Published in final edited form as:
Arthritis Care Res (Hoboken). 2018 July ; 70(7): 1030–1038. doi:10.1002/acr.23438.

General and Abdominal Obesity as Risk Factors for Late-Life Mobility Limitation after Total Knee or Hip Replacement for Osteoarthritis among Women

Aladdin H. Shadyab, PhD[1], **Wenjun Li, PhD**[2], **Charles B. Eaton, MD, MS**[3], and **Andrea Z. LaCroix, PhD**[1]

[1]Division of Epidemiology, Department of Family Medicine and Public Health, University of California San Diego School of Medicine, La Jolla, CA, USA

[2]Division of Preventive and Behavioral Medicine, Department of Medicine, University of Massachusetts Medical School, Worcester, MA, USA

[3]Center for Primary Care and Prevention, Memorial Hospital of Rhode Island and Department of Family Medicine, Warren Alpert Medical School, Brown University, Pawtucket, RI, USA

Abstract

Objective—To investigate associations of body mass index (BMI), waist circumference (WC), and waist-hip ratio (WHR) with survival to age 85 with mobility limitation or death before age 85 among older women with total knee (TKR) or total hip (THR) replacement for osteoarthritis.

Methods—This was a prospective study of women (aged 65–79 years at baseline) from the Women's Health Initiative recruited during 1993–1998 and followed through 2012. Women's Health Initiative data were linked to Medicare claims data to determine TKR (n=1,867) and THR (n=944) for osteoarthritis. Women were followed for up to 18 years after undergoing THR or TKR to determine mobility status at age 85.

Results—Compared with normal-weight women, overweight, obese I, and obese II women with THR had significantly increased risk of survival to age 85 with mobility limitation (*P* for linear trend <0.001), with the strongest risk among obese II women (OR = 4.37; 95% CI = 1.96–9.74). Obese II women with THR also had increased risk of death before age 85. Women with THR and WC >88 cm relative to ≤88 cm had increased risk of survival to age 85 with mobility limitation (OR = 1.65; 95% CI = 1.17–2.33) but not death before age 85. High BMI, WC, and WHR were associated with significantly increased risk of late-life mobility limitation and death among women with TKR for osteoarthritis.

Conclusion—Among older women who underwent THR or TKR for osteoarthritis, baseline general and abdominal obesity were associated with increased risk of late-life mobility limitation.

Corresponding Author: Aladdin H. Shadyab, PhD, Division of Epidemiology, Department of Family Medicine and Public Health, University of California, San Diego School of Medicine, 9500 Gilman Drive #0725, La Jolla, CA, 92093, Phone: (858) 246-0439, ahshadya@ucsd.edu.

Conflict of Interest: The authors declare no conflict of interest.

Osteoarthritis (OA) is a major cause of disability among older adults, leading to pain, functional limitations, and poor quality of life (1). Currently affecting 30.8 million people in the United States (US), the prevalence of OA is expected to increase dramatically due to an aging population and the burgeoning obesity epidemic (1,2). Total joint replacement (TJR; including total hip [THR] and total knee [TKR] replacements) is effective to improve mobility and alleviate pain among patients with severe hip or knee OA (1,3,4). More than 7 million people, the majority (>4 million) of whom are women, are currently living with a THR or TKR in the United States (5). In the coming decades, these numbers are expected to increase with the rise in OA and need for improved mobility among OA patients (6). Concurrently, life expectancy among women is increasing, and by 2060, approximately 12 million women will be ages 85 years and older (7). As millions of women with THR and TKR reach this advanced age, it is important, from a public health perspective, to understand which modifiable factors predict disability-free survival after surgery.

High body mass index (BMI) is associated with increased risk of hip and knee OA and utilization of THR and TKR (8,9). In prior studies, associations of BMI with functional outcomes following TKR and THR have been conflicting (10–25). Some studies have shown worse functional outcomes and poorer mobility following THR and TKR for obese compared with normal-weight persons (11–13,17,21), whereas others have suggested that BMI is not associated with differences in function after surgery (14,15,19,20,23,24,25).

Waist circumference (WC) and waist-hip ratio (WHR), measures of abdominal obesity, have been studied to a less extent in relation to OA. A limited number of studies has observed associations of higher WC and WHR with increased risk of hip and knee OA and greater utilization of THR and TKR (8,9). However, no study has evaluated associations of WC and WHR with functional outcomes after TJR. Previous studies were limited by reliance on hospital-based registries with short post-surgery follow-up periods (11,19–21,25). Long-term studies are needed to examine the potential impact of general and abdominal obesity on late-life disability after undergoing TJR for hip or knee OA. General and abdominal obesity are associated with incident mobility limitation among older adults in the general population (26,27,28) and may influence mobility outcomes in OA patients via distinct mechanisms. Whereas general obesity results in an overload effect on joint cartilage leading to cartilage destruction (29), abdominal obesity is more closely linked to inflammation (30), a risk factor for mobility limitation among older adults (31).

