Weight Change and the Risk of Total Hip Replacement

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Background: We examined the effect of adult weight change on risk for total hip replacement resulting from primary osteoarthritis, using a prospective study design.
Methods: We linked data on body mass index and body weight from 3 screening surveys in 3 Norwegian counties (mean ages at screenings 34, 43, and 47 y; n = 38,868) with follow-up data on total hip replacement (n = 572). Mean age at the start of follow up was 55 years, and mean duration of follow up was 9 years. For each participant we calculated a rate of weight change (weight slope) by linear regression of body weight versus time from the first through the third screening.
Results: Among men, mean weight change from first to last screening was +9.8 kg in the highest quartile and −3.7 kg in the lowest quartile. In women, the corresponding figures were +9.5 kg in the highest quartile and −5.2 kg in the lowest quartile. There was no association of weight slope, absolute weight change, or relative weight change between screenings with later total hip replacement resulting from primary osteoarthritis. We saw no change in the association between body mass index and later hip arthroplasty as the participants' age increased from 34 to 47 years at the 3 screenings.
Conclusion: The risk for later total hip replacement resulting from primary osteoarthritis was unaffected by weight change during the fourth and fifth decades of life. The dose-response association between adult body mass index and later total hip replacement was similar across these age groups.

Key Words: osteoarthritis, hip, body mass index, weight gain, weight loss, obesity, Norway

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Primary osteoarthritis of the hip is a major reason for pain and disability in the elderly. Because of this condition, 2 to 4 persons per thousand in the age group 60-80 years undergo a total hip replacement each year in the Nordic countries.[1] A strong hereditary component has been demonstrated.[2-5] The incidence increases with age and is higher in women.[6] We have previously shown that a high body mass index (BMI), as well as physical activity at work, are important risk factors for later total hip replacement resulting from primary osteoarthritis.[7] Other authors have shown previous hip injury,[8,9] sports activity,[10-13] and the presence of Heberden's nodes[9] to be associated with increased risk for primary hip osteoarthritis. Estrogen replacement therapy could be protective,[14-17] whereas the effects of smoking habits and bone mineral density need further elucidation.

Weight reduction has proven useful in the conservative treatment of symptomatic knee osteoarthritis,[18,19] and it has also been associated with reduced risk for later osteoarthritis of the knee.[20,21] Little is known about the effect of middle-age weight reduction on the risk for later osteoarthritis of the hip.

The aim of this study was to investigate the association between adult weight change and the risk for later total hip replacement resulting from primary osteoarthritis. We also wanted to evaluate the association between BMI and the risk for later total hip replacement across a spectrum of ages to see whether the association changes with age.

METHODS

During the years 1974-1978 and 1977-1983, the National Health Screening Service twice screened the population in 3 Norwegian counties for risk factors related to cardiovascular disease (Table 1). Participants answered a questionnaire concerning lifestyle factors, and screening nurses measured body height and weight in a standardized way. The number of people invited to both screenings was 47,797. For 40,739 of these, information on body height and weight was available from both screenings as well as from a nationwide compulsory tuberculosis screening completed from 1963-1975. Using the national personal identification code, we combined information from these screenings with data from the National Arthroplasty Register initiated in

TABLE 1. The Years of Birth of the Invited Cohort and the 3 Periods of Screening

County	Year of Birth	Tuberculosis Screening*	Cardiovascular Screening I	Cardiovascular Screening II
Oppland	1927–41	1963–75	1976–78	1981–83
Sogn og Fjordane	1926–40	1963–75	1975–76	1980–81
Finnmark	1925–39	1963–75	1974–75	1977–78

*Of the participants included in this investigation, 94% were examined during the years 1966–1969.

1987. Reporting to the Register improved gradually, and since 1989 this register has captured more than 95% of all total hip replacements performed in Norway,[22,23] including information on indications for surgery. We also used data from the Norwegian Registry of Vital Statistics on death and emigration during follow up. We excluded from the analysis all subjects in the screened cohort who died, emigrated, or underwent total hip replacement before the start of follow up. This left an eligible study group of 38,868 participants (81% of those invited to both cardiovascular screenings). The follow-up period in this investigation was from January 1, 1989, to June 16, 1998. The Norwegian Board of Health, the Data Inspectorate, and the Regional Committee on Ethics in Medical Research approved the study.

