Relationships Between Body Mass Indices and Surgical Replacements of Knee and Hip Joints

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Background: Osteoarthritis is both the most common form of arthritis and the most common reason for joint replacement surgery. Obese persons are believed to be more likely to develop generalized osteoarthritis that leads not only to knee but also to hip joint replacement surgeries. We hypothesized that obesity is also a risk for partial joint replacements and surgical revisions.

Methods: A frequency-matched case-control study was conducted in Utah. Between 1992 and 2000, 840 hip and 911 knee joint replacement surgery patients, aged 55 to 74 years, were included in this study. Cases were randomly matched to 5578 controls, defined as Utah residents enrolled in a cancer screening trial. Odds ratios (ORs) were calculated using ICD-9 (International Classification of Diseases, 9th revision) procedural codes and body mass index (BMI) groups.

Results: There was a strong association between increasing BMI and both total hip and knee replacement procedures. In males, the highest OR was for those weighing 37.50 to 39.99 kg/m^2 (total hip: OR=9.37, 95% confidence interval [CI] 2.64–33.31; total knee: OR=16.40; 95% CI 5, 19–51.86). In females, the highest OR was for those weighing $\geq$40 kg/m^2 (total hip: OR=4.47; 95% CI, 2.13–9.37; total knee: OR=19.05; 95% CI, 9.79–37.08). There were slight gender-specific differences in risk found for partial hip replacement procedures. Unexpectedly, no statistically significant association was found between obesity and the risk for hip or knee revision procedures.

Conclusions: While there is an association between obesity and hip and knee joint replacement surgeries, obesity does not appear to confer an independent risk for hip or knee revision procedures.

(Am J Prev Med 2003;25(4):290-295) © 2003 American Journal of Preventive Medicine

Introduction

Osteoarthritis (OA) is the most common form of arthritis, with about 5% of the U.S. population having hip or knee OA. Among adults aged $\geq$62 years, the prevalence of knee OA has been estimated at 9.5%.[1] OA is severely debilitating in many cases and frequently leads to joint replacement surgery. More than 70% of total hip and knee joint replacements are due to OA.[1]

Body mass index (BMI), a relative measure of weight, has been associated with OA of the knee in a number of cohort,[2–5] case-control,[6,7] and cross-sectional studies,[8–10] but the data relating obesity and hip OA are inconsistent. Although a few studies have found an association between obesity and hip OA,[11–13] other studies have found no association.[14,15] The effect of BMI on OA is a rising concern as obesity rates in the United States continue to climb. According to 1999 national statistics, 61% of the U.S. adult population is either overweight (BMI 25 kg/m^2 to 29.9 kg/m^2) or obese (BMI >30 kg/m^2).[16]

We hypothesized that those overweight and obese are more likely to develop generalized OA[17–19] that leads to OA of both the hip and knee joints, which will be associated with elevated risks for joint replacement surgeries. It was also hypothesized that obesity is a risk for partial hip replacements and revisions of the hip and knee joint replacement surgeries, although we are unaware of any previous studies of those outcomes. A large case-control study was designed to estimate the risk of increasing BMI on knee and hip replacement surgeries.

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0749-3797/03/$–see front matter
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doi:10.1016/S0749-3797(03)00218-6

Methods

The University of Utah's Institutional Review Board approved this study.

Cases

Between 1992 and 2000, there were 2583 hip procedures performed (ICD-9 [International Classification of Diseases, 9th Revision] codes 81.51–53) and 1764 knee procedures performed (ICD-9 codes 81.54–55) at LDS Hospital, a 520-bed, tertiary hospital operating in Salt Lake City, Utah. LDS Hospital is the largest hospital in Utah and has 21.6% of the inpatient market share in the Salt Lake Valley. The computerized hospital record was used to obtain age, gender, and BMI (measured at the time of admission). Cases were defined as individuals who had either hip or knee replacement surgery, defined by the ICD-9-CM code. The ICD-9 codes utilized were total hip (81.51); partial hip (81.52); revision of hip replacement (81.53); total and partial knee, including total, partial, unicompartmental, bicompartmental, and tricompartmental (81.54); and revision of knee replacement (81.55).

The accessed database eliminated all coded cases relating to trauma. A small number of cases with extreme BMIs were excluded due to suspected information error (see Table 1). All cases with BMI <17.5 kg/m^2 and >50 kg/m^2 were excluded. Cases aged <55 years and ≥75 years were excluded for all procedures other than revisions because of the limited age range of the controls (as described below). The controls used for the hip revision and knee revision surgical procedures were selected from the case set of replacement procedures and, thus, did not limit the age of the case set as stringently (those aged <39 and >90 years were excluded).