In this prospective study, we examined associations of BMI, WC, and WHR with survival to age 85 with mobility limitation and death before age 85 among women who underwent THR or TKR for OA. The data were from the Women's Health Initiative (WHI) — a population-based, longitudinal study of postmenopausal women who were followed for up to 18 years after undergoing TJR.

MATERIALS AND METHODS

Study population and design

Details of the WHI study design are described elsewhere (32). Briefly, 161,808 postmenopausal women aged 50–79 years were recruited between 1993 and 1998 (baseline time point for this study) from 40 US clinical centers to participate in one or more of three Clinical Trials (N=68,133), including one of two Hormone Therapy (HT) trials, or an Observational Study (N=93,676). The Observational Study and Clinical Trials followed women through 2005, at which time 77% agreed to be followed through 2010 in the first Extension Study. In 2010, 87% consented to follow-up through 2015 in the second Extension Study. Our study was exclusive to women ages 65 years and older at baseline who were continuously enrolled in fee-for-service Medicare from baseline until the end of follow-up in 2012, and who underwent THR (N=1,867) or TKR (N=944) for OA at any time during follow-up (Supplementary Methods and Supplementary Figures 1 and 2). Medicare claims data were used to identify THR and TKR. Participants provided written informed consent, and institutional review board approval was received by all participating institutions.

Anthropometric characteristics

BMI, WC, and WHR were measured at baseline. Clinic staff measured weight to the nearest 0.1 kg and height to the nearest 0.5 cm using a calibrated beam balance scale and a stadiometer anchored to the wall, respectively. BMI was defined as weight in kilograms divided by height in meters squared and categorized as follows (33): normal-weight (≤24.9 kg/m^2), overweight (25–29.9 kg/m^2), obese I (30–34.9 kg/m^2), and obese II (≥35.0 kg/m^2). As there were few women in the underweight (<18.5 kg/m^2) and obese III (≥40.0 kg/m^2) categories, these women were included in the normal-weight and obese II categories, respectively. Waist circumference and hip circumference were measured to the nearest 0.5 cm over nonbinding undergarments at the level of the umbilicus and the fullest hip circumference, respectively. WC and WHR were dichotomized at cutpoints of 88 cm and 0.85, respectively, clinically-defined cutpoints indicating abdominal obesity among women (34). Because WC and WHR have varying associations with health outcomes (34), both indicators of abdominal adiposity were examined in this study.

Covariates

At baseline, participants completed questionnaires assessing demographic characteristics, lifestyle behaviors, and medical history. Participants selected race/ethnicity as American Indian/Alaskan Native, Asian/Pacific Islander, black/African American, Hispanic/Latina, white, or other. Additional demographic characteristics included education, income, and marital status. Lifestyle behaviors included alcohol consumption, smoking status, and total energy expenditure from self-reported duration and frequency of recreational physical activity (summarized into metabolic equivalent-hours/week). The Burnham scale was used to assess symptoms consistent with depressive disorders (35). Participants reported their general health and joint pain or stiffness. HT use was defined according to self-reported use and participation in the HT trials.

History of chronic diseases associated with obesity and loss of mobility, including coronary heart disease, stroke, congestive heart failure, peripheral arterial disease, diabetes, cancer, and hip fracture, was collected (26,36,37). Chronic disease history was self-reported at baseline, and incident diseases were identified during study follow-up via periodic clinic visits and mailed questionnaires sent biannually to participants in the Clinical Trials and annually to Observational Study and Extension Study participants. Diagnoses of incident diseases except for diabetes were ascertained by physician adjudication. Diabetes was defined as self-reported physician diagnosis of diabetes treated with either oral medication or insulin. Total number of chronic diseases was used for this analysis.

Outcomes

The outcome had three categories: survived to age 85 with mobility limitation; survived to age 85 with intact mobility (reference); or died before age 85.

Women were classified as having survived to age 85 or died before this age. Trained physician adjudicators verified deaths with hospital records, autopsy or coroner's reports, or death certificates. WHI staff performed periodic linkage to the National Death Index for all participants, including those lost to follow-up, for verification if medical records or death certificates were not available.

