results are similar to those found in previous studies of weight or BMI change among total knee arthroplasty patients. Neither Woodruff and Stone,¹⁶ following 68 knee patients, nor Heisel et al.,¹⁷ examining 45 knee patients, found a significant change in mean weight. Similarly, Pritchett and Bortel found that 45 morbidly obese women had no sustained weight loss. Our study found the same conclusion among

overweight and obese patients even when statistical power was increased by including 152 patients in our analyses.

Unlike previous studies of knee arthroplasty patients, we also examined change in BMI. Often studies of weight change among adults do not include BMI because adult height generally remains constant. However, decreasing height with age is well-documented,²⁸ and we found that many of our patients lost height over the two year period. This height reduction may explain why BMI, but not weight increased significantly at two years of follow-up.

We examined preoperative LEAS score in an attempt to identify which patients were most likely to experience weight or BMI change two years after arthroplasty. Preoperative LEAS score was not significantly associated with weight or BMI change at two years. The relationship between weight and activity is unclear. Similar to our results, Elia et al. found no correlation between physical activity and BMI in subjects over age 65,²⁹ but McClung et al. reported that lower activity, measured with a pedometer, was associated with a higher BMI among 151 hip and knee arthroplasty patients.²³ This disagreement may result from the differences in the tools used to measure typical activity.

This study has several limitations. Although it was a prospective study, the case series design increased the potential for both confounding and selection bias. While we examined the relationship between preoperative LEAS score and weight at two years, Jain et al. surveyed

total hip arthroplasty patients about their weight postoperatively and reported that many factors influenced postoperative weight change including illness, change in diet, and enjoyment of food.¹⁸ Although we analyzed co-morbidities limiting ambulation using a modified Charnley classification, we did not identify all co-morbidities that may have affected weight change in this population.

In addition, only 81% of patients had weight/BMI data at two years and 49% had completed the LEAS both preoperatively and at two years. Although no significant differences in preoperative characteristics were detected between patients who were included and excluded in weight/BMI or LEAS analyses, unknown differences may exist between patients who returned for follow-up and those who were not interviewed at follow-up or between patients who completed the LEAS form and those who failed to complete the LEAS form.

The validity of these findings is strengthened by our large consecutive sample with a robust follow-up percentage. One surgeon interviewed and operated on all patients, and two trained personnel performed all weight and height measurements. Unlike previous studies, we limited our population to only overweight and obese primary total knee arthroplasty patients and followed patients until two years post-operatively.

The generalizability of these results may be limited to patients having total knee arthroplasty at academic medical centers in the Southeastern United States. However, we suspect that this is not the case

because the characteristics of our population are comparable to most populations of patients undergoing primary total knee arthroplasty in the United States.²

The findings of this study have important implications for patient expectations and counseling prior to primary total knee arthroplasty. Although increased patient weight does not prevent a successful surgical outcome, overweight and obese patients should not expect total knee arthroplasty alone to result in weight loss.

Introduction Addendum (Background and Systematic Review)

Background

Overweight and Obesity in the United States

Quetelet's Index or Body Mass Index (BMI), defined by the ratio of body weight in kilograms divided by the height in meters squared,³⁰ is often used to define overweight and obese.³¹ Frequently, people with BMI greater or equal to 25 kg/m² are considered overweight and people with BMI greater or equal to 30 kg/m² are considered obese.³¹ The National Heart, Lung, and Blood Institute guidelines divide patients into more specific, but also commonly used risk categories. Individuals are classified as underweight (BMI<18.5 kg/m²), normal (18.5≤BMI<25), overweight (25≤BMI<30), obese/obesity class I (30≤BMI<35), obese/obesity class II (35≤BMI<40) and extreme obesity/obesity class III (BMI≥40).¹⁹

From 1960 to 2002, the prevalence of overweight and obesity in the American population rose dramatically for people of all ages, sexes, and racial or ethnic groups. Mean weight for both adult men and women increased by more than 24 pounds. Mean BMI increased from 25.1 kg/m² to 27.8 kg/m² among men aged 20-74 and from 24.9 kg/m² to 28.2 kg/m² among women aged 20-74.³²

As the general population of the United States has become more overweight, so have those in the age-groups requiring total knee arthroplasty.² Nearly 60% of persons over age 65 report arthritis and/or chronic joint symptoms,³³ and total knee arthroplasty is most frequently

performed on patients greater than 60 years of age. The NHANES Survey from 1999-2001 indicates that most men and women 60 years of age or older are overweight or obese. Seventy-four percent of men 60 years or older are overweight (BMI $\geq$ 25) and 32% are obese (BMI $\geq$ 30). Similarly, 68% of women 60 years or older are overweight (BMI $\geq$ 25) and 32% are obese (BMI $\geq$ 30).³⁴

This trend has implications for physicians who care for patients with knee osteoarthritis (OA) and for surgeons who perform total knee arthroplasty. These physicians must be prepared to discuss with their patients the influence of increased weight on OA of the knee and the effect of obesity on surgical outcome of total knee arthroplasty.

