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The Impact of Body Mass Index on Later Total Hip Arthroplasty for Primary Osteoarthritis

A Cohort Study in 1.2 Million Persons

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***Objective*. To investigate the effects of body mass index (BMI), height, and age on the risk of later total hip arthroplasty for primary osteoarthritis (OA).**

***Methods*. We matched screening data on body height and weight from 1,152,006 persons ages 18–67 years who attended a compulsory screening for tuberculosis in 1963–1975 with data from the Norwegian Arthroplasty Register for the years 1987–2003. We identified 28,425 total hip replacements because of primary OA.**

***Results*. We found dose-response associations between both height and BMI and later hip arthroplasty. The relative risk (RR) among men with a BMI ≥32 kg/m^2 versus a BMI of 20.5–21.9 kg/m^2 was 3.4 (95% confidence interval [95% CI] 2.9–4.0). The corresponding RR in women was 2.3 (95% CI 2.1–2.4). There was a decreasing trend in the RR with an increasing age at screening. Among men, the RR for an increase of 5 kg/m^2 in the BMI was 2.1 (95% CI 1.7–2.5) when measured at age <25 years and 1.5 (95% CI 1.3–1.7) when measured at ages 55–59 years. Among women, the corresponding RR values were 1.7 (95% CI 1.5–1.9) and 1.1 (95% CI 1.1–1.2).**

***Conclusion*. There was a strong dose-response association between BMI and later total arthroplasty for OA of the hip. Being overweight entailed the highest RR among young participants, and the participants who were overweight at a young age maintained an excess RR for arthroplasty throughout the followup period.**

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Osteoarthritis (OA) of the hip is a disabling disease and a major cause of pain and physical impairment (1). In some patients, the reason for the OA is known (e.g., hip fracture, dysplasia, or rheumatoid arthritis). In ~70% of patients, no direct cause can be discerned, and the condition is called primary OA (2).

The risk of primary OA of the hip is higher in women than in men (2), and it increases with increasing age (2). We have previously shown that a high body mass index (BMI) and strenuous physical activity at work increase the risk of later total hip arthroplasty for primary OA (3). In a subsequent investigation, we could not demonstrate any positive or negative effect of weight change between the ages of 34 and 47 years on the later need for arthroplasty (4). In an investigation of female nurses, their recalled weight at 18 years of age was more predictive of later total hip arthroplasty than was their BMI measured during middle age (5).

The aim of the present study was to investigate the relationship between BMI, age, and total hip arthroplasty for primary OA. Our hypothesis was that a high BMI is more detrimental to the hip joint at a young age than later in life.

SUBJECTS AND METHODS

Study participants. During 1963–1975, a nationwide screening for tuberculosis was performed in Norway (6). The screening was compulsory for all citizens ages 15 years and older, and ~85% of this population attended. The screening included standardized measurements of height and weight. Persons whose data were noted at the time of screening to be invalid were excluded from the present study. Reasons for invalid data were as follows: the subject was measured with shoes on, was pregnant, refused to be measured, or had anisomelia or severe back deformity.

In 1987, the Norwegian Arthroplasty Register was initiated to monitor the insertion of total hip prostheses (later arthroplasties in all joints) and to ensure early detection of implants for which there were high rates of revision. Orthopedic surgeons report total hip arthroplasties and revision hip surgery on a voluntary basis. The reporting surgeon gives the indication for arthroplasty as either primary OA (the case definition for the present investigation), rheumatoid arthritis, sequela after fracture, sequela after dysplasia, dislocated dysplastic hip, other pediatric hip diseases, ankylosing spondylitis, or other (2). Since 1989, more than 95% of all hip arthroplasties performed in Norway have been registered (2). Followup in the present study (the period of observation for total hip arthroplasties) was from September 15, 1987, to December 31, 2003.