During the Extension Studies, participants completed an annual questionnaire that included the physical function subscale of the 36-item Short Form Health Survey (38). The subscale has ten questions about limitations in various daily activities. Participants reported whether their health limited "a lot" or "a little" or did not limit their ability to perform these activities.

Women who survived to age 85 and reported at that time that their health limited "a lot" or "a little" their ability to walk one block or climb one flight stairs were classified as having mobility limitation in late life (26,36); otherwise, they had intact mobility. The most recent measures that were collected within 2 years of the 85th birth year with the least missing data were used to classify women's mobility status in late life. The age of 85 was chosen because traditionally, individuals ages 85 years and older have been used in census reports to define the "oldest-old" population, which is the fastest-growing segment of the population ages 65 years and older (39). Therefore, this analysis focused on the mobility status of women with TJR at an important, but vulnerable, age milestone.

Statistical analysis

Frequencies and percentages are presented for categorical variables, and means and standard deviations (SD) are shown for continuous variables. Descriptive characteristics were compared across adiposity categories using chi-square tests for categorical variables. Normally-distributed continuous variables were compared using analysis of variance and two-sample t-tests, whereas non-normally distributed continuous variables were compared using Kruskal-Wallis or Wilcoxon-rank sum tests.

The analytic approach for this study was similar to previous studies evaluating associations of risk factors with aging outcomes (27,40). Multinomial logistic regression models were used to examine associations of BMI, WC, and WHR with the mobility outcome. Separate models were fit for THR and TKR analyses. The multivariable models were adjusted for potential confounders selected from the literature including age at first THR or TKR, race/ethnicity, study membership (Observational Study or Clinical Trial), education, marital status, alcohol consumption, smoking, physical activity, HT use, number of chronic diseases, depression, and occurrence of a second THR (or TKR) (26,28,36,41). Models for THR were also adjusted for occurrence of a TKR and vice versa. Due to collinearity, BMI and abdominal adiposity measures were not included in the same model.

Linear trend tests for BMI and WC were tested by including these variables as continuous predictors in the models. Multicollinearity between independent variables in the models was tested using tolerance values but was not observed in the analyses. Because age at TJR may predict post-operative outcomes (42), interactions between adiposity variables and age at TJR were tested using likelihood ratio tests. Stratified analyses by age at TJR were performed for significant interactions using the following categories: 67–74 years, 75–79 years, and 80–82 years. These cutpoints were selected because average age at THR and TKR among US Medicare beneficiaries is 75 years (43); hence, women who received their first TJR at <75 years were considered young at TJR. Women who underwent TJR at ages 80 years and older were considered older at TJR (44). Interactions between BMI, WC, and WHR were also tested.

Several sensitivity analyses were conducted. Alternative definitions for mobility limitation were considered. First, if women responded that their health limited "a lot" their ability to walk one block or climb one flight of stairs, they were classified as having mobility limitation; women who reported that their health limited "a little" or did not limit their ability to perform these activities were placed in the intact mobility category. A previous definition for mobility limitation (27), in which women who reported using a walker, crutches, or a wheelchair to walk on a level surface or that their health limited "a lot" the ability to walk one block or climb one flight of stairs, was also tested. To address potential misclassification due to timing of adiposity assessment, the analysis was restricted to women whose baseline visit was within five years of the first TJR. Additional multivariable models were adjusted for year of surgery to determine if changes in surgical factors throughout time influenced the findings.

P-values were two-sided and significant at $P < 0.05$. Interactions were considered significant at $P < 0.10$. Statistical analyses were conducted using SAS Version 9.3 (SAS Institute, Cary, NC).

RESULTS

Descriptive characteristics

Women were aged on average 69.3 (SD, 2.9; range, 65–79) years old at baseline (Table 1). Median follow-up time after TJR was 8 (range, 3–18) years. The majority (94.7%) were white, 3.0% were African American, and 2.3% were in other race/ethnicity groups. Average ages at THR and TKR were 76.9 (SD, 3.5; range, 67–82) and 76.8 (SD 3.6; range, 67–82) years, respectively. Among women with THR, 45.7% had mobility limitation at age 85, 34.8% had intact mobility at age 85, and 19.6% died before age 85. Among the TKR cohort, 47.9% survived to age 85 with mobility limitation, 30.4% survived to age 85 with intact mobility, and 21.8% died before age 85.

Women who were obese, had high WC, or had high WHR were more likely to be African American, have lower income, have lower levels of physical activity, have mobility limitation, and have severe joint pain or stiffness at baseline (Supplementary Table 2). They were also more likely to have a history of chronic diseases and less likely to be college graduates, consume alcohol, or use HT.

