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Original Research

The Effect of Body Mass Index on Functional Outcome of Patients With Knee Replacement

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KEYWORDS
Body mass index;
Rehabilitation;
Total knee arthroplasty

Abstract *Objective:* To investigate the effects of body mass index (BMI) on the rehabilitation process in patients with a recent knee replacement.
Design: This retrospective cohort study included all patients admitted to a rehabilitation hospital, with a recent diagnosis of knee replacement and available hospital admission data including height and weight, between 2014 and 2017.
Setting: Rehabilitation hospital.
Participants: Study participants included patients who had undergone knee replacement surgery (N=742), with available BMI data.
Interventions: None.
Main Outcome Measures: FIM scores, including FIM change per day (FIM efficiency) by BMI category.
Results: The chart review identified 742 patients who had undergone knee replacement surgery, with available BMI data. The identified patients ranged in age from 58 to 85 years, with a mean age of 70 years. Of the patients included in the study, 24 were male, 49 were female, 73 were within the normal weight class, 180 in the overweight class, 189 in the obese class I, 143 in the obese class II, and 157 patients were classified as obese class III. The mean FIM efficiency was highest in the obese class II category (3.96). In a multivariate analysis after controlling for age, obese classes II and III had significantly better FIM efficiency.

List of abbreviations: BMI, body mass index; IRF, inpatient rehabilitation facility; OA, osteoarthritis; TKA, total knee arthroplasty.
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Conclusion: This study did not demonstrate that obesity adversely affects the rate of recovery during hospitalization after knee replacement surgery.

According to the United States Census Bureau, the nation's median age has grown 2.6 years since the year 2000.[1] In addition, the portion of the population that is older than 65 years has begun to climb. This growth has been largely attributed to the aging *baby boomer* population who began turning 65 years old in 2011.[1] This aging generation accounts for roughly 20% of the current United States population.

As individuals age, their joints often deteriorate, with a growing number failing conservative treatment. As a result, many now turn to surgical intervention. Therefore, with an aging population, the prevalence of joint replacements also continues to increase.[2]

In parallel with the aging of the population, the incidence of obesity is also increasing, now reaching epidemic proportions globally. According to the World Health Organization, in 2016, 1.9 billion adults age 18 and older were overweight (body mass index [BMI] of 25-29.9 kg/m^2).[3] In addition, more than 650 million adults were obese.[3] The number of overweight individuals has doubled since 1980 and continues to rise.[4] Although initially affecting only high income nations in the 1980s, this epidemic has now spread to include middle- and low-income countries. Because weight increases to levels categorized as overweight or obese, the risk of other conditions increases. Among these is osteoarthritis (OA).[5] Data from the National Health and Nutrition Examination Survey as well as the Framingham Heart Study have found an association between BMI and OA of the knee.[6,7] Some have concluded that the additional mechanical stress resulting from obesity is the principal reason for the association between obesity and OA, whereas others have suggested that this cause and effect may not be so clear.[8,9]

To combat pain and reduced function that often accompanies OA, orthopedic surgeons often perform total joint replacements. It is estimated that approximately 700,000 primary total knee replacement procedures are performed annually in the United States alone.[2] By 2030, it is estimated that this number will increase to 3.48 million annually.[2] Given this rise in OA of the knee and the increased number of patients requiring total knee replacements, is important to review the population at risk and understand the options for care and the decision-making process when contemplating the appropriate course of care.

In the surgical literature, some data suggest that advanced BMI is associated with higher rates of surgical and anesthetic complications.[10] These complications may include sequelae such as deep vein thrombosis, respiratory problems, low oxygen levels, complications with pain relief, and longer recovery after anesthesia. These patients have also been found to be at an increased risk of premature joint failure and revision.[11]

Although these medical considerations must be contemplated, from the patient's prospective, improvement of their circumstances is paramount, with most seeking a reduction in pain and an improvement in functional status. Collins et al[12] found that patients with BMIs greater than normal can have significant improvements in pain and function after total knee arthroplasty (TKA), including greater improvement in pain and function relative to baseline at 3 months postoperatively versus normal weight patients, and similar improvements from 3 to 24 months.[12]

Therefore, given that the improvement in patients can be considerable despite their BMI, we have initiated this study to better understand the effects of BMI on the postacute rehabilitation process.