Using the Norwegian 11-digit personal identification code, we matched data on weight and height from the tuberculosis screening with information on hip replacement surgery from the arthroplasty registry. Data on death and emigration were obtained from the Norwegian Registry of Vital Statistics and were included in our study.

The cohort investigated in the present study consisted of all subjects who attended the tuberculosis screening and had valid height and weight records. We excluded persons whose records indicated that they had undergone arthroplasty prior to the start of the Arthroplasty Register, persons who were younger than 18 years at the tuberculosis screening, and persons who had died, emigrated, or reached the age of 80 years before the start of the Arthroplasty Register. A total of 1,152,006 persons were included in the study group.

Approval for the study was obtained from the Norwegian Board of Health, the Data Inspectorate, and the Regional Committee on Ethics in Medical Research.

Statistical analysis. The data were analyzed with the Cox proportional hazards regression model, with time since the start of followup as the time variable and computing hazard rate ratios to estimate relative risks (RRs) (7). For these analyses, an event was defined as a *first* total hip arthroplasty for primary OA. We analyzed persons, rather than hips, so that arthroplasty of the other hip was not considered. Censoring occurred at end of followup (n = 760,459 subjects), death/emigration (n = 346,021 subjects), or arthroplasty for indications other than primary OA (sequelae after femoral neck fracture [n = 5,891 subjects], hip diseases of childhood [n = 3,564], rheumatoid diseases [n = 1,423], and other [n = 1,637]). Another 4,586 participants were censored at their 80th birthday, since a significant proportion of very old subjects may not have received a total hip arthroplasty despite severely symptomatic OA.

The Cox analyses were stratified on sex, and controlled simultaneously for age at screening, age at the start of followup, height, and BMI. Age at screening and age at the start of followup were used as categorical variables. Weight and height were analyzed either as continuous variables or were categorized according to quintiles. BMI was divided into 10 categories. This categorization was more detailed than, but consistent with, the recommendations from the World Health Organization, which defined the following categories: underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0 kg/m^2) (8). Varying advice has been given concerning further subdivision of the obese category (8,9); however, because there were few participants with very high BMI, we set the highest category to include persons with a BMI ≥32 kg/m^2.

We checked the Cox model's assumption of proportional hazards by inspecting log(−log) plots and analyses stratified according to the duration of followup. We also examined smoothed, scaled Schoenfeld residual plots (10) to investigate whether the impact of BMI varied over time.

Analyses using attained age as the time variable gave similar results as the analyses using time since the start of followup as the time variable (data not shown).

We used SPSS version 12.0 (SPSS, Chicago, IL) and S-plus version 6.1 (for Windows; Insightful, Seattle, Washington) software for the computations.

Table 1. Characteristics of 1.2 million participants in a tuberculosis screening study in Norway performed between 1963 and 1975 who were followed up with regard to total hip arthroplasty for primary OA*

	Men	Women
No. of screening study participants	526,972	625,034
No. undergoing total hip arthroplasty for primary OA	8,749	19,676
Age, mean ± SD years		
At screening	38.2 ± 12.5	39.1 ± 12.6
At the start of followup	55.9 ± 12.6	56.9 ± 12.7
At event/censoring	69.7 ± 10.6	71.2 ± 10.8
Weight at screening, mean ± SD kg	75.3 ± 10.1	64.9 ± 11.0
Height at screening, mean ± SD cm	176 ± 6.4	163 ± 5.9
BMI at screening, mean ± SD kg/m^2	24.3 ± 2.9	24.5 ± 4.2

* OA = osteoarthritis; BMI = body mass index.

RESULTS

We identified 28,425 first total hip arthroplasties that were performed because of primary OA during the followup period, 69% of which were in women (Table 1). The mean age of the subjects at the time of arthroplasty was 69 years, and the mean time from screening to the start of followup was 18 years (range 12–24 years).

Effects of sex on later total hip arthroplasty for OA. Women had more than twice as high a risk of undergoing total hip arthroplasty during followup as compared with men. After adjusting for age at screening, age at the start of followup, height, and BMI, the RR in women was 2.5 (95% confidence interval [95% CI] 2.4–2.6).