Total hip replacement findings

Relative to normal-weight women with THR, the odds of mobility limitation at age 85 were significantly higher among overweight (OR, 1.53; 95% CI, 1.04–2.25), obese I (OR, 2.40; 95% CI, 1.49–3.85) and obese II (OR, 4.37; 95% CI, 1.96–9.74) women in the multivariable model (Table 2). The odds of death before age 85 were significantly higher among obese II compared with normal-weight women with THR (OR, 6.08; 95% CI, 2.39–15.49) but were not significantly higher among overweight or obese I women. BMI was linearly associated with mobility limitation and death among women with THR (*P* for trend <0.001). Women with THR and WC >88 compared with ≤88 cm had significantly higher odds of mobility limitation (OR, 1.65; 95% CI, 1.17–2.33) but not death; however, there were linear associations of WC with mobility limitation (*P* for trend<0.001) and death (*P* for trend=0.002). There were no significant associations between WHR and mobility limitation or death. There were no significant interactions between any of the adiposity measures and age at first THR.

Total knee replacement findings

Associations of BMI and WC with mobility limitation and death varied by age at first TKR (Tables 3 and 4; $P_{interaction}$=0.08 and $P_{interaction}$=0.002, respectively). Among women who had their first TKR at 67–74 years old, the odds of mobility limitation were significantly higher among obese I (OR, 2.75; 95% CI, 1.30–5.82) and obese II (OR, 3.24; 95% CI, 1.40–7.50) relative to normal-weight women. The odds of death were significantly higher among obese I and obese II but not overweight women. Among women aged 75–79 years at TKR, only obese II women had increased odds of mobility limitation, and BMI was not associated with death. In the oldest age group (80–82 years), the odds of mobility limitation were significantly higher among obese but not overweight women, whereas the odds of death were higher among overweight and obese women. Obese I and II women were not separated in the oldest age group due to small sample size for the obese II category. BMI was linearly associated with mobility limitation among all age groups and linearly associated with death only among the youngest age group.

The odds of mobility limitation among women with WC >88 cm compared with ≤88 cm were significantly higher among all three age groups and strongest among women aged 67–74 years at first TKR (OR, 1.88; 95% CI, 1.14–3.10), whereas the odds of death were significantly higher only among the youngest age group (OR, 3.77; 95% CI, 2.08–6.83). There were significant linear associations between WC and mobility limitation among all age groups; further, WC was linearly associated with death in the youngest age group. WHR >0.85 was associated with increased risk of mobility limitation and death, but did not vary by age at TKR.

Sensitivity analyses

Women aged 67–74 years at first TKR were more likely to have fair or poor health, have mobility limitation, and have severe joint pain or stiffness than the older age groups at study baseline. However, findings for BMI and WC in TKR analyses were similar after adjusting for self-rated health, baseline function, and joint pain. Alternative definitions for mobility limitation did not alter the findings. Findings were similar when classifying women according to overall level of physical function rather than mobility. After restricting the analysis to women whose baseline study visit was within five years of the TJR, findings were similar. Further, in this cohort, adiposity measures remained fairly stable throughout time. Controlling for year of surgery did not materially alter the findings. There were no significant interactions between BMI and WC or BMI and WHR (data not shown).

DISCUSSION

This was the first study to follow women with THR or TKR to an age milestone of 85 years to examine the implications of body adiposity on late-life mobility. In this prospective study with up to 18 years of follow-up after TJR, overweight, general obesity, and abdominal obesity were risk factors for survival to age 85 with mobility limitation among older women with THR or TKR for OA.

Our findings agree with prior studies showing increased risk of disability following THR and TKR among persons with high BMI (11,12,16,20,23). In a prospective study of >18,000 older adults, obese but not overweight persons were less likely to be capable of walking without support for one hour or walk up one flight of stairs in years 3–9 after THR compared with normal-weight persons (16). In the general population, including a previous study among all WHI women, obesity was a predictor of incident mobility disability later in life (26,27). However, these studies did not evaluate a cohort consisting exclusively of patients with TJR for OA, a population that is particularly vulnerable to disability. Nonetheless, many studies have suggested that functional improvements after THR or TKR are not significantly different between obese and non-obese persons, and that obesity is not associated with clinically important differences in function after these surgeries (10,13,18,19,22,24).