Osteoarthritis of the Knee

OA is the most common form of arthritis, and more than 70% of total knee or hip arthroplasties are performed for symptomatic OA.³⁵ Six percent of adults 30 years or older have symptomatic knee OA and disease prevalence increases with age.³⁶ Over the age of 50, women have a higher prevalence of symptomatic knee OA than do men.³ In the Framingham Osteoarthritis Study, men and women aged 63-94 had similar prevalence of radiographic OA, but 31% of women reported knee symptoms compared to 21% of men.³⁷

Obesity and Osteoarthritis of the Knee

Several cross-sectional population-based studies have shown an association between obesity and OA. Data from the National Health and Nutrition Examination Survey of 1971-1975 (HANES I) identified a dose-response relation between current BMI and radiographic OA of the knee (p for trend < 0.001).³⁸ In addition, among women, there was a significant association between self-reported minimum adult weight, a proxy for long-term obesity, and radiographic OA of the knee (RR=2.66, 95% CI, 1.60-4.42). Similarly, the Behavioral Risk Factor Surveillance System in 2001 found that people with a BMI of 25-29.9 have 1.38 (95% CI, 1.31-1.44) times the odds of self-reported arthritis than do people of normal weight, adjusted for covariates.³⁹ The adjusted odds of arthritis increased to 2.03 (95% CI, 1.92-1.44) and 4.41 (95% CI, 3.91-4.97) for those with a BMI of 30-39.9 and BMI greater than 40, respectively.

While cross-sectional studies can only note associations, multiple cohort studies provide evidence that overweight/obesity is a strong risk factor for knee OA. Using the Framingham cohort, Felson et al. examined whether preoperative weight increased the risk of radiographic knee OA about 35 years later.⁴⁰ Adjusting for covariates, they found that women in the highest (RR=1.44; 95% CI, 1.11-1.86) and second quintiles of weight (RR=2.07; 95% CI, 1.67-2.55) and men in the highest quintile of weight (RR=1.51; 95% CI, 1.14-1.98) had a significantly higher risk of OA than did adults in the three lightest quintiles (normal weight or underweight).

The increase in risk was similar for both symptomatic and asymptomatic patients suggesting that obesity is contributing to knee OA, rather than severe knee pain leading to a sedentary lifestyle and obesity.

More recently, findings from the Framingham Osteoarthritis Study noted that higher BMI increased the risk of incident radiographic knee OA 10 years later (OR=1.6 per 5-unit increase; 95% CI, 1.2-2.2).⁴¹ Moreover, weight gain over 10 years was associated with the development of OA (OR=1.4 per 10-lb; 95% CI, 1.1-1.8). Spector et al. examined another subgroup in the Framingham Osteoarthritis Study, middle-age women in with radiographic unilateral knee OA, and found that BMI was the strongest risk factor for incident OA in the contralateral knee, but the relative risk was not significant.⁴²

Two studies from Northern Europe have looked at the relationship between BMI and clinically significant knee OA potentially leading to total knee arthroplasty. A cohort study of Finnish farmers followed for 10 years found that BMI was predictor of disabling knee OA.⁴³ The adjusted relative risk was 1.4 (95% CI, 1.2-1.5) per standard deviation of BMI (3.8 kg/m²). Järvholm et al. used total knee arthroplasty as a proxy for severe knee OA, and noted that among Swedish male construction workers higher BMI increased the risk of OA/arthroplasty both for men with high BMI and for men within the range of normal BMI.⁴⁴

Evidence suggesting that weight loss decreases the risk of symptomatic OA and reduces knee-joint forces during walking also helps

to strength this relationship. Among both all women and overweight women ($BMI \geq 25$) in the Framingham Osteoarthritis Study, a decrease in BMI of 2 units or more over 10 years decreased the odds for developing symptomatic OA by over 50% ($p=0.02$).⁴⁵ Another study found that when overweight and obese older adults with knee OA participated in an 18-month trial of diet and exercise, each pound of weight lost resulted in 4-fold reduction in the load exerted on the knee per step while walking.⁴⁶ While the study did not correlate load reduction to any patient-oriented outcomes, the authors suggest that a reduction of this magnitude would likely be clinically meaningful when accumulated over thousands of steps per day.⁴⁶

The biological mechanism by which excess weight may cause OA is still not completely clear, but may be due to both local mechanical stress and some systemic factor(s).⁴⁷ Evidence for the load theory is especially strong for knee OA because the force of body weight is multiplied many times as the load moves over the knee joint. The increase force on the joint is thought to induce cartilage breakdown or cause failure of ligamentous or other structural support leading to OA.³ Unknown systemic factors, perhaps a circulating cartilage growth factor or bone factor, may contribute to this relationship as well by accelerating cartilage breakdown.⁴⁷ This systemic theory is supported by a few studies showing that obesity increases the risk of OA of the hand, even though obesity does not dramatically increase the load over interphalangeal joints,^{47, 48} In

addition, most studies show that the relationship between obesity and OA is stronger in women than in men, which has not been explained by the load theory.^{3, 47}

Outcomes of Total Knee Arthroplasty in Obese Patients

Since obesity is a risk factor for knee OA, both obese and morbidly obese patients commonly have total knee arthroplasty. In the past, high patient weight has been considered a relative contraindication for total knee arthroplasty.⁶ One study examining long-term outcomes found that the best results, based on Knee Society scores and ten-year survival rates, were in non-obese women with OA over the age of 60, who had a ten-year survival rate of 99.4%.¹² Obese men with OA who were less than 60 years of age had the worse results and a ten-year survival rate of 35.7%.