Table 2. RR of total hip arthroplasty for primary osteoarthritis in 1.2 million Norwegian men and women screened between 1963 and 1975, categorized according to BMI and height*

	No. of subjects	No. of person-years	No. of events	No. of events per 1,000 person-years	Crude RR	Multivariate adjusted RR (95% CI)
BMI, range (mean) kg/m^2						
Men						
<18.5 (17.8)	4,937	74,026	9	0.1	0.2	0.4 (0.2–0.7)
18.5–20.4 (19.7)	38,366	571,268	177	0.3	0.6	0.7 (0.6–0.9)
20.5–21.9 (21.3)	74,820	1,098,864	569	0.5	1	1
22.0–23.4 (22.8)	105,633	1,517,784	1,294	0.9	1.6	1.4 (1.3–1.5)
23.5–24.9 (24.2)	110,333	1,533,794	1,954	1.3	2.5	1.8 (1.6–2.0)
25.0–26.4 (25.7)	84,319	1,119,055	1,884	1.7	3.3	2.2 (2.0–2.4)
26.5–27.9 (27.2)	53,232	677,618	1,314	1.9	3.7	2.3 (2.1–2.6)
28.0–29.9 (28.8)	35,764	435,003	968	2.2	4.3	2.6 (2.4–2.9)
30.0–31.9 (30.8)	13,064	150,457	384	2.6	4.9	3.0 (2.7–3.4)
≥32.0 (33.9)	6,504	72,324	196	2.7	5.2	3.4 (2.9–4.0)
P for trend						<0.001
Women						
<18.5 (17.7)	16,281	254,370	87	0.3	0.3	0.4 (0.3–0.5)
18.5–20.4 (19.7)	74,090	1,166,161	883	0.8	0.6	0.7 (0.7–0.8)
20.5–21.9 (21.3)	99,977	1,546,327	1,965	1.3	1	1
22.0–23.4 (22.7)	107,276	1,606,059	3,068	1.9	1.5	1.3 (1.2–1.4)
23.5–24.9 (24.2)	95,469	1,369,848	3,427	2.5	2.0	1.5 (1.4–1.6)
25.0–26.4 (25.7)	70,724	967,515	2,934	3.0	2.4	1.7 (1.6–1.8)
26.5–27.9 (27.2)	52,968	690,442	2,282	3.3	2.6	1.8 (1.7–1.9)
28.0–29.9 (28.9)	45,697	570,121	2,106	3.7	2.9	2.0 (1.9–2.1)
30.0–31.9 (30.9)	27,768	334,497	1,267	3.8	3.0	2.0 (1.9–2.2)
≥32.0 (35.1)	34,784	396,307	1,657	4.2	3.3	2.3 (2.1–2.4)
P for trend						<0.001
Height, range (mean) cm						
Men						
<171 (167)	99,959	1,232,371	1,526	1.2	1	1
171–173 (172)	80,167	1,060,199	1,316	1.2	1.0	1.1 (1.0–1.2)
174–177 (176)	129,493	1,783,032	2,248	1.3	1.0	1.2 (1.1–1.3)
178–180 (179)	89,305	1,274,685	1,561	1.2	1.0	1.3 (1.2–1.4)
≥181 (184)	128,048	1,899,906	2,098	1.1	0.9	1.3 (1.2–1.4)
P for trend						<0.001
Women						
<158 (154)	107,148	1,373,023	2,598	1.9	1	1
158–161 (160)	142,281	1,964,547	4,263	2.2	1.1	1.3 (1.2–1.3)
162–163 (162)	85,282	1,218,493	2,727	2.2	1.2	1.4 (1.3–1.5)
164–167 (165)	152,042	2,237,840	5,117	2.3	1.2	1.6 (1.5–1.7)
≥168 (171)	138,281	2,107,744	4,971	2.4	1.2	1.9 (1.9–2.0)
P for trend						<0.001

* Multivariate adjusted relative risk (RR) was determined according to a Cox regression model that included as covariates the age at screening, age at the start of followup, height, and body mass index (BMI). 95% CI = 95% confidence interval.