We observed that the relationship between BMI and WC and survival outcomes varied by age at TKR, but not age at THR. Age at TJR may be a predictor of future functional outcomes (44). Furthermore, obese patients may be more likely to undergo THR and TKR at earlier ages (45). In our study, associations of BMI and WC with adverse survival outcomes for TKR recipients were strongest among the youngest age group. Women in our study who underwent TKR at an earlier age were more likely to be in fair or poor health and to report poor mobility and severe joint pain or stiffness at baseline than women who underwent TKR at older ages; however, findings were independent of these factors. It is possible that implant survival may explain our findings of poor late-life function for the younger age group. Although older (i.e., 80–82 years) TKR recipients were healthier than their younger counterparts at baseline, the increased risk of mobility limitation for obese and high WC women in this group suggests that functional recovery after surgery may be slower for older women with high adiposity.

We observed that being in the obese II category was associated with increased risk of death before age 85 among women with THR. In the TKR cohort, general obesity was associated with risk of death in the youngest and oldest age groups, whereas abdominal obesity was associated with risk of death only in the youngest age group. Although risk of short-term mortality following TKR and THR is low (46,47), older age (i.e., ≥80 years) may be a risk factor for short- and long-term mortality following these surgeries (44). A meta-analysis showed that mortality following TKR does not differ between obese and non-obese persons (9). Overweight and obesity were shown to be protective against mortality after THR and TKR (48), likely explained by the observation that overweight and obese patients undergoing elective surgery may be healthier than the general population. However, these studies did not examine outcomes by age at surgery.

Although WC and WHR have not been studied in relation to functional outcomes after TJR, they have been associated with risk of late-life disability and mortality among older adults in the general population (28,34). We observed that associations with survival outcomes were stronger for BMI than for WC or WHR, consistent with a prior study showing a stronger association of BMI than WC or WHR with risk of severe hip and knee OA (8). WHR was associated with mobility limitation and death for TKR, but not THR, consistent with previous studies showing varying associations of abdominal adiposity indicators with health outcomes (34).

The relationship between adiposity and mobility limitation may be due to several mechanisms. Obese individuals may be more likely to have chronic diseases such as cardiovascular disease, diabetes, and cancer, and may be less physically active, both of which are risk factors for loss of function and poor mobility (34,36); however, our findings were independent of these factors. The association of BMI with mobility limitation was stronger than associations for WC or WHR, lending support to the major role of biomechanical factors, such as joint loading, in OA pathogenesis (29). The association of WC with late-life mobility limitation may be mediated by inflammation. WC is strongly associated with low-grade systemic inflammation, especially in women (30), and inflammation increases risk of mobility limitation among older adults (31).

Our study has some limitations. We included only women who were continuously enrolled in Medicare Part A or Parts A+B and excluded those in Managed Care plans, limiting generalization of our findings to fee-for-service beneficiaries. WHI women of lower socioeconomic status and minority women are underrepresented among fee-for-service beneficiaries. Although we lacked information on BMI, WC, or WHR at the time of TJR, we found that weight remained fairly stable throughout time among the majority of women. We also observed that, when restricting the analysis to women whose baseline assessment was within five years of the TJR, findings were the same, suggesting that the timing of adiposity measurement did not bias our findings. We lacked information on surgical factors that may change over time; however, findings were similar after adjusting for year of surgery. We did not have information on body fat percentage, an important indicator of adiposity. BMI may not fully account for total body fat among older adults (49). Rather, WC has been shown to be a better indicator of body fat distribution in this age group (50). Our study was focused solely on examination of healthy aging outcomes in TJR recipients and did not address if adiposity measures were associated with increased risk of mortality among TJR survivors.

A major strength of our study is the population-based cohort of women followed for a long period of time after TJR to determine functional outcomes in old age. The linkage between WHI and Medicare data provided a rich and comprehensive resource from which we could determine associations between adiposity measures and survival outcomes. Finally, we adjusted for many confounders, including physician-adjudicated chronic diseases.

In conclusion, general and abdominal obesity were associated with increased risk of survival to age 85 with mobility limitation and death before age 85 after undergoing TJR for hip or knee OA among older women. These findings inform the evidence base about prognostic factors associated with long-term functional outcomes following TJR and can be used when advising patients on the risks and benefits of THR and TKR. Future studies should evaluate whether weight loss before TJR for hip or knee OA improves long-term aging outcomes. At present, these findings support the maintenance of healthy body weight among women with hip or knee OA scheduled to undergo TJR to lessen the burden of mobility loss in late life.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Women's Health Initiative Investigators:

Program Office: (National Heart, Lung, and Blood Institute, Bethesda, Maryland) Jacques Rossouw, Shari Ludlam, Dale Burwen, Joan McGowan, Leslie Ford, and Nancy Geller.

Clinical Coordinating Center: (Fred Hutchinson Cancer Research Center, Seattle, WA) Garnet Anderson, Ross Prentice, Andrea LaCroix, and Charles Kooperberg.