For each participant, weight change was assessed by linear regression of body weight over time. The slope (kg/year) of this straight line gave an estimate of each participant's weight change.[24,25] We also computed absolute weight change (in kilograms) as the difference between body weight recorded at the second cardiovascular screening and the tuberculosis screening. Relative weight change was computed as absolute weight change divided by body weight at the first examination.

We computed age-adjusted and multivariate adjusted relative risks using Cox proportional hazard regression. In the Cox analysis each subject's survival time is computed either to an event (a first total hip replacement resulting from primary osteoarthritis) or to censoring (any incident other than an event, eg, death or end of registration, occurring after the start of follow up, that precludes the participant from later experiencing an event). Relative risks were estimated with incidence rate ratios. Multivariate analysis was stratified on sex and adjusted for the continuous variables age-at-screening and BMI (calculated as the mean from the 3 screenings). We also adjusted for height as a continuous variable and for the categorical variables of physical activity at work, physical activity during leisure, smoking, and marital status, as recorded at the second cardiovascular screening. Physical activity at work and in leisure were classified independently as sedentary, moderate, intermediate, or intensive.[7] Smoking was classified as current, former, or never. Marital status was classified as unmarried, married, separated, divorced, or widowed. To evaluate the effect of body weight, a separate analysis was performed using weight in place of BMI.

To detect a possible change in the association between BMI and later total hip replacement with increasing age, we performed 3 separate Cox analyses, including BMI recorded at the first, second, or third screening. All 3 analyses were adjusted for age at screening, height, physical activity at work and in leisure, smoking, and marital status.

RESULTS

The study group included 18,705 men and 20,163 women (Table 2). The 3 screenings covered a mean time span of 13 years. From the first to the last screening, the mean body weight of both men and women increased 3.3% and mean BMI increased 3.7% (Table 3). Mean height decreased only very slightly (0.17%), so that body weight and BMI changed proportionately throughout the 3 screenings.

Mean age at start of follow-up was 55 years. During follow up, 799 participants received their first total hip replacement. The indication for surgery was primary osteoarthritis for 572 (235 men and 337 women). The 227 participants who had a total hip replacement for other indications were censored. The most common reasons other than primary osteoarthritis for total hip replacement were sequelae to a hip fracture (n = 95) and rheumatoid arthritis (n = 26). Partic-

TABLE 2. Age Distribution of 38,868 Men and Women at the First Screening (Tuberculosis Screening)

Age at First Screening (y)	Men No. (%)	Women No. (%)
20–24	136 (0.7)	167 (0.8)
25–29	4115 (22)	4784 (24)
30–34	5886 (32)	6309 (31)
35–39	6729 (36)	7108 (35)
40–44	1710 (9)	1723 (9)
45–49	129 (0.7)	72 (0.4)
Total	18,705 (100)	20,163 (100)

TABLE 3. Basic Characteristics of the Cohort of 38,671 Participants as Recorded at 3 Consecutive Screenings

	Age at Screening (y)	Height (m)	Weight (kg)	Body Mass Index (kg/m^2)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Men				
Tuberculosis screening	34 (4.7)	1.76 (0.07)	75.8 (9.8)	24.6 (2.7)
Cardiovascular screening I	43 (4.4)	1.75 (0.06)	77.1 (10.3)	25.1 (2.9)
Cardiovascular screening II	47 (4.6)	1.75 (0.07)	78.5 (10.9)	25.5 (3.1)
Women				
Tuberculosis screening	34 (4.6)	1.63 (0.06)	64.3 (10.6)	24.3 (3.9)
Cardiovascular screening I	42 (4.5)	1.62 (0.06)	65.3 (10.9)	24.8 (4.1)
Cardiovascular screening II	47 (4.6)	1.62 (0.06)	66.3 (11.2)	25.1 (4.1)

SD, standard deviation.

ipants were also censored during follow up as a result of emigration (n = 32) or death (n = 3107). The majority of participants were censored at the end of follow up (n = 34,930).

The rate of weight change ranged from −4.4 kg/year to 8.2 kg/year. The 25th, 50th, and 75th percentiles were −0.07 kg/year, 0.18 kg/year, and 0.45 kg/year, respectively, for men, and −0.11 kg/year, 0.14 kg/year, and 0.41 kg/year, respectively, for women. In both men and women, those with the highest weight gain had a higher mean BMI and mean body weight, and showed somewhat lower levels of physical activity (Tables 4 and 5). The proportion of exsmokers was highest among participants who gained most in weight. The incidence of total hip replacement showed no association with weight slope (Table 6). The age-adjusted and multivariate-adjusted relative risks for total hip replacement were also unaffected by weight slope.