Methods

This study has been approved by the Institutional Review Board. Data were compiled during a 5-year period from May 2012 through May 2017 from consecutive patients admitted for postacute rehabilitation after receiving a TKA to better understand how BMI affects recovery of TKA patients admitted to an acute rehabilitation hospital. Data used in this study, including data from the Emory Rehabilitation Network, were provided by the American Medical Rehabilitation Providers Association and organized by eRehab to include all patients whose records contained the following information: age or birth date, sex, height, weight, length of stay in hospital, admission date, discharge destination, race, prehospital setting, prior level of care, and prior indoor mobility. FIM scores were used to assess the functional ability of patients at admission and discharge. The 18-item (FIM) measure assesses 5 cognitive and 13 motor function items, with each item scored on a scale of 1-7. A score of 1 indicates a need of total assistance, and a score of 7 indicates total independence.[13] Overall, FIM gains were calculated by summing the motor and cognitive FIM scores. The improvement in FIM scores during the inpatient rehabilitation facility (IRF) stay was divided by the length of stay to calculate the FIM efficiency. The overall FIM efficiency as well as the motor and cognitive subscore FIM efficiencies were compared by BMI groups.

During the study period, 743 patients met the requirement for TKA-related IRF admissions. The BMI was calculated for each patient, which is body weight (in kg) divided by height (in m^2). These patients were then separated into 5 different groups according to BMI as defined by the WHO.[14] Groups classified by BMI were as follows: (normal weight) 18.5-24.9 kg/m^2, (overweight) 25-29.9 kg/m^2, (class I obesity) 30-34.99 kg/m^2, (class II obesity) 35-39.99

Table 1 Baseline characteristics

Characteristics	BMI				
	Normal Range (18.50-24.99) (n=73)	Overweight (25.00-29.99) (n=180)	Obese Class I (30.00-34.99) (n=189)	Obese Class II (35.00-39.99) (n=143)	Obese Class III (≥40.00) (n=157)
Age (y)*	76 (69.0, 85.0)	74 (67, 80)	69 (63, 78)	68 (62, 73)	65 (58, 71)
Sex†					
Male	24 (32.9)	71 (39.4)	68 (36.0)	40 (28.0)	37 (23.6)
Female	49 (67.1)	109 (60.6)	121 (64.0)	103(72.0)	120 (76.4)
Length of stay (d)*	8 (7, 10)	8.5 (7, 11)	9.0 (7, 11)	9 (7, 11)	9 (7, 12)
FIM score at admission*	74 (61.5, 81.0)	73 (64, 80)	72 (64, 80)	71 (63, 78)	72 (63, 78)
FIM score at discharge*	104 (92.5, 111.5)	108 (100, 113)	109.0 (100.5, 113)	108 (102, 112)	108 (101.5, 113)

* Median (25th and 75th percentiles).
† Number of patients (%).

kg/m^2, and (class III obesity) ≥40 kg/m^2.[14] There was only 1 patient in the underweight class. We eliminated this patient from the analysis.

Statistical analysis

Analysis was performed by using IBM's Statistical Package for the Social Sciences 24 (SPSS[a]). Frequency distributions of demographic and FIM score information were completed, as were correlation tests. Linear and multivariable regression analysis of FIM efficiency and score change was performed with BMI categories adjusting for sex, age, and length of hospital stay. All statistical tests were 2-sided, and a P value≤.05 was considered statistically significant.

Results

The participants were 742 patients admitted to the IRF with ages ranging from 58 to 85 years, with a mean age of 70 years. Of the patients included in the study, 32% were male including 33% of the normal weight group, 39% of the overweight group, 36% of the obese I group, 28% of the obese II group, and 24% of the obese III group, as shown in table 1. These data demonstrate that of the overall group 10% were normal weight, 24% were overweight, 25% were obese I, 19% were obese II, and 21% were obese III. Sex and age differences were identified between the weight groups, as shown in table 1.