Table 1. Total number of cases for 1992 to 2000 with exclusions by surgical procedure

Procedure	Male *n* (%)	Female *n* (%)
Total hip cases[a]	643 (100.00)	1001 (100.00)
Exclusions		
Age <55	118 (18.35)	117 (11.69)
Age >74	171 (26.59)	373 (37.26)
BMI <17.5	2 (0.31)	5 (0.50)
BMI ≥50	8 (1.24)	10 (1.00)
Total	299 (46.50)	505 (50.45)
Total inclusions	344 (53.50)	496 (49.55)
Total knee cases[b]	517 (100.00)	1000 (100.00)
Exclusions		
Age <55	36 (6.96)	81 (8.10)
Age >74	150 (29.01)	328 (32.80)
BMI <17.5	0 (0.00)	2 (0.20)
BMI ≥50	3 (0.58)	6 (0.60)
Total	189 (36.56)	417 (41.70)
Total inclusions	328 (63.44)	583 (58.30)
Hip revision cases[c]	254 (100.00)	369 (100.00)
Exclusions		
Age <39	7 (2.76)	17 (4.61)
Age >90	2 (0.79)	2 (0.54)
BMI <17.5	2 (0.79)	5 (1.36)
BMI ≥50	5 (1.97)	7 (1.90)
Total	16 (6.30)	31 (8.40)
Total inclusions	238 (93.70)	338 (91.60)
Knee revision cases[d]	98 (100.00)	149 (100.00)
Exclusions		
Age <39	2 (2.04)	1 (0.67)
Age >90	0 (0.00)	0 (0.00)
BMI <17.5	2 (2.04)	2 (1.34)
BMI ≥50	3 (3.06)	2 (1.34)
Total	7 (7.14)	5 (3.36)
Total inclusions	91 (92.86)	144 (96.64)
Partial hip cases[e]	74 (100.00)	242 (100.00)
Exclusions		
Age <55	1 (1.35)	3 (1.24)
Age >74	57 (77.03)	191 (78.93)
BMI <17.5	1 (1.35)	2 (0.83)
BMI ≥50	0 (0.00)	0 (0.00)
Total	59 (79.73)	196 (80.99)
Total inclusions	15 (20.27)	46 (19.01)

[a]ICD-9 81.51.
[b]ICD-9 81.54.
[c]ICD-9 81.53.
[d]ICD-9 81.55.
[e]ICD-9 81.52.
BMI, body mass index; ICD-9, International Classification of Diseases, 9th revision.

Controls

The controls for the total hip, total knee, and partial hip surgical procedures came from a group of 5578 Utah residents enrolled in the National Cancer Institute's Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial during the years 1996 through 2000. Enrollees were healthy men and women aged 55 to 74 years, as described elsewhere.[20] Thus, the cases and controls were both drawn from the same population in Utah. We were provided with each control's age and self-reported height and weight. BMI was then calculated for each control. Errors made in coding and data entry are believed to be nondifferential. The information regarding these controls was optically scanned with an edit program that catches nonsense and out-of-range values.[21]

For both the hip revision and knee revision surgical procedures, total hip and total knee cases, respectively, were used as controls (since appropriate controls for revision procedures should have experienced initial joint replacement procedures). This was done rather than using the general population controls in order to determine whether an independent association between BMI and revision procedure risks could be ascertained.

Approximately two controls were randomly chosen through a multistage frequency match for each case by gender and age within 4 years. Overall incidence rates for knee and hip replacements in the state of Utah were also obtained. The age-specific incidence rates for the analyzed surgical procedures in Utah are listed in Table 2. Those rates were applied to the control population as a measure of the chance an individual within the control group had undergone a joint replacement. Using these data, it is expected that no more than one person serving as a control would also have undergone total hip replacement surgery (see Table 2).