TABLE 4. Distribution of Variables According to Quartile of Weight Slope in 18,705 Men Attending 3 Consecutive Health Screenings

Quartile of Weight Change	1st	2nd	3rd	4th
Age at screenings (y) (mean; SD)*	42.2 (4.2)	41.5 (4.3)	42.0 (4.4)	40.3 (4.5)
Body weight (kg) (mean; SD)*§	75.5 (9.8)	75.2 (9.4)	77.1 (9.2)	80.8 (10.4)
Body height (m) (mean; SD)*	1.75 (0.063)	1.75 (0.064)	1.75 (0.063)	1.76 (0.065)
Body mass index (kg/m^2) (mean; SD)*	24.6 (2.7)	24.5 (2.6)	25.1 (2.5)	26.1 (2.9)
Absolute weight change (kg) (mean; SD)†	−3.7 (2.9)	+0.9 (1.1)	+4.2 (1.4)	+9.8 (4.1)
Physical activity at work (%)‡				
Sedentary	22	23	24	26
Physical activity during leisure (%)‡				
Sedentary	14	14	15	19
Smoking habits (%)‡				
Never smokers	25	27	27	21
Exsmokers	20	24	31	41
Current smokers	55	50	43	39
Marital status (%)‡				
Married	83	85	87	83

*Mean of 3 screenings.
†From tuberculosis screening to cardiovascular screening II.
‡Cardiovascular screening II.
§To analyze the effect of body weight, weight rather than body mass index was included in the model. For all the other results in the table, body mass index, not body weight, was included.
SD, standard deviation.

TABLE 5. Distribution of Variables According to Quartile of Weight Slope in 20,163 Women Attending 3 Consecutive Health Screenings in 3 Norwegian Counties

Quartile of Weight Change	1st	2nd	3rd	4th
Age at screenings (y) (mean; SD)*	41.5 (4.4)	41.3 (4.4)	41.0 (4.5)	40.3 (4.5)
Body weight (kg) (mean; SD)*§	65.7 (10.4)	63.0 (9.4)	63.6 (9.3)	68.9 (11.4)
Body height (m) (mean; SD)*	1.63 (0.057)	1.62 (0.056)	1.63 (0.058)	1.62 (0.060)
Body mass index (kg/m^2) (mean; SD)*	24.8 (3.8)	23.9 (3.4)	24.1 (3.4)	26.2 (4.3)
Absolute weight change (kg) (mean; SD)†	−5.2 (3.9)	+0.2 (1.2)	+3.5 (1.4)	+9.5 (4.4)
Physical activity at work (%)‡				
Sedentary	12	14	14	12
Physical activity during leisure (%)‡				
Sedentary	16	15	16	21
Smoking habits (%)‡				
Never smokers	45	52	54	55
Exsmokers	11	11	14	18
Current smokers	45	37	32	27
Marital status (%)‡				
Married	87	89	90	88

*Mean of 3 screenings.
†From tuberculosis screening to cardiovascular screening II.
‡Cardiovascular screening II.
§To analyze the effect of body weight, weight rather than body mass index was included in the model. For all the other results in the table, body mass index, not body weight, was included.
SD, standard deviation.

We divided the cohort into quartiles according to BMI as recorded at the first screening, and performed the Cox analysis for each subgroup separately. There was no association between weight change and risk for later total hip replacement in any of the BMI categories. Including information on cardiovascular disease, diabetes mellitus, sick leave, or sick leave pension in the regression model did not alter the results (data not shown).

We tested for effect modification of weight change by each of the other variables used in the model. Only for weight change and age at screening in women did the interaction term reach statistical significance ($P = 0.025$). Stratifying the analysis on both sex and age at the second cardiovascular screening, none of the subgroups showed any association between high weight gain and risk for later total hip replacement. On the contrary, among women who were 50 years old or more at the second cardiovascular screening, those who were in the third and fourth quartiles of weight change showed a somewhat reduced risk for later total hip replacement compared with the lowest weight change quartile (relative risk [RR] = 0.60, 95% confidence interval (CI) = 0.38-0.95 for the third quartile, and RR = 0.51, CI = 0.32-0.82 for the fourth quartile).