The mean FIM efficiencies were calculated for the normal weight, overweight, obese class I, obese class II, and obese class III weight groups. Compared to the normal weight group, the FIM changes, adjusted for length of stay and age were significantly better for the obese II patients (P=.026), and obese III patients (P=.023), but was not for the overweight (P=.086) and obese I patients (P=.079). We then reviewed the subsets of the FIM. There were no statistically significant differences in the cognitive and motor FIM comparisons of any of the weight classes, as compared to the normal weight group. However, compared to the FIM motor efficiency of the normal weight class, all other weight classes had better mean FIM motor efficiencies. In addition, when comparing the mean cognitive FIM efficiency scores to those of the normal weight class (0.15), all others were better. Median FIM scores are presented in table 2.

Discussion

This study of patients presenting for knee replacement surgery found that those with a BMI above the normal range do not exhibit significantly reduced rates of recovery as compared to those in the normal weight group. We found this to be true even in those at higher levels of BMI. We found instead that those who recovered most quickly were in the overweight category, with no significant difference in rate of recovery between the normal weight category and any of the obese weight categories.

Considering established medical beliefs about the adverse effects of obesity on health outcomes, one may have expected completely different results. For example, in studies examining surgical outcomes, obesity is linked with longer duration of surgery, elevated rates of infection, increased blood loss, elevated risk of return to the operating room, and increased length of hospital stay.[10,15] As a result, surgery is frequently denied to obese patients, or delayed until satisfactory weight loss is achieved.[16-19]

This position has been codified by organizations which regulate the flow of patients into surgery. Guidelines published by the American Academy of Orthopedic Surgeons suggest caution and those by the United Kingdom National Health Service suggests outright rejection based on BMI.[2,20] This would appear to be a reasonable position, because the term obesity has been used to connote poor health for some time.[21,22] The concern that surgery may increase this risk seems a logical inference from earlier data. However, our data and that of others suggest that we consider outcome as well.[23,24]

Recent literature examining the correlation between obesity and postoperative complications suggests that confounding variables, such as comorbidities, found within the obese categories may be the cause of increase in adverse events, and that BMI is not as strong a risk factor as once thought.[10] Controlling for these, Jackson and Devine found significantly greater risk for

Table 2 FIM score change by BMI

BMI	FIM Motor Efficiency*	FIM Cognitive Efficiency*	FIM Score Efficiency*	FIM Overall Change*
Normal range (18.50-24.99)	3.3 (2.4, 4.3)	.10 (0.0, 5.0)	3.71 (2.68, 4.73)	32 (22.5, 39)
Overweight (25.00-29.99)	3.6 (2.8, 4.6)	.17 (0.0, .46)	3.92 (2.85, 5.0)	33 (26, 41)
Obese class I (30.00-34.99)	3.3 (2.6, 4.3)	.21 (0.0, .57)	3.67 (2.83, 4.74)	33 (27.5, 41)
Obese class II (35.00-39.99)	3.4 (2.6, 4.4)	.25 (0.0, .56)	3.88 (2.9, 4.83)	34 (28, 41)
Obese class III (≥40.00)	3.2 (2.5, 4.3)	.25 (0.0, .63)	3.67 (2.70, 4.76)	34 (28, 41)

* Median (25th and 75th percentiles).

postoperative complications only among those within the obese III classification (BMI index of ≥40 kg/m^2).[10,25] Others have found that those in the overweight and obese classifications may experience better recovery trajectories than do those in normal weight categories.[11] Mouchti et al[11] found that the 90-day mortality was significantly lower in overweight, obese class I, and class II patients when compared to normal weight patients.[11] This apparent contradiction was initially identified among patients seen in cardiology and is now termed as *obesity paradox*.[26] Subsequent researchers have identified this *paradox* in areas other than cardiology and within patients outside of the hospital setting.[11] A meta-analysis conducted by Flegal et al[27] linked obesity with increased all-cause mortality; however, they found that those in the overweight BMI category (25-30 kg/m^2) actually experience lower rates of all-cause mortality as compared to those with normal BMI (18.5-24.99 kg/m^2), and that class I obesity (BMI of 30-35 kg/m^2) was not associated with an increased risk for mortality. Vemmos et al[28] in a study of stroke patients found poststroke mortality to be lower among those who are overweight and obese. These findings have implications for approximately 39% of adult men and 40% of adult women who reside in the overweight category.[3]