Statistical Analysis

Data were analyzed with SPSS 10.0 (SPSS Inc., Chicago IL, 1999) using $\alpha=0.05$ for statistical significance. Crude odds ratios (ORs; data not shown) and Mantel–Haenszel–adjusted ORs were calculated and stratified by age (using two 10-year age strata) for both genders and each ICD-9 code. With more

Table 2. Population-based estimates of hip and knee surgical procedures for Utah, 1993–1998[a]

Procedure	Incidence rate/100,000	Overlap cases[b]
Total hip		
55–64 years	27.70	
65–74 years	66.67	
Combined (55–74)[c]	44.35	0.75
Total knee		
55–64 years	53.52	
65–74 years	120.22	
Combined (55–74)	83.28	1.53
Revision hip		
55–64 years	6.02	
65–74 years	14.92	
Combined (55–74)	9.98	NA[d]
Revision knee		
55–64 years	5.56	
65–74 years	12.64	
Combined (55–74)	8.72	NA[d]
Partial hip		
55–64 years	2.63	
65–74 years	12.00	
Combined (55–74)	6.82	0.01

[a]Complete data were available from 1993 to 1998.
[b]Applied statewide incidence rate to control set, indicating the possible number of controls expected to also be cases by chance.
[c]One control or less (0.04%) would be expected to have had a total hip replacement by chance alone; thus, such overlaps would be rare.
[d]Overlap is not applicable because the controls were not taken from the general population.
NA, not applicable.

cases of total hip and total knee procedures, cases and controls were analyzed with narrower BMI increments than for the partial hip, revision of hip replacement, and revision of knee replacement surgical procedures. BMI strata for the total hip and total knee procedures were divided into increments of 2.5 kg/m^2 up to the largest BMI group of ≥40 kg/m^2. For both the total hip and total knee procedures, the BMI group of 20.0 to 22.49 kg/m^2 was used as the reference group. For the hip revision and knee revision procedures, the reference group was 20.0 to 24.99 kg/m^2, with subsequent increments of 5 kg/m^2 up to ≥40 kg/m^2. For the partial hip replacement procedure, the reference group used was <25 kg/m^2, with subsequent increments of 5 kg/m^2 up to ≥30 kg/m^2 due to small numbers of cases. Although risk estimates did not differ appreciably when stratified by age group, both the crude and Mantel–Haenszel age-adjusted analyses are presented. Confidence intervals (95% CIs) were calculated as well as chi-square linear tests for trends (DF=1). Interaction between gender and BMI was analyzed by logistic regression. The variables of age, BMI, gender, and gender × BMI (interaction term) were included in the model.

Results

The relationship between increasing BMI and total hip replacement surgery appears stronger in males than females (see Table 3). However, there is a fairly consistent relationship in both genders. Statistical significance was achieved in the BMI groups 30.00 to 32.49 kg/m^2 and above in males and in the BMI groups 27.50 to 29.99 kg/m^2 and above in females. The chi-square linear test for trend in both males and females was highly significant (p<0.0001). The interaction term from the regression model was found to be statistically significant (p=0.001).

A similar but stronger association between BMI and total knee replacement surgery was also present (see Table 3). In both male and female cases, statistical significance was achieved for those in the 25.00 to 27.49 kg/m^2 BMI groups (OR=2.14; 95% CI, 1.06–4.31 in males; and OR=2.07; 95% CI, 1.25–3.44 in females). The chi-square linear test for trend demonstrated a strong relationship in both males and females (p<0.0001). Interaction between gender and BMI was again tested but found to be not significant in this case (p=0.435).

There was no clear association shown between increasing BMI and hip revision and knee revision surgical procedures (see Table 4). Although lacking statistical significance, in females the risk was consistently less than 1. In each gender, there was neither statistical significance at any value nor a significant test for trend.

The OR for BMI and partial hip replacement surgery showed no clear association between increasing BMI and surgery (see Table 3). The OR appeared to show a borderline protective association for females with BMI of 25.00 to 29.99 kg/m^2 (OR= 0.44; 95% CI, 0.18–1.05), but was not statistically significant.

Discussion

The relationship between increasing BMI and total hip replacement surgeries in this study is strong in contrast with some prior reports.[11–15] This study confirmed other findings of strong associations for knee replacement surgery.[2–10] The compelling OR concerning the total knee procedure lends greater evidence that being overweight, not just obese, is a risk factor for developing OA. There was also a relationship between increasing BMI and hip revision and knee revision surgeries when analyzing cases against the general population (data not shown). However, independent relationships between increasing BMI and the need for hip or knee joint revision surgeries (i.e., accelerating the need to revise a replaced joint) were not found.

While the interaction between gender and BMI was statistically significant in the logistic model for the total hip procedure, there was no statistically significant interaction for gender and BMI among those undergoing total knee replacements. The biologic foundation for these results is unclear. Age and BMI were also statistically significant in the logistic regression model, indicating that the relation between BMI and surgical joint replacements was robust. Trends toward significance of low BMIs (<20 kg/m^2) to result in joint replacements are of uncertain significance.