Investigators and Academic Centers: (Brigham and Women's Hospital, Harvard Medical School, Boston, MA) JoAnn E. Manson; (MedStar Health Research Institute/Howard University, Washington, DC) Barbara V. Howard; (Stanford Prevention Research Center, Stanford, CA) Marcia L. Stefanick; (The Ohio State University, Columbus, OH) Rebecca Jackson; (University of Arizona, Tucson/Phoenix, AZ) Cynthia A. Thomson; (University at Buffalo, Buffalo, NY) Jean Wactawski-Wende; (University of Florida, Gainesville/Jacksonville, FL) Marian Limacher; (University of Iowa, Iowa City/Davenport, IA) Robert Wallace; (University of Pittsburgh, Pittsburgh, PA) Lewis Kuller; (Wake Forest University School of Medicine, Winston-Salem,NC) Sally Shumaker.

Funding: The Women's Health Initiative Program is funded by contracts HHSN268201100046C, HHSN268201100001C, HHSN268201100002C, HHSN268201100003C, HHSN268201100004C, and HHSN271201100004C from the National Heart, Lung, and Blood Institute, National Institutes of Health, US Department of Health and Human Services. This study was also funded by the Women's Health Center of Excellence at the University of California, San Diego School of Medicine. A.H.S. was funded by grant T32 AR064194 from the National Institute of Arthritis and Musculoskeletal and Skin Diseases, National Institutes of Health, US Department of Health and Human Services.

Role of the Sponsor: The National Heart, Lung, and Blood Institute has representation on the Women's Health Initiative Steering Committee, which governed the design and conduct of the study, the interpretation of the data, and preparation and approval of manuscripts.

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SIGNIFICANCE AND INNOVATIONS

- Maintaining mobility into old age after total knee or total hip replacement for osteoarthritis is an important public health issue.
- No previous prospective study has followed patients with total knee or total hip replacement for osteoarthritis into late life to determine modifiable factors associated with functional limitations in old age.
- In this prospective study, overweight, general obesity, and abdominal obesity were associated with risk of survival to age 85 with mobility limitation among women with total knee or total hip replacement for osteoarthritis.
- Findings support maintenance of healthy body weight among women with total joint replacement for severe osteoarthritis of the hip or knee to lessen mobility limitations in late life.

Table 1

Baseline characteristics among women with total hip or knee replacement for osteoarthritis (N=2631)

Age, years, mean ± SD	69.3 ± 2.9
Race/ethnicity, no. (%)	
White	2486 (94.7)
African American	78 (3.0)
Other	60 (2.3)
Body mass index, kg/m^2, no. (%)	
Normal (≤24.9)	678 (26.0)
Overweight (25.0–29.9)	945 (36.2)
Obese I (30.0–34.9)	618 (23.7)
Obese II (≥35.0)	367 (14.1)
Waist circumference, cm, no. (%)	
≤88	1342 (51.2)
>88	1277 (48.8)
Waist-hip ratio	
≤0.85	1756 (67.1)
>0.85	860 (32.9)
Education, no. (%)	
Less than high school	82 (3.1)
High school	430 (16.4)
Some college	936 (35.7)
College graduate	1175 (44.8)
Income, no. (%)	
<$20,000	348 (14.1)
$20,000–$50,000	1252 (50.9)
>$50,000	862 (35.0)
Marital status, no. (%)	
Married/living as married	1620 (61.7)
Widowed	640 (24.4)
Divorced/separated	257 (9.8)
Never married	107 (4.1)
Alcohol consumption, no. (%)	
Non-drinker	255 (9.8)
Past drinker	391 (15.0)
Current drinker	1970 (75.3)
Smoking status, no. (%)	
Never smoked	1331 (51.2)
Past smoker	1180 (45.4)
Current smoker	89 (3.4)
Physical activity, MET-hours/week, mean ± SD	13.4 ± 14.0
Hormone therapy use, no. (%)	

Never	934 (36.5)
Past	642 (25.1)
Current	981 (38.4)
Self-rated health, no. (%)	
Excellent	354 (13.6)
Very good	1063 (40.8)
Good	988 (37.9)
Fair/poor	202 (7.8)
Burnham depression scale score ≥0.06, no. (%)	192 (7.5)
History of chronic diseases*, no. (%)	
Coronary heart disease	270 (10.3)
Stroke	218 (8.3)
Congestive heart failure	127 (4.8)
Peripheral arterial disease	104 (4.0)
Diabetes	419 (15.9)
Cancer	731 (27.8)
Hip fracture	155 (5.9)
Any disease	1799 (68.4)
Mobility limitation, no. (%)	729 (28.0)

Note. Sample sizes for variables in each column do not sum to total due to missing data.