Effects of BMI on later total hip arthroplasty for OA. There was a dose-response association between the BMI and the risk of later arthroplasty of the hip (Table 2). An increase of 5 kg/m^2 in the BMI increased the risk by 68% (95% CI 62–74%) in men and by 35% (95% CI 33–37%) in women. Obese men had more than 8 times the risk as compared with underweight men, whereas obese women had 5 times the risk as compared with underweight women (Table 2). We also computed the RR per 5 kg/m^2 increase in weight separately for each category of age at screening (Figure 1). The RR associated with increased BMI diminished with increasing age. The effect was most pronounced among women: the RR per 5 kg/m^2 increase in BMI was 1.7 (95% CI 1.5–1.9) when measured at age <25 years and 1.1 (95% CI 1.1–1.2) when measured at age 55–59 years. Among the men, the corresponding values were 2.1 (95% CI 1.7–2.5) and 1.5 (95% CI 1.3–1.7).

Repeating this analysis using the BMI as a categorical variable confirmed that, particularly in women, the association between obesity and the RR of later total hip arthroplasty for OA was strongest among young persons (Figure 2). Women ages <25 years at screening with a BMI ≥32.0 kg/m^2 had a 2.8 (95% CI 1.2–6.5) times higher risk than those with a BMI of 18.5–21.9 kg/m^2. Among women ages 55–64 years, those with a BMI ≥32.0 kg/m^2 had only 1.8 (95% CI 1.3–2.6) times higher risk than those with a BMI of 18.5–21.9 kg/m^2.

To assess whether the obese subjects maintained their excess risk of total hip arthroplasty for OA over time, we analyzed separately those who had a short followup period and those who had a long followup period. Men with a followup of fewer than 10 years had a 67% increased risk of total hip arthroplasty per 5 kg/m^2 increase in BMI, whereas men with a followup for more than 10 years had a 69% increased risk. For women, the corresponding values were 34% and 35%. Plots of time-dependent regression coefficients for BMI indicated only a moderate decrease in the RR of total hip arthroplasty for OA throughout the followup period.

Effects of height on later total hip arthroplasty for OA. Among both men and women, we found dose-response associations between height and the risk of later total hip arthroplasty for primary OA (Table 2). A 10-cm increase in height increased the risk of later arthroplasty by 17% (95% CI 13–21%) among the men and by 46% (95% CI 43–50%) among the women. No diminishing of the relative impact with increasing age was seen for body height.