Many other cases series have also compared the total knee arthroplasty outcomes of obese or morbidly obese patients to non-obese or normal weight patients. Overall, the evidence suggests that obese patients can have successful total knee arthroplasty with only a slight increase in intra-operative and postoperative complications. The extent and severity of the complications, however, is controversial. Moreover, since total knee arthroplasty is an elective procedure and patients are not randomly selected, these obese patients may only represent those patients judged by the surgeon to have the highest likelihood of successful

surgery. These studies may also over-represent wealthy individuals who are well-insured, receive good medical care, and perhaps, have less advanced disease.

Preoperative morbidity and a several peri-operative complications are thought to be higher among obese patients undergoing total knee arthroplasty. Miric et al., examining an extensive number of complications, found positive correlations between BMI and cardiac history ($p=0.02$), history of diabetes ($p=0.006$), postoperative hospital stays longer than 7 days ($p=0.03$), discharge to rehabilitation facility ($p=0.02$), and the risk of a postoperative complication ($p=0.004$).⁴⁹ The greatest differences were detected between patients with $BMI < 35$ and patients with $BMI \geq 35$. Patients with $BMI \geq 35$ were more likely than lighter patients to have a complication ($p=0.002$) as well as to experience multiple complications ($p=0.03$). In contrast, Jiganti et al. found that total hip and knee arthroplasty patients greater than 20% of ideal body weight were actually less likely to experience a minor or major peri-operative complication than lighter patients.⁷ Longer operative times among obese patients was the only outcome which reached statistical significance.

Few clinical differences have been detected between obese and non-obese patients after short-term follow-up. Stern and Insall found that total knee patients whose weight was greater than 120% of desired weight had no overall difference in Hospital of Special Surgery scores after 2-5 years of follow-up.¹¹ Patients whose weight was greater than 150% of

desired weight did report significantly more patellofemoral symptoms ($p < 0.03$). Smith et al. found that in total knee arthroplasty patients with two years of follow-up all differences between obese and non-obese patients in Hospital of Special Surgery scores, incidence of radiolucencies on x-ray, and peak extension torque disappeared after adjusting for gender and age.⁶ Similarly, Konig et al. found that overall Knee Society score (including knee and function scores) and knee score were not influenced by BMI, but higher BMI predicted a lower function score at a minimum of two years of follow-up.⁵⁰ In contrast, Foran et al. found that although obese and non-obese patient had similar preoperative knee and function Knee Society scores, patients with a BMI ≥ 30 had significantly lower knee and function scores five years after total knee arthroplasty.⁵¹

Short-term improvement and satisfaction is reported for both obese and non-obese patients after total knee arthroplasty. Deshmukh et al. noted definite improvements in both the Nottingham Health Profile and Knee Society score one year after total knee arthroplasty regardless of BMI.¹⁰ The results from a voluntary survey of over 1600 hip and knee arthroplasty patients found no difference in between patient satisfaction and decision to repeat surgery one year after arthroplasty.⁹ In addition, no difference were detected by BMI in change in physical or mental component summaries of the Short Form-36 or in change in Western Ontario and McMaster Universities Osteoarthritis Index scores. The

survey did find that BMI was significantly associated with an increase risk of having difficulty descending or ascending stairs one year after surgery.

Since obese patients have a higher risk of knee OA, perhaps due to greater mechanical loading of the knee, obese patients might also “wear out” their joints faster. However, evidence shows that obese patients can have successful total knee arthroplasty in the long-term. Spicer et al. found that obese ($BMI \geq 30$) and non-obese ($BMI < 30$) patients had similar ten-year survivorship figures and no differences in revisions or change in Knee Society scores.⁸ The authors noted that obese patients had lower preoperative Knee Society scores leading to lower postoperative scores, and although there was no difference in linear radiolucencies, obese patients had significantly more focal osteolysis on x-ray examination. Griffin et al. found that after ten years of follow-up, obese patients ($BMI \geq 30$) had lower Knee Society function scores and more patellofemoral symptoms than non-obese patients ($BMI < 30$). However, no differences were detected in overall Knee Society score, Hospital of Special Surgery score, or revision rates.¹³