MET = metabolic equivalent; SD = standard deviation; THR = total hip replacement; TKR = total knee replacement.

*Includes diseases reported at baseline and incident diseases during follow-up.

Table 2

Multivariable associations of body mass index, waist circumference, and waist-hip ratio with mobility and survival status among women with total hip replacement for osteoarthritis*

	Survived to age 85 with mobility limitation		Died before age 85	
	No. survived to 85 with mobility limitation/total (%)	**Multivariable-adjusted† OR (95% CI)**	**No. died before 85/ total (%)**	**Multivariable-adjusted† OR (95% CI)**
Body mass index‡, kg/m^2				
Normal (≤24.9)	125/335 (37.3)	1 [Ref]	54/335 (16.1)	1 [Ref]
Overweight (25.0–29.9)	151/329 (45.9)	1.53 (1.04–2.25)	63/329 (19.2)	1.40 (0.83–2.37)
Obese I (30.0–34.9)	108/189 (57.1)	2.40 (1.49–3.85)	36/189 (19.1)	1.40 (0.72–2.72)
Obese II (≥35.0)	45/87 (51.7)	4.37 (1.96–9.74)	32/87 (36.8)	6.08 (2.39–15.49)
Waist circumference§, cm				
≤88	238/570 (41.8)	1 [Ref]	99/570 (17.4)	1 [Ref]
>88	192/372 (51.6)	1.65 (1.17–2.33)	86/372 (23.1)	1.48 (0.93–2.35)
Waist-hip ratio¶				
≤0.85	287/643 (44.6)	1 [Ref]	120/643 (18.7)	1 [Ref]
>0.85	143/299 (47.8)	1.11 (0.78–1.58)	65/299 (21.7)	1.10 (0.69–1.77)

CI = confidence interval; OR = odds ratio.

*Reference group is survived to age 85 with intact mobility.

†Adjusted for age at first total hip replacement, study membership, education, race/ethnicity, baseline marital status, baseline alcohol consumption, baseline smoking status, baseline total physical activity, total number of chronic diseases, hormone therapy use, baseline depression, second total hip replacement, and total knee replacement.

‡*P* for interaction with age at first total hip replacement = 0.77. *P* for trend (survived to age 85 with mobility limitation) = <0.001. *P* for trend (died before 85) = <0.001.

§*P* for interaction with age at first total hip replacement = 0.51. *P* for trend (survived to age 85 with mobility limitation) = <0.001. *P* for trend (died before 85) = 0.002.

¶*P* for interaction with age at first total hip replacement = 0.60.

Table 3

Multivariable associations of body mass index, waist circumference, and waist-hip ratio with mobility and survival status among women with total knee replacement for osteoarthritis*

	Survived to age 85 with mobility limitation		Died before age 85	
	No. survived to 85 with mobility limitation/total (%)	**Multivariable-adjusted† OR (95% CI)**	**No. died before 85/total (%)**	**Multivariable-adjusted† OR (95% CI)**
Body mass index‡, kg/m^2				
Normal (≤24.9)	159/379 (42.0)	1 [Ref]	62/379 (16.4)	1 [Ref]
Overweight (25.0–29.9)	319/692 (46.1)	1.22 (0.90–1.64)	135/692 (19.5)	1.44 (0.95–2.20)
Obese I (30.0–34.9)	245/468 (52.4)	1.75 (1.24–2.48)	109/468 (23.3)	1.81 (1.13–2.91)
Obese II (≥35.0)	159/308 (51.6)	2.32 (1.52–3.53)	98/308 (31.8)	2.78 (1.63–4.76)
Waist circumference§, cm				
≤88	377/858 (43.9)	1 [Ref]	150/858 (17.5)	1 [Ref]
>88	513/997 (51.5)	1.62 (1.28–2.06)	254/997 (25.5)	1.57 (1.15–2.15)
Waist-hip ratio¶				
≤0.85	583/1227 (47.5)	1 [Ref]	229/1227 (18.7)	1 [Ref]
>0.85	305/625 (48.8)	1.35 (1.05–1.73)	174/625 (27.8)	1.65 (1.20–2.28)

CI = confidence interval; OR = odds ratio.

*Reference group is survived to age 85 with intact mobility.

†Adjusted for age at first total knee replacement, study membership, education, race/ethnicity, baseline marital status, baseline alcohol consumption, baseline smoking status, baseline total physical activity, total number of chronic diseases, hormone therapy use, baseline depression, second total knee replacement, and total hip replacement.