In another analysis, we used weight change as a continuous variable in the multivariate analysis, and found a relative risk for men with a weight increase of 10 kg per 10 years of 0.93 (CI 0.69-1.25) compared with a man with no weight change. For women the corresponding relative risk was 0.85 per kg/year (CI 0.70-1.04).

In additional analyses, we compared the 5% of participants with the highest rate of weight gain (male >0.96 kg/year, female >0.94 kg/year) with the rest of the cohort and then the 5% of participants with highest rate of weight loss (male <-0.45 kg/year, female <-0.59 kg/year) with the other 95%. We found no differences in the risk for later total hip replacement (data not shown).

In a further analysis, we used the continuous variable absolute weight change rather than weight slope as an indicator of weight change. A man with 10-kg weight reduction from the first to the last screening had a relative risk for total hip replacement of 1.11 (CI 0.91-1.52) compared with a man with no weight change. For women the corresponding relative risk was 1.11 (CI 1.00-1.35). Using relative weight change as the indicator of weight change, there was no effect on the risk for total hip replacement (data not shown).

To detect any change, with increasing age, on the association between BMI and risk for later total hip replacement, we first found the relative risk for total hip replacement related to BMI at the tuberculosis screening (2.84 per 10 kg/m^2 CI 1.79-4.41 for men, and 2.37 per 10 kg/m^2 CI

TABLE 6. Absolute and Adjusted Risk for Total Hip Replacements Resulting From Primary Osteoarthritis According to Weight Slope Quartile in a Cohort of 18,705 Men and 20,163 Women Screened at Mean Ages 34, 43, and 47 Years

Quartile of Weight Change	1st*	2nd	3rd	4th
Men				
No. of participants	4,408	4,407	4,408	4,407
No. of person-years	38,829	39,587	39,681	39,315
No. of total hip replacement	54	57	64	49
Unadjusted incidence	0.012	0.013	0.015	0.011
Total hip replacement per 10,000 person-years (crude rate)	13.9	14.4	16.1	12.5
Crude relative rate	1	1.04	1.16	0.90
Age-adjusted relative risk†	1	1.12	1.31	1.10
Multivariate-adjusted relative risk (95% CI)‡	1	1.09 (0.75–1.58)	1.16 (0.81–1.68)	0.83 (0.55–1.25)
Women				
No. of participants	4,836	4,837	4,840	4,837
No. of person-years	43,925	44,158	44,204	44,055
No. of total hip replacement	91	81	75	79
Unadjusted incidence	0.019	0.017	0.015	0.016
Total hip replacement per 10,000 person-years (crude rate)	20.7	18.3	17.0	17.9
Crude relative rate	1	0.89	0.82	0.87
Age-adjusted relative risk†	1	0.90	0.85	0.93
Multivariate-adjusted relative risk (95% CI)‡	1	1.01 (0.74–1.36)	0.93 (0.68–1.27)	0.78 (0.58–1.07)

*Reference category.
†Adjusted for age at screening (mean of 3 screenings).
‡Adjusted for age at screening and body mass index (mean of 3 screenings), body height, physical activity during work and leisure, smoking habits, and marital status (covariate data obtained at cardiovascular screening II).

1.97-3.11 for women). We then computed the relative risk for total hip replacement related to BMI as recorded at the next 2 screenings. There were no differences among these relative risks (Table 7).

DISCUSSION

Adult weight change between the ages of 34 and 47 years did not affect subsequent risk for total hip replacement. This was true irrespective of sex, initial BMI, and the magnitude of weight change. The investigation was strengthened by the population-based design and high response rates, and by the fact that we had screening information on most known confounders. However, information on hormone replacement therapy, previous hip injury, and bone mineral density was not available.

TABLE 7. Multivariate Analysis* of Risk for Total Hip Replacement Resulting From Primary Osteoarthritis Using BMI from 3 Screenings in a Cohort of 18,705 Men and 20,163 Women

	Age at Screening (y) Mean (SD)	Relative Risk per 10 kg/m^2	95% Confidence Interval
Men			
Tuberculosis screening	34 (4.7)	2.84	(1.79–4.41)
Cardiovascular screening I	43 (4.4)	2.59	(1.79–3.71)
Cardiovascular screening II	47 (4.6)	2.37	(1.48–3.39)
Women			
Tuberculosis screening	34 (4.6)	2.37	(1.97–3.11)
Cardiovascular screening I	42 (4.5)	2.16	(1.79–2.84)
Cardiovascular screening II	47 (4.6)	2.16	(1.79–2.84)

*Adjusted for age at screening (mean of 3 screenings), body height, physical activity during work and leisure, smoking habits, and marital status (data obtained at cardiovascular screening II).
SD, standard deviation.