Obese and non-obese patients may have different natural histories of total knee arthroplasty over the long-term. Foran et al. followed patients for 15 years and noted that differences in failure rates between obese ($BMI \geq 30$) and non-obese ($BMI < 30$) patients did not become statistically significant until after 14 years of follow-up.⁵² After 15 years, non-obese patients had a significantly greater number of polyethylene spacer

revisions suggesting increased wear from active use. On the other hand, obese patients, although not statistically significant, had a trend toward greater rates of aseptic loosening, which may be due to increase stress at the bone-prosthesis interface.⁵² Similarly, Ranawat et al. found that patients who weighted more than 80 kg had significantly lower survivorship after 15 years, and in their series of 112 knees, all patients with radiographically loose components weighed more than 80 kg.⁵ Since total knee arthroplasty survival rates reflect wear and use rather than time, obese patients may have successful long-term outcomes despite increased mechanical load, because higher BMI has been associated with lower activity in total joint arthroplasty patients.²³

Although evidence suggests that obese patients can have a successful outcome with total knee arthroplasty, morbidly obese patients may be at a greater risk for complications. Pritchett and Bortel found that, compared to non-obese women, morbidly obese women, who on average were 200% of ideal body weight, had greater operative blood loss and longer hospital stays as well as more patellofemoral symptoms and fewer good or excellent Knee Society scores at a mean follow-up of 33 months.¹⁵ After five years of follow-up, Winiarsky et al. noted that morbidly obese patients ($BMI \geq 40$) had significantly lower Knee Society scores ($p < 0.0001$) and higher peri-operative complications ($p < 0.0001$), including increased problems with primary wound-healing, wound infections, and avulsion of the medial collateral ligament

**Systematic Review of the Literature:
Lower extremity Arthroplasty and Weight/Body Mass Index Change**

We conducted a systematic review of the literature to identify studies examining the association between lower-extremity arthroplasty and postoperative weight or BMI.

Selection of Articles

The Medline/Pubmed database was searched the using exploded Medical Subject Headings (MeSH) descriptors: "arthroplasty," "body weight," and "body mass index". Searches were limited to English language articles published between January 1980 and April 2006.

Searching the combination of "arthroplasty" and "body weight" found 97 citations, while searching "arthroplasty" and "body mass index" found 53 citations. Twenty-three duplicate citations were discarded, and the remaining 127 titles were assessed for relevance. Inclusion criteria were that studies pertain to either total hip or total knee arthroplasty and that the titles contained words related to either weight/BMI (eg., "overweight" or "obese" or "weight change") or patient characteristics (eg. "patient-controllable factors" or "risk factors"), but not including "nutrition" or "nutritional factors." Eighty-one articles were excluded and the abstracts of the remaining 46 articles were reviewed. Articles not pertaining to postoperative weight or BMI changes were excluded. Editorials, comments, newspaper articles, and review articles were also excluded. The bibliographies of articles examining the outcomes of total knee

arthroplasty in overweight or obese patients were hand-searched for articles with titles that appeared relevant to our hypotheses (eg. articles about “body weight change” or body mass index change”).

The search resulted in 5 original research articles examining weight or body mass index change following total lower extremity arthroplasty (Appendix Table A). Two were case series,^{14, 16, 17} one was a prospective study,¹⁷ one was a retrospective study,¹⁸ and one was a non-randomized comparison study.¹⁵ One case series and the prospective study examined postoperative weight of both total knee and hip arthroplasty patients, while the other case series and the retrospective study examined only total hip arthroplasty patients. The comparison study examined weight change in morbidly obese women who elected to undergo total knee arthroplasty compared to both non-obese women that had arthroplasty and morbidly obese women who declined arthroplasty.

Appraisal of Literature Examining Weight or Body Mass Index Change Following Lower Extremity Arthroplasty

Internal Validity Ratings

Appendix Table B presents quality rating for each of the five articles during systematic review of the literature. The articles were assigned quality ratings by the primary reviewer (AL) using a 1-3 point scale checklist (1=poor, 2=fair, 3=good) for each of the components described below, i.e., setting and study population, measurement and data collection, statistical analyses, and overall reporting of results. Overall

quality score assessing internal validity was the average of the individual component scores.

Selection of Study Population

Selection of the study population was evaluated according to whether the source population was adequately described and whether the study population was representative of the source population. Only one study received a good for adequately describing the source population.¹⁸ Two different studies received a good rating on whether the study population represented the source population.^{14, 15} In one, the source population and study population were clearly the same,¹⁵ and in the other, the populations were the same except for three patients who were excluded for incomplete follow-up.¹⁴

Most studies received scores of fair or poor because of moderate potential for selection bias. Without a clear description of the source population, it was difficult to discern if the study population was representative. For example, one study population included 100 randomly selected patients, but how they were selected or who they were selected from was not described.¹⁷ Another study received a score of fair because the authors did not describe a source population, but implied that the source and study populations were the same.¹⁶ Jain et al. received a fair score because 20% of patients failed to return the questionnaire after second mailings.¹⁸

Measurements and Data Collection

Measurements were evaluated based on means of data collection, and identification of the data collectors. Studies received higher scores if the authors adequately described the method of collecting of weight and/or height data and any dependent variables analyzed. Reliability and validity was an important factor in measurement quality score. Studies received higher measurement scores if data collectors were identified.