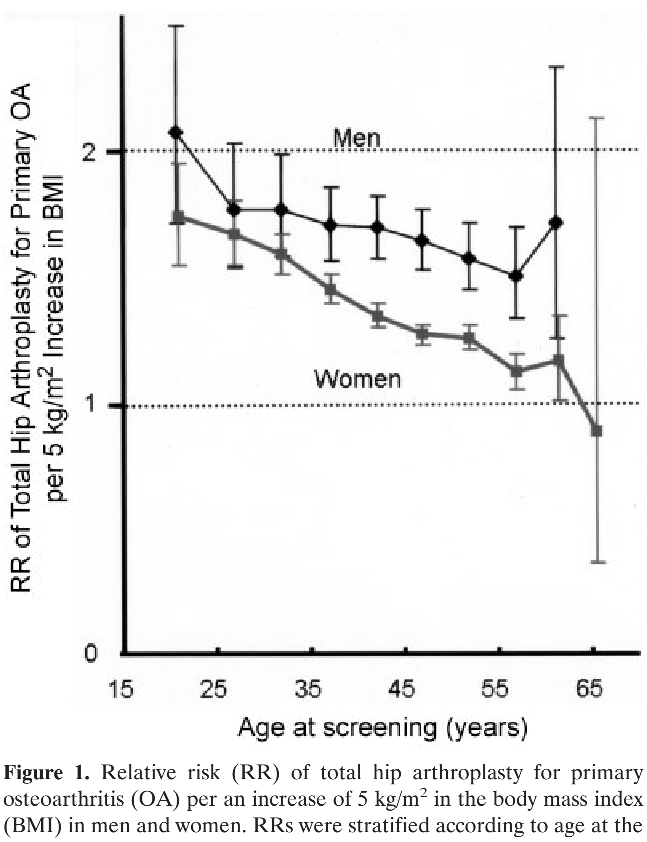

Figure 1. Relative risk (RR) of total hip arthroplasty for primary osteoarthritis (OA) per an increase of 5 kg/m^2 in the body mass index (BMI) in men and women. RRs were stratified according to age at the time of screening and were adjusted for height. Bars show the 95% confidence intervals.

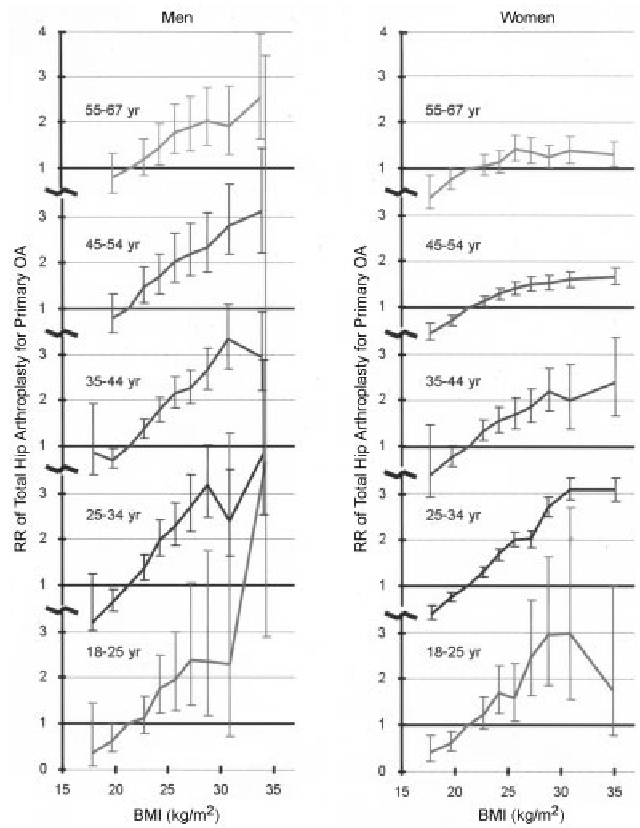

Figure 2. Relative risk (RR) of total hip arthroplasty for primary osteoarthritis (OA) in men and women according to body mass index (BMI) category and age at screening. RRs were stratified according to age at screening and were adjusted for age at the start of followup and height. BMI was categorized as in Table 2, with 20.5–21.9 kg/m^2 used as the reference category for each age group. Bars show the 95% confidence intervals. Some RRs and 95% confidence intervals are lacking because of insufficient data.

DISCUSSION

In a cohort of 1.2 million people who were screened during 1963–1975 at the ages of 18–67 years, a high BMI was associated with an increased risk of later total hip arthroplasty for primary OA. Being overweight when young had a higher impact than being overweight when older.

The high inclusion rate of subjects in the Norwegian Arthroplasty Register (2) as well as the very large numbers of participants and recorded arthroplasties lend strength to the findings of the present investigation. Our results are further strengthened by the measured weight and height, since self-reported data are less reliable among those with extreme values (11) as well as among the old (12).

Among the limitations of the present study, information on known risk factors for total hip arthroplasty for primary OA, such as physical activity, joint injury, and heredity, was lacking. However, in previous studies of OA of the hip (3) and knee (13), adjustment for activity or injury did not substantially alter the estimates of the effect of the BMI.