Table 3. Risk estimates for joint replacement surgeries by BMI in males and females

BMI	Male			Female		
	n	OR	(95% CI)	*n*	OR	(95% CI)
Total hip						
<20.00	12	2.46	(0.71–8.50)	57	1.90	(1.01–3.58)
20.00–22.49	82	1.00	. . .	186	1.00	. . .
22.50–24.99	167	1.09	(0.58–2.05)	313	1.20	(0.80–1.81)
25.00–27.49	292	1.33	(0.74–2.38)	304	1.22	(0.81–1.84)
27.50–29.99	220	1.73	(0.96–3.13)	242	1.72	(1.12–2.62)
30.00–32.49	132	2.54	(1.35–4.77)	160	1.61	(1.01–2.56)
32.50–34.99	64	3.30	(1.61–6.77)	90	2.18	(1.28–3.72)
35.00–37.49	35	6.65	(2.76–16.00)	63	2.38	(1.31–4.32)
37.50–39.99	15	9.37	(2.64–33.31)	31	2.19	(0.99–4.82)
≥40.00	18	6.82	(2.22–20.89)	37	4.47	(2.13–9.37)
p trend		<0.0001		<0.0001		
Total knee						
<20.00	7	2.06	(0.35–12.10)	56	0.71	(0.26–1.99)
20.00–22.49	68	1.00		187	1.00	
22.50–24.99	153	1.43	(0.67–3.03)	323	1.16	(0.68–1.97)
25.00–27.49	259	2.14	(1.06–4.31)	338	2.07	(1.25–3.44)
27.50–29.99	192	2.98	(1.47–6.06)	269	4.62	(2.81–7.59)
30.00–32.49	100	3.61	(1.69–7.75)	215	6.42	(3.86–10.69)
32.50–34.99	74	5.88	(2.64–13.13)	147	7.52	(4.37–12.96)
35.00–37.49	40	8.62	(3.35–22.20)	89	11.88	(6.41–22.03)
37.50–39.99	25	16.40	(5.19–51.86)	59	8.72	(4.42–17.21)
≥40.00	19	14.89	(4.24–52.32)	84	19.05	(9.79–37.08)
p trend		<0.0001			<0.0001	
Partial hip						
<25.00	15	1.00	67	1.00		
25.00–29.99	27	0.44	(0.11–1.81)	43	0.44	(0.18–1.05)
≥30.00	5	2.00	(0.25–15.99)	28	0.69	(0.27–1.76)
p trend		0.92			0.25	

BMI, body mass index; CI, confidence interval; OR, odds ratio.

The mechanism by which obesity causes degenerative joint disease remains unclear. While initially thought to be biomechanically related,[22] the findings of increased degenerative joint disease in non–weight-bearing joints among those obese[6,23,24] suggest a systemic mechanism. Particularly, as the relationship between BMI and knee degenerative joint disease was compared to that of the hand,[6] the probability of the primacy of biomechanics as the mechanism for the action of obesity appears less likely. Degenerative joint disease of the hip joint has

Table 4. Risk estimates for joint revision surgeries by body mass indices in males and females

BMI	Male			Female		
	n	OR	95% CI	*n*	OR	95% CI
Revision hip						
<20.00	9	1.56	(0.39–6.33)	67	1.08	(0.62–1.89)
20.00–24.99	172	. . .	. . .	313		. . .
25.00–29.99	320	1.19	(0.80–1.78)	350	1.09	(0.79–1.50)
30.00–34.99	131	1.25	(0.76–2.06)	178	0.81	(0.54–1.22)
35.00–39.99	50	0.83	(0.40–1.71)	67	0.76	(0.43–1.36)
>40.00	16	0.93	(0.30–2.86)	27	0.74	(0.32–1.74)
p trend		0.94			0.32	
Revision knee						
<20.00	1	NA	NA	15	0.35	(0.09–1.40)
20.00–24.99	45			88		
25.00–29.99	122	0.72	(0.35–1.47)	136	0.62	(0.36–1.07)
30.00–34.99	72	1.32	(0.61–2.87)	120	0.59	(0.33–1.05)
35.00–39.99	26	0.92	(0.32–2.68)	43	0.51	(0.22–1.17)
≥40.00	4	NA	NA	30	0.47	(0.18–1.14)
p trend		0.49			0.54	

BMI, body mass index; CI, confidence interval; NA, not applicable; OR, odds ratio.

been well associated with farming activities[25,26] and also malformations of the hip.[27] These previous studies suggest a potential relationship between forceful hip use prior to closure of the epiphyses, resulting in a deformity causing hip degenerative changes. The findings of the current study suggest that hip OA may be related to obesity potentially through a systemic factor as well. The nature of the systemic risk for OA is unclear, but some research has implicated enzymatic activities in this disease.[28–30] Whether or not there is a relationship between enzymatic activity and obesity appears to be an area in need of research.