Two studies received scores of poor/fair^{14, 18} and three studies received scores of poor.¹⁵⁻¹⁷ All studies have large potential for measurement bias. One study mentioned that postoperative weight and height were self-reported, implying that preoperative weight and height were measured.¹⁸ In addition, while these authors did not mention if their questionnaire was validated, they clearly described the components of the questionnaire, which included some validated scales. The other four studies had no mentioned of how weight and/or height were measured. One study acknowledged the three individuals who collected data.¹⁴ Without any description of measurement, it was impossible to know if either the effect or outcome measures were valid or reliable. Overall, these studies did a fair job of describing the other dependent variables that were collected, but did not clearly explain how they were measured or whether measurements were valid

Measurements and chart reviews were not blinded for any of the studies reviewed. While this could potential lead to incorrect or

manipulated data, any coding errors are likely be randomly distributed between patients who gained, lost, or had no change in weight.

Statistical Analysis and Confounding

Quality of analysis was based on the description and use of appropriate statistical methods and the potential for confounding of the results. While the knowledge of the unadjusted relationship between pre- and postoperative weight/BMI is valuable for patient counseling on expectations, studies received higher scores if the authors examined or controlled for any other factors that might influence the relationship.

These studies differed in analytical strategy and the extent of analysis. One study described the percentage of patients who gained and lost weight, but received a poor because no method of analysis was described¹⁵ Another study reported the mean absolute weight and BMI change, the correlation between pre-operative BMI and change in BMI, and the number of patients with unacceptable BMI, acceptable BMI, overweight BMI, and obese BMI pre- and postoperatively.¹⁸ This study received a fair because, while the analysis was more extensive, no method of statistical analyses was described. The other three looked for a statistically significant difference between preoperative and postoperative weight/BMI,^{14, 16, 17} and one of these compared changes between non-obese and obese patients.¹⁴ All three received good ratings for clear description of statistical techniques.

Although several studies stratified by gender, only two studies examined or attempted to control for other factors, such as preoperative function or ambulation capacity, that might confound the relationship between pre- and postoperative weight/BMI. One study also compared changes in Harris hip scores, which describe hip function, between obese and non-obese patients, but did not control for preoperative hip score when examining BMI change.¹⁴ Another study, however, examined weight change when patients were stratified by Charnley class, a description of ambulation capacity.¹⁷

Many reasons potentially exist causing patients to gain, lose, or experience no change in weight/BMI after undergoing total joint arthroplasty. These could be considered confounders in the relationship, but most authors sought only to know whether arthroplasty patients change weight/BMI following arthroplasty regardless of the cause.

Results

Quality of reporting was based on the whether the preoperative characteristics of study population and weight/BMI changes were adequately described and easily comprehensible. Higher scores were given for clear and complete tables and/or figures.

Overall, the preoperative characteristics of study population were adequately described. The studies varied more in the reporting of the results. Three studies received ratings of good.^{14, 16, 17} One study received

a poor rating because the authors reported only that no patients sustained weight loss greater than 20% and that 24% of patients gained 5-15% of body weight.¹⁵ Another study received a fair because the authors did not report the p-value for BMI change or a correlation coefficient when they stated that preoperative BMI and BMI change were uncorrelated.¹⁸

Total Knee Arthroplasty

Overall, no studies were able to detect significant difference in pre- and postoperative weights/BMI among knee arthroplasty patients. However, these studies may lack the power to detect a statistically significant difference since they were all limited by small sample sizes (45-68 patients). Studies found that 24% of morbidly obese female patients¹⁵ and 41.2% of all patients gain weight after arthroplasty.^{15, 16}

Total Hip Arthroplasty

The results on total hip arthroplasty were inconsistent. The study with large sample (n=140) found that unilateral, uncemented hip arthroplasty patients had statistically significant weight gain.¹⁴ Another study found that the weight gain among all hip arthroplasty patients had borderline significance, but the weight gain for women undergoing hip arthroplasty was significant.¹⁶ The third study detected that hip resurfacing arthroplasty patients, but not total hip arthroplasty patients had significant weight gain.¹⁷ For these groups with a statistically significant mean weight change, mean weight gain was 1.87-3.2 kg, an amount that may lack clinical significance.

Summary of Internal Validity

The overall quality of the articles in this systematic review was fair to poor. The potential for both selection bias and measurement bias was high. The source population was rarely described adequately. In most studies, the study population appeared to be the same as the source population, but often the information provided was insufficient to detect exactly how well the study population represented the source population. Since most studies were observing the population as a whole, comparability between groups was not a major concern. Maintenance was rarely described, and several of the studies excluded all patients without follow-up data from the analyses. No studies adequately described how weight and/or height were measured making it difficult to judge the reliability and validity of measurements. None of the studies attempted to control for confounders in the relationship between pre- and post-operative weight/BMI with regression analyses, but some looked for potential confounding or effect modification by Harris hip score, Charnley classification, gender, or preoperative weight by stratifying or comparing the data. Finally, case series and comparative studies are highly susceptible to confounding as a result of the study design.