Followup in the present investigation was incomplete. It did not start at the time of screening, and it stopped while many subjects were still at risk of arthroplasty for hip OA. Participants who were ages 18–25 years at the time of screening were 46–65 years old at the end of the followup period. Since the age-specific incidence of total hip arthroplasty peaks at 70–79 years (2), we had no data on how being overweight as a young adult affects the risk of arthroplasty for OA at the age when the absolute risk for arthroplasty is highest. However, when the analysis was stratified according to the length of followup as well as when the time-dependent regression coefficients for BMI were plotted, we saw only a small diminishing of the RR through the followup period. It is therefore probable that the participants who were overweight as young adults will retain their excess risk beyond the period of our followup.

Both height (14) and BMI (6,15,16) are associated with age. Thus, the differences between the crude and adjusted RRs in the present study may have been affected by age as a confounder.

With regard to using total hip arthroplasty as surrogate end point for severely symptomatic OA, we need to emphasize that health care in Norway is publicly financed. Whether a person receives hip surgery is not dependent upon whether he or she has insurance, and the patient does not incur any direct costs. In a previous study (3), we discussed the annual incidence of total hip arthroplasty among Norwegians ages 35–85 years (2.2 per thousand). This value was equal to the objective need for arthroplasty as estimated in an English investigation (17), indicating that Norwegians' access to hip surgery has been reasonably adequate. However, the English investigation found that for every 100 persons cleared for surgery, there were another 17 persons with severe hip pain who were not candidates for surgery (due to medical contraindications, personal preferences, or other reasons). A Canadian investigation found underuse of hip surgery to be more prevalent among women than among men (18). In Norway, however, the rate of hip surgery is about twice as high among women as among men (2), which is consistent with the sex-specific prevalence of severe hip pain in the Canadian study (5% in women versus 2.3% in men). We conclude that although some patients with severely symptomatic OA of the hip do not undergo total hip arthroplasty, there is little reason to suspect that socioeconomic or sex differences have biased the analyses presented.

Obesity at a young age increased the RR for total hip arthroplasty more than did obesity at an older age, and obese persons maintained an increased RR throughout followup. This means that the persons who were obese when they were young carried with them an excess risk for severe OA into the age when total hip arthroplasty becomes prevalent. This is consistent with the results of the Nurses Health Study that investigated risk factors for total hip arthroplasty in 93,442 women (5). They found that recalled BMI at 18 years was a stronger risk factor than the BMI at a later age. The Johns Hopkins Precursors study found that in 1,180 men followed up for more than 30 years, BMI measured when in medical school was more strongly associated with symptomatic knee OA than was BMI reported later in life (13). The investigators could not demonstrate any association with hip OA, but with only 27 cases, the power to detect an association was limited.

Our previous finding, that the risk for arthroplasty was unaffected by weight change during the fourth and fifth decades of life (4), indicates that the effect of weight may be most prominent during the first decades of life and that the age at onset of obesity may be more important than the duration of obesity. If the relative impact of the BMI is indeed higher at a young age when controlling for all confounding factors, an explanation may be that hip joint cartilage is more vulnerable during the early stages of life.

We found a dose-response association between body height and arthroplasty, which was more pronounced among women than among men. An English investigation of persons without hip disease found that an increase in body height of 10% was accompanied by an increase in minimum hip joint space (an indicator of cartilage thickness) of only 8% among men and 7% among women (19). This suggests that taller persons may not have correspondingly thicker hip joint cartilage and may therefore be more predisposed to the development of OA.