Comparisons between the National Arthroplasty Register and other official Norwegian registries indicate a high level of reporting. After excluding 1 hospital with poor reporting (not located within the counties of the present investigation), the completeness nationwide has been reported as 97%.[22] During 1991-1995, 69% of the total hip replacements recorded in the Norwegian Arthroplasty Register were the result of primary osteoarthritis.[6] This is in good agreement with the Swedish National Hip Arthroplasty Register, which during 1992-1996 reported that 69% of 48,007 total hip replacements were done for this indication.[26] We have previously compared the Norwegian incidence of total hip replacement with an estimate of the actual demand for the same surgery in England and found similar values.[7]

Participants were 46-67 years old at the start of follow up and 56-77 at the end. Of all total hip replacements resulting from primary osteoarthritis recorded in the Norwegian Arthroplasty Register from the 3 counties, 3.8% were performed on patients younger than 55 years and 40.6% on patients aged 55-70 years (B. Espehaug, written personal communication, 1999). From 1991-1995, 13% of total hip replacements in the Norwegian Arthroplasty Register were the result of sequelae after fracture of the femoral neck, 8% the result of sequelae of hip dysplasia, and 4% the result of rheumatoid arthritis. This is very similar to the frequencies of indications recorded in the present investigation, suggesting that the total hip replacements that occurred during our follow up are representative of all total hip replacements that our study population would sustain during their lifetime.

Body weight and BMI are risk factors for osteoarthritis in the knee and hip. The association is considered to be stronger for knee osteoarthritis.[27,28] However, the association we previously reported between BMI and hip osteoarthritis[21] is very similar to that described between BMI and knee osteoarthritis. In the Framingham osteoarthritis study weight loss over the previous 10 years was associated with reduced risk for symptomatic knee osteoarthritis in women approximately 60 years of age with baseline BMI 25 kg/m^2 or more, but weight gain did not increase the risk.[20] This effect might have been the result of reduced joint pathology, but might also be explained by less weight provocation of already pathologic joints. In another Framingham study (64% women), weight gain was associated with increased risk for radiographic knee osteoarthritis.[21] In that report the screening period covered 4 years, ending 4 years before index radiographs taken at a mean age of 71 years.

At the last screening 95% of the participants were aged 54 years or less, which is younger than the usual age of onset for primary osteoarthritis of the hip.[28] There was no difference between operated and nonoperated participants with regard to change in physical activity from the first to the second cardiovascular screening. This supports the assumption that symptoms of osteoarthritis were negligible at all 3 screenings and that hip pain did not influence weight change from the first to the last screening.

For the majority of the study group body weight and BMI remained fairly constant throughout the screening period (and possibly even up to the age of hip replacement). However, even in the subgroups with extreme weight gain or weight loss we could not demonstrate any change in risk for later total hip replacement resulting from osteoarthritis. In the study population 3524 participants (with 51 total hip replacements) had a decrease in BMI from first to third screening of at least 2 kg/m^2, and 1126 participants (with 24 total hip replacements) had a decrease in BMI of at least 3 kg/m^2. There were 10,107 participants (145 total hip replacements) with a BMI increase of at least 2 kg/m^2, and 5244 participants (78 total hip replacements) with a BMI increase of at least 3 kg/m^2. The power to detect a 67% risk reduction (or a 3-fold increase) among the most extreme of these groups was greater than 95%.

If one could determine at what age a high BMI is most detrimental to the hip joint, this information would help to focus a preventive strategy. Case-control studies of male and female recipients of total hip replacements indicated that recalled BMI at 40 years was more predictive of later hip osteoarthritis than recalled BMI at 20, 30, and 50 years of age.[29,30] These reports indicated that BMI impact peaked at age 40 years, but the differences were very small. We found that the association between BMI and later total hip replacement resulting from primary osteoarthritis remained unchanged during the fourth and fifth decades of life.

In this study we found no association between adult weight change and the risk for later total hip replacement resulting from primary osteoarthritis. Future research should focus on weight reduction during the first 3 decades of life or after the age of 55 years to define a preventive strategy against disabling osteoarthritis of the hip.

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