External Validity of Findings from the Systematic Review

External validity of the findings from the systematic review to other primary total knee arthroplasty patients is discussed in this section. No quality ratings for external validity were assigned.

Overall, the patients in these study populations were 60-70% female, had a mean age of 58-71 years, were predominately diagnosed with OA, and were mostly overweight or obese. While these are the typical demographics for patients undergoing total joint arthroplasty,² they may not represent all total knee arthroplasty populations.

Results from the studies on total hip arthroplasty may not apply to patients undergoing total knee arthroplasty. Knee arthroplasty patients are often older and heavier than hip arthroplasty patients.^{16, 17} After the age of 50, women have a higher prevalence of knee OA, but most studies show that hip OA is more frequent in men.³ In addition, hip and knee OA may be associated with different risk factors, and the relationship between obesity and hip OA is weaker than its association with knee OA.³

In addition, postoperative weight/BMI trends may differ based on preoperative BMI classification. Several studies combined normal weight or underweight patients with overweight or obese patients in their analyses. While we would like for overweight and obese patients to lose weight postoperatively, weight loss would be undesirable for normal weight or underweight patients. Although the majority of patients in all studies were overweight and obese, results from combined analyses may

not provide accurate information regarding postoperative expectations for overweight and obese patients. Another study examined only morbidly obese women, and since morbidly obese patients likely experience greater disability due to their weight, these results may not apply to less obese patients.

Finally, these studies all involved patients at a single hospital or institute and may not be generalizable to patients outside the facility catchment area. Patients who receive arthroplasty at university-affiliated hospitals are probably different from those receiving arthroplasty from an orthopedist in private practice. In addition, the prevalence of obesity and the factors that influence weight change are likely to vary by region and socio-economic status. Therefore, findings from European patients may not apply to patients in the United States.

Discussion Addendum

Research in Context

As discussed above, our findings are similar to those found in previous studies of weight and BMI change in total joint arthroplasty patients. Moreover, the increase in activity postoperative was not surprising. Mechanisms in the existing literature may explain the lack of weight loss despite an increase in activity. First, increased body weight generally decreases the ability to be physically active,⁵³ and overweight and obese patients are still faced with this obstacle after successful surgery. Secondly, the progressive decline in energy turnover with aging²⁹ may prevent these patients from losing any notable amount of weight even with an increase in physical activity. Moreover, the energy expenditure resulting from increased activity following total knee arthroplasty is unlikely to be sufficient to cause weight loss. A study of Caucasian adults found that an increased energy expenditure from physical activity required for weight loss or maintenance is approximately 1500-2000 kcal/week.⁵⁴

Critical Appraisal of Study

Selection of Study Population

Previous studies on weight/BMI change total knee arthroplasty patients are limited by small sample sizes, ranging from 45-68 patients. We increased statistical power by including 152 patients in our analyses. Nevertheless, the case series study design increases the potential for

selection bias and limits the generalizability of the findings. We tried to decrease bias by including a consecutive sample. In addition, we detected no differences in preoperative characteristics between those who were included in our analyses and those who were excluded due to incomplete weight, BMI, or LEAS score data. However, unknown differences may still exist between these groups. We clearly described who was included in our study population and their preoperative characteristics so that readers could decide if these results applied to their patient populations.

Measurements and Data Collection

We clearly described methods of collecting of weight and height data and all dependent variables analyzed. Weight and height were accurately measured by trained personnel on one scale. Although patients remained dressed in clothes and shoes while measured, we do not believe that this resulted in a systematic bias. Additional weight contributed by clothing is unlikely to be differential among patient groups and should be canceled out when weight change is calculated. Moreover, patients with severe knee arthritis rarely wore shoes with substantial heels.

Measurement of typical physical activity is also likely to be accurate. The LEAS is a new scale that has not been used extensively in practice, but has been previously validated. While the only published validation study included patients undergoing revision total knee

arthroplasty, the activity scale is also likely to be accurate in patients undergoing primary arthroplasty.

A weakness of the LEAS is that it requires patient self-assessment. A patient completing the scale must choose only one of the eighteen levels of activity that most closely matches his own activity. Patients with low literacy, low education, or vision problems may have difficulty choosing the appropriate level. Patients may altogether neglect to complete the additional sheet of paperwork during their visit. In addition, we examined whether preoperative activity level is associated with postoperative weight, and the LEAS may not reliably measure energy expenditure from physical activity.