One of the strengths of this study was the large sample size for both cases and controls. Some prior studies on hip replacement surgery[31,32] might not have demonstrated a significant association for many reasons, one of which was an insufficiently large case set. Also, the ascertainment of cases in this study was likely 100% complete due to data set development for reimbursement purposes.

Another strength of this study was the endpoint (surgery) used to analyze the relationship between arthritis and obesity. Many other studies have used radiographic methods,[2–4,6,8,9,17,33] which may be less precise measures, to determine the presence of OA[18,19,34] since the correlation between radiographic criteria and severity at the time of surgery shows imprecision. In this study, however, joint replacement surgery was used, perhaps as a clearer endpoint even if some subjectivity might still be involved to determine the need for surgery.

This study found a borderline protective association from an elevated BMI on partial hip replacement surgery risk in females. However, the number of cases analyzed was small and largely elderly. In addition, these findings may be due to a selection bias: those selected for this procedure might not be representative of the general population with OA.

Results from the revision of hip and knee replacements using these total hip and total knee replacement surgery cases as controls were of interest. While expecting to find that obesity increased the risk for reoperation through accelerating the biomechanical stresses of the prosthesis on the bone, the data failed to support that supposition. Thus, it seems that either obesity does not play a role in wearing out the surgical joints faster than in non-obese patients or perhaps activity levels of nonobese subjects confound this relationship. The findings that increasing BMI may have a protective (although not statistically significant) effect against joint revision surgery in women were unexpected. This may possibly be due to a greater incidence of osteoporosis and thus lower bone density in thinner women.

Despite the strengths of this study, there were limitations that need to be taken into consideration. This was a case–control study; therefore, it cannot resolve any issues concerning temporality. However, since cohort studies have shown that obesity precedes OA, rather than arthritis leading to an increase in obesity due to physical inactivity,[2,18,22] temporality in this study was of less concern.

This study could also have been subject to some information bias regarding BMI. Weight for each control was self-reported, whereas each case was weighed before surgery. As self-reported weight has been noted to be underestimated (especially for females[35–37]), this could have biased the results toward increasing the observed effect. However, the magnitude of underestimation[35] regarding BMI has been estimated to be no more than 1.14 kg/m^2; thus the results would not likely be appreciably different.

The control set's BMIs were compared to both the Utah Behavioral Risk Factor Surveillance Survey BMI data (1996–1999) as well as the Utah portion of the National Health and Nutrition Examination Survey III BMI data (1998–1994). In both comparisons, the current study's controls actually had slightly higher BMIs than those of the two other data sets. The BMI of this study's control group was approximately 2.0% greater than other Utah population-based controls; thus these results may be slightly biased toward a weaker association than actually exists. This study was also conducted in Utah, whose population has been reported to have a modestly lower proportion of overweight people than the national average (50.9% overweight or obese versus 61%, respectively).[16,38]

Information on the duration of obesity and other potential risk factors (e.g., highest BMI ever, occupation, genetics, ethnicity, and reproductive variables in women) was not available. However, there are no risk estimates for other factors that even approach the risk estimates found in this study. Additionally, in a study stratifying on Heberden's nodes and history of knee injury or menisectemy, risk estimates for knee joint replacement were similar to those found in this study.[39] Thus, while some confounding is possible, it appears unlikely to account for these results.

This study has shown strong relationships between obesity (measured by BMI) and total hip and knee replacement surgeries as a measure of OA. Unexpectedly, no evidence of elevated risk for hip or knee revision procedures from obesity was detected. There was also no clearly identifiable relationship between increasing BMI and partial hip replacements. The preventive implications of this study are applicable to all age groups, not just those represented herein (55- to 74-year-olds). Similar to one study showing that weight loss may alleviate symptoms related to OA[29] and another showing reduced weight loss appears to prevent knee joint surgery,[40] we suggest that knee and hip replacement surgery due to OA may be prevented by maintaining ideal weight.

This study was partially supported by a grant from the Centers for Disease Control and Prevention/National Institute for Occupational Safety and Health (Training Grant T42/ CCT810426-06-1). This study was also partially funded by the Prostate Lung Colorectal and Ovarian Cancer Screening Trial, University of Utah (contract N01-CN25524).

We are grateful for the help of Dr. Brent James and Abe Lindemen from Intermountain Health Care for helping obtain the data. We are also grateful to Dr. Saundra S. Buys for assisting with access to a large control population.

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