‡*P* for interaction with age at first total knee replacement = 0.08. *P* for trend (survived to age 85 with mobility limitation) = <0.001. *P* for trend (died before 85) = <0.001.

§*P* for interaction with age at first total knee replacement = 0.002. *P* for trend (survived to age 85 with mobility limitation) = <0.001. *P* for trend (died before 85) = <0.001.

¶*P* for interaction with age at first total knee replacement = 0.54.

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Table 4

Multivariable associations of body mass index, waist circumference, and waist-hip ratio with mobility and survival status stratified by age at total knee replacement for osteoarthritis*

	Survived to age 85 with mobility limitation		**Died before age 85**	
	No. survived to 85 with mobility limitation/total (%)	**Multivariable-adjusted† OR (95% CI)**	**No. died before 85/total (%)**	**Multivariable-adjusted† OR (95% CI)**
Age 67–74 years‡				
Body mass index, kg/m^2				
Normal (≤24.9)	27/75 (36.0)	1 [Ref]	17/75 (22.7)	1 [Ref]
Overweight (25.0–29.9)	71/154 (46.1)	1.95 (0.97–3.91)	38/154 (24.7)	1.97 (0.83–4.66)
Obese I (30.0–34.9)	66/144 (45.8)	2.75 (1.30–5.82)	54/144 (37.5)	4.36 (1.80–10.54)
Obese II (≥35.0)	47/117 (40.2)	3.24 (1.40–7.50)	55/117 (47.0)	5.73 (2.19–14.97)
Waist circumference, cm				
≤88	81/185 (43.8)	1 [Ref]	37/185 (20.0)	1 [Ref]
>88	132/307 (43.0)	1.88 (1.14–3.10)	127/307 (41.4)	3.77 (2.08–6.83)
Age 75–79 years§				
Body mass index, kg/m^2				
Normal (≤24.9)	76/181 (42.0)	1 [Ref]	39/181 (21.6)	1 [Ref]
Overweight (25.0–29.9)	146/323 (45.2)	0.96 (0.61–1.49)	72/323 (22.3)	0.99 (0.56–1.74)
Obese I (30.0–34.9)	124/220 (56.4)	1.60 (0.97–2.65)	43/220 (19.6)	0.92 (0.47–1.78)
Obese II (≥35.0)	78/141 (55.3)	1.99 (1.10–3.62)	38/141 (27.0)	1.58 (0.75–3.32)
Waist circumference, cm				
≤88	177/410 (43.2)	1 [Ref]	91/410 (22.2)	1 [Ref]
>88	252/460 (54.8)	1.55 (1.10–2.18)	101/460 (22.0)	0.95 (0.61–1.47)
Age 80–82 years¶				
Body mass index, kg/m^2				
Normal (≤24.9)	56/123 (45.5)	1 [Ref]	6/123 (4.9)	1 [Ref]
Overweight (25.0–29.9)	102/215 (47.4)	1.32 (0.81–2.15)	25/215 (11.6)	3.44 (1.18–10.02)
Obese (≥30.0)	89/154 (57.8)	1.78 (1.03–3.06)	17/154 (11.0)	3.78 (1.23–11.67)
Waist circumference, cm				
≤88	119/263 (45.3)	1 [Ref]	22/263 (8.4)	1 [Ref]
>88	129/230 (56.1)	1.61 (1.07–2.43)	26/230 (11.3)	1.61 (0.79–3.28)

CI = confidence interval; OR = odds ratio.

*Reference group is survived to age 85 with intact mobility.

†Adjusted for study membership, education, race/ethnicity, baseline marital status, baseline alcohol consumption, baseline smoking status, baseline total physical activity, total number of chronic diseases, hormone therapy use, baseline depression, second total knee replacement, and total hip replacement.

‡*P* for trend (BMI): 1. Survived to age 85 with mobility limitation = 0.007. 2. Died before 85 = <0.001.

P for trend (waist circumference): 1. Survived to age 85 with mobility limitation = 0.01. 2. Died before 85 = <0.001.

§*P* for trend (BMI): 1. Survived to age 85 with mobility limitation = 0.01. 2. Died before 85 = 0.30.

P for trend (waist circumference): 1. Survived to age 85 with mobility limitation = 0.002. 2. Died before 85 = 0.38.

¶*P* for trend (BMI): 1. Survived to age 85 with mobility limitation = 0.02. 2. Died before 85 = 0.22.

P for trend (waist circumference): 1. Survived to age 85 with mobility limitation = 0.002. 2. Died before 85 = 0.23.