Statistical Analyses and Confounding

We clearly described our use of appropriate statistical methods and assess the potential for confounding of the results. The lack of ability to control for co-morbid conditions is a substantial limitation that was discussed above. In addition, we did not adjust for preoperative or postoperative pain that may limit physical activity and energy expenditure. In our analyses of the relationship between activity and weight/BMI at two years, we chose to examine preoperative activity as the exposure rather than change in activity. Using change in activity as the exposure would require controlling for preoperative activity, and we were concerned about collinearity among the covariates.

There is some concern for incidental significant findings due to multiple analyses/comparisons in our study. Although we established questions and hypotheses a priori, perhaps we could have used a significance level of $p < 0.01$ for secondary questions and subgroup analyses.

Internal and External Validity

The overall internal validity our results are likely fair to poor as the study is very susceptible to biases from its study design. However, we clearly defined and analyzed our study population, performed accurate measurements, and controlled for several known confounders in attempts to reduce biases as much as possible.

The external validity of our study is discussed above in detail and is likely fair. Generalizability of our study is improved because the preoperative characteristics of our study population resemble the characteristics of the most American primary knee arthroplasty populations.²

Implications for Clinical Practice

These findings confirmed our hypothesis that overweight and obese patients do not lose weight after arthroplasty despite an increase in typical physical activity. In this population, total knee arthroplasty should not be considered a mechanism for weight loss or at least not a sufficient

mechanism. Surgeons should screen patients for realistic expectations prior to surgery and correct any misconceptions they may have about the operation. Patients should be told that they will, if anything, have more responsibility for adhering to a healthy diet and exercise postoperatively.

Preoperative counseling may also help prepare patients to change diet and exercise habits postoperatively. The importance of reduced caloric intake, in addition to increased physical activity, should be stressed to patients who believe that arthroplasty will result in weight loss.⁵⁵ Counseling on these lifestyle modifications could take place in a primary care setting prior to referral or incorporated into postoperative rehabilitation and physical therapy practices.

Physicians should also make preoperative referrals for dietary counseling or bariatric surgery when appropriate. Notable weight loss resulting from dieting or bariatric surgery may facilitate later arthroplasty, and Parvizi et al. demonstrated that morbidly obese patients can have successful total joint arthroplasty following surgical treatment for obesity.⁵⁶ In addition, as the number of overweight and obese persons continues to increase in the United States, surgeons should be prepared to address any of potential complications that may arise when operating on obese and morbidly obese patients.

Perspectives on Future Research

Future studies relating to this topic would benefit from the use of comparison or control groups. Comparison groups could include patients with osteoarthritis who chose not to undergo arthroplasty or participants of a similar age in the general population. Although only 17% of patients lose $\geq 5\%$ of weight following arthroplasty, perhaps they are more likely to lose weight after two years than those who do not undergo arthroplasty.

Unfortunately, the elective nature of this procedure and the well-established effectiveness of this procedure with a lack of alternatives make randomized studies of this question unethical. Additional studies could also examine the relationship between preoperative BMI classification as overweight or obese and postoperatively LEAS score or change in LEAS score adjusted for covariates.

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Table A: Studies Examining Weight or Body Mass Index Change Following Lower Extremity Arthroplasty

Study authors, Year	Study Design and Source Population	Study Population	Joint	Length of follow-up	Change in weight (kg) or BMI	p value*	Controlled for any other variables?	Comments
Pritchett and Bortel, 1991	Prospective comparative study Patients of a University-affiliated hospital, Seattle, WA	50 morbidly obese women with OA & TKA (mean age: 69yrs; mean pre-op weight: 104kg) 50 morbidly obese women with OA w/o TKA (mean age: 68yrs; mean pre-op weight: 101kg) 50 non-obese women with OA & TKA (mean age: 71yrs; mean pre-op weight: 69kg) All consecutive patients that met study criteria were included	Knee	Mean: 33 months (range, 24-60 months)	No obese patients w/ TKA sustained weight loss greater than 20%, 11 patients (24%) gained 5-15% No obese patients w/o TKA had significant weight change	Not given	None	Morbidly obese = 45kg overweight or twice ideal body weight All obese were advised by a physician to lose weight and counseled by a dietician Maintenance: 8 obese w/o TKA were lost, 5 obese/TKA were lost/died
Woodruff and Stone, 2001	Case series Patients of a large acute care hospital, Leeds, UK	68 TKA patients (59% female; mean age 71yrs; mean pre-op weight: 71.6kg) 124 THA patients (63% female; mean age: 68yrs; mean pre-op weight: 68.8kg) Unclear if patients were consecutive	Knee and Hip	1 year	Mean weight change for TKA patients was +0.6kg (range, -15-10kg); 41.2% gained weight and 17.6% lost weight Mean weight change for THA patients was +2.8kg (range, -8-21kg); 59.7% gained weight and 11.3% lost weight Stratified by gender, only weight gain for women undergoing THA was statistically significant	TKA p=0.75 THA p=0.087 THA women p=0.04	None	Normal weight and overweight/obese patients were combined in analyses