In summary, we used objective measures of body height and weight and found a strong dose-response association between the BMI and later arthroplasty for primary OA of the hip in both women and men. The increase in RR entailed by being overweight and obese was greatest among participants who were screened at a young age. Tall persons also had an increased RR for total hip arthroplasty, but this association was unaffected by age at screening. Our findings highlight the desirability of prevention and early treatment of obesity. We have previously shown that reducing the BMI-related risk for total hip arthroplasty in a cohort of middle-aged Norwegians to that of the quartile with lowest BMI would, theoretically, reduce the need for hip surgery by 25% (95% CI 8–37%) among men and by 36% (95% CI 23–46%) among women (3). It is important to verify whether this possibly large health gain depends on intervention at a young age. The effect of weight intervention with regard to the development of hip OA remains to be shown. Experimental studies may clarify whether cartilage has a changing susceptibility to mechanical load throughout life.

REFERENCES

1. Dunlop DD, Manheim LM, Yelin EH, Song J, Chang RW. The costs of arthritis. Arthritis Rheum 2003;49:101–13.
2. Havelin LI, Engesater LB, Espehaug B, Furnes O, Lie SA, Vollset SE. The Norwegian Arthroplasty Register: 11 years and 73,000 arthroplasties. Acta Orthop Scand 2000;71:337–53.
3. Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE. Risk factors for total hip replacement due to primary osteoarthritis: a cohort study in 50,034 persons. Arthritis Rheum 2002;46: 675–82.
4. Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE. Weight change and the risk of total hip replacement. Epidemiology 2003;14:578–84.
5. Karlson EW, Mandl LA, Aweh GN, Sangha O, Liang MH, Grodstein F. Total hip replacement due to osteoarthritis: the importance of age, obesity, and other modifiable risk factors. Am J Med 2003;114:93–8.
6. Waaler HT. Height, weight and mortality: the Norwegian experience. Acta Med Scand Suppl 1984;679:1–56.
7. Cox DR. Regression models and life tables (with discussion). J R Stat Soc [Ser B] 1972;34:187–220.
8. WHO Consultation. Obesity. Preventing and managing the global epidemic: report of a WHO consultation on obesity. Geneva: World Health Organization; 1998.
9. WHO Expert Committee on Physical Status. Physical status: the use and interpretation of anthropometry. Geneva: World Health Organization; 1995.
10. Grambsch PM, Therneau TM. Proportional hazards tests and diagnostics based on weighted residuals. Biometrika 1994;81: 515–26.
11. Kuskowska-Wolk A, Bergstrom R, Bostrom G. Relationship between questionnaire data and medical records of height, weight and body mass index. Int J Obes Relat Metab Disord 1992;16:1–9.
12. Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the Third National Health and Nutrition Examination Survey, 1988-1994. J Am Diet Assoc 2001;101:28–34.
13. Gelber AC, Hochberg MC, Mead LA, Wang NY, Wigley FM, Klag MJ. Body mass index in young men and the risk of subsequent knee and hip osteoarthritis. Am J Med 1999;107:542–8.
14. Meyer HE, Selmer R. Income, educational level and body height. Ann Hum Biol 1999;26:219–27.
15. Heitmann BL. Ten-year trends in overweight and obesity among Danish men and women aged 30-60 years. Int J Obes Relat Metab Disord 2000;24:1347–52.
16. Sheehan TJ, DuBrava S, DeChello LM, Fang Z. Rates of weight change for black and white Americans over a twenty year period. Int J Obes Relat Metab Disord 2003;27:498–504.
17. Frankel S, Eachus J, Pearson N, Greenwood R, Chan P, Peters TJ, et al. Population requirement for primary hip-replacement surgery: a cross-sectional study. Lancet 1999;353:1304–9.
18. Hawker GA, Wright JG, Coyte PC, Williams JI, Harvey B, Glazier R, et al. Differences between men and women in the rate of use of hip and knee arthroplasty. N Engl J Med 2000;342:1016–22.
19. Lanyon P, Muir K, Doherty S, Doherty M. Age and sex differences in hip joint space among asymptomatic subjects without structural change: implications for epidemiologic studies. Arthritis Rheum 2003;48:1041–6.