Health is measured by more than just survival. Therefore, our examination of the effect of BMI on health should extend beyond the outcome measure of mortality. Our data for recovery during hospitalization were provided by the American Medical Rehabilitation Providers Association and include data from the Emory Rehabilitation network. These data are from the charts of patients who had just undergone their surgical procedure and were discharged for postacute hospitalization in an inpatient rehabilitation hospital setting. Our data appear to resonate with the mortality data, as well as other postacute hospital data. Data from postacute IRF studies have found similar results for patients with stroke, traumatic brain injury, amputation, and debility.[29-32] Acute findings of marginally better but not statistically significant recovery during hospitalization of overweight as compared to normal weight patients have been found in patients hospitalized for cardiovascular disease, pulmonary disease, traumatic brain injury, and in those hospitalized for amputation.[29-33] Therefore, our findings seem to follow a trend noted by others, that both short- and long-term outcomes of those who are overweight are not sufficiently different from the normal weight to trigger a resistance to treatment.

Study limitations

The patients in our study were referred by medical teams at the surgical site and accepted for admission after review by the admissions team at the acute rehabilitation hospital. The screening process for referral and a separate screening process for acceptance assure that the data in our study are not a representative sample of all who underwent joint replacement. In fact, given data published concerning a negative bias within society, and within medical teams, against those who are overweight, we cannot be assured that elevated BMI was not a factor in the rejection of some patients who had undergone this surgery. If this were the case, then those in the overweight category who were accepted for postacute care might have been those who had demonstrated some factor during their acute recovery which would overcome this bias. For example, if someone in the obese class III were to demonstrate enthusiasm, during the acute hospitalization, for getting out of bed and beginning to ambulate, this person may be more likely to be referred than a person with similar BMI but with less enthusiasm. To better understand this potential, it is necessary to study all patients undergoing joint replacement and their place of referral, compared with their BMI. This might shed some light on a potential bias. Although this would move us closer to understanding the full implications of BMI for patients undergoing joint replacement, we would still not understand the full potential given the tendency to deny surgery to patients with BMI above normal. A prospective study is warranted that allocates surgery based on the signs and symptoms of OA, and with the selection criteria, excluding BMI, and based instead on medical conditions with known implications for medical outcome.

Further, the data that we reviewed here represent a contracting group of patients admitted to acute care rehabilitation after a joint replacement. Data suggesting cost savings without adverse events for patients discharged to home rather than a rehabilitation hospital are rapidly moving the recovery phase of these patients out of the acute rehabilitation hospitals and into the home or other facilities. Therefore, such studies in the United States may be impossible in the near future.

Conclusions

This study of consecutive patients admitted to an acute rehabilitation hospital for postoperative care of a total knee arthroplasty found that, compared to those in the

normal weight class, the functional gains per hospital day were considerably better for those in all other weight categories. When functional gains were adjusted for both length of stay and age, the functional gains per day were considerably higher in the obese class II and obese class III weight categories. Overall, the data are clear that those in the overweight and obese categories do not have inferior rates of recovery than do those in the normal weight category.

Because of changing insurance regulations, during the course of this study, a dwindling number of patients undergoing knee replacements qualified for admission to a postacute rehabilitation hospital. The population in this study therefore represents a group that may not be available for study in this setting in the near future.

In the future, patients with such surgeries will likely need another significant neurologic or medical qualification for IRF admission, thus complicating the analysis of this group.

Supplier

a. SPSS 24; IBM.

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