Abbreviations: OA=osteoarthritis, TKA= total knee arthroplasty, THA=total knee arthroplasty, BMI=body mass index

*p value for significant change at follow-up compared to baseline

Table A: Studies Examining Weight or Body Mass Index Change Following Lower Extremity Arthroplasty (continued)

Study authors, Year	Study Design and Source Population	Study Population	Joint	Length of follow-up	Change in weight (kg) or BMI	p value*	Controlled for any other variables?	Comments
Jain, Roach, and Travlos, 2003	Retrospective chart review and survey Patients of 6 Consultants at single District General Hospital, UK	98 patients undergoing primary, cemented THA for OA who met study criteria (74% overweight/obese; about 67% female; mean age 66yrs; mean pre-op weight: 74.7kg; mean pre-op BMI: 26.8) 71 additional patients were excluded due to bilateral THA, non-OA, uncemented THA, grafting, other lower limb joints significantly affected, or incomplete pre-operative details	Hip	At least 2 years	78 (80%) of patients returned questionnaire and were included in analyses Mean absolute weight change was +1.87kg (+2.5%) Mean absolute BMI change was +2.1%, 53% of patients increase BMI and 2.6% had no BMI change Pre-op BMI had no correlation with BMI change after the operation	Not given	Self-reported mobility score and WOMAC OA index score BMI change was not correlated with either score	Weight and height measured pre-operatively and self-reported at follow-up
Heisel, Silva, Dela Rosa, and Schmalzried, 2005	Prospective study Patients of 1 surgeon at a joint replacement specialty clinic, Los Angeles, CA	100 randomly selected patients with successful arthroplasty 45 primary TKA, 55 primary THA 36 hip resurfacing arthroplasty (66% female, mean age: 58yrs, no mean pre-op weight reported)	Knee and Hip	Mean: 32 months (range, 12-115 mo.)	Mean weight change was +1.2kg (range, -35-23.2kg) Charnley class A patients (n=32) had significant weight gain (mean: 2.9 kg), but not class B or C patients Hip resurfacing patients had significant weight gain (mean: +3.2 kg), but not TKA (mean: +1.4 kg) or THA patients (mean: +0.2 kg)	p=0.128 Charnley Class A p=0.018 B p=0.257 C p=0.349 Hip resurfacing p=0.0064 THA p=0.9 TKA p=0.16	Stratified by pre-op Charnley class (a measure of potential ambulation)	Randomized selection process was unexplained Analyses combined both normal weight and overweight/obese patients

Abbreviations: OA=osteoarthritis, TKA= total knee arthroplasty, THA=total knee arthroplasty, BMI=body mass index

*p value for significant change at follow-up compared to baseline

Table A: Studies Examining Weight or Body Mass Index Change Following Lower Extremity Arthroplasty (continued)

Study authors, Year	Study Design and Source Population	Study Population	Joint	Length of follow-up	Change in weight (kg) or BMI	p value*	Controlled for any other variables?	Comments
Aderinto, Brenkel, and Chan, 2005	Case series Patients at a large acute care hospital, Dunfermline, Scotland	140 unilateral, cemented THA patients (42% obese/BMI $\geq$ 30; 62% female; mean age 67yrs; mean pre-op weight: 76.7kg) 3 additional patients were excluded due to insufficient follow-up	Hip	3 years	Mean weight change was +2.3kg Among patients who loss weight (26%), mean weight loss was -4.7kg; Among patients who gained weight (66%), mean weight loss was +5.4kg Mean weight change was +1kg and +4kg for non-obese and obese patients, respectively Mean weight increase was greater among obese patients (p<0.01) There was no difference in the likelihood of weight gain between non-obese and obese patients (p=0.103)	p<0.001 Non-obese p=0.106, Obese p<0.001	Compared Harris hip scores (a measure of hip function) b/w obese and non-obese pts; Obese pts had lower Harris hip scores at 3 years (p=0.01)	Stratified patients by BMI as non-obese (BMI <30) or obese (BMI $\geq$ 30)

Abbreviations: OA=osteoarthritis, TKA= total knee arthroplasty, THA=total knee arthroplasty, BMI=body mass index

*p value for significant change at follow-up compared to baseline

Table B: Quality ratings for studies in systematic review. Each study was rated 1-3 for each category, with 1=poor, 2=fair, 3=good.

Study authors, Year	Source population adequately described?	Study population representative of source population?	Description of measurement and data collection?	Appropriate analyses?	Controlled for functional capacity, mobility, or physical activity?	Results reported adequately?	Overall quality score
Pritchett and Bortel, 1991	2	3	1	1	1	1	1.5
Woodruff and Stone, 2001	1	2	1	3	1	3	1.83
Jain, Roach, and Travlos, 2003	3	2	1/2 (1.5)	2	1	2	1.92
Heisel, Silva, Dela Rosa, and Schmalzried, 2005	1	1	1	3	2	3	1.83
Aderinto, Brenkel, and Chan, 2005	2	3	1/2 (1.5)	3	2	3	2.42