

The effect of middle-age body weight and physical activity on the risk of early revision hip arthroplasty

A cohort study of 1,535 individuals

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Background Overweight and a high level of physical activity are known risk factors for loosening of a total hip arthroplasty (THA) due to primary osteoarthritis. We wanted to investigate how these factors, together with age and sex, affect the risk of revision surgery.

Patients and methods We matched data from the Norwegian Arthroplasty Register with information on risk factors collected at a cardiovascular screening. We identified 1,535 primary THAs in the screened cohort (930 cemented implants using well-documented cement). Of the participants included, 969 were female. Mean age at screening was 49 years, at primary THA 63 years, and 69 years at the end of follow-up. We used Cox regression analysis to estimate relative risks (RRs). Event was defined as implant revision due to aseptic loosening of cup, stem or both. Follow-up was time from primary THA to event or censoring.

Results Men were at greater risk than women of loosening of the femoral stem (RR 2.0, 95% CI 1.3–3.2). Both men and women with upper-quartile body weight were at increased risk of revision due to loosening of the stem (RR 2.5 and 2.7, respectively). Men with a high level of physical activity during leisure time were at increased risk of revision due to loosening of the cup (RR 4.8, 95% CI 1.3–18). In the multivariate model with adjustment for activity, there was little association between age at primary THA and risk of revision due to loosening.

Interpretation We found that body weight and physical activity recorded long before THA affected the survival of total hip arthroplasties. Controlling for

these variables weakened the association between age at primary surgery and aseptic loosening. Men had an increased risk of loosening of the femoral stem, also after controlling for lifestyle factors. ■

Investigators have consistently reported survival rates of more than 90% for total hip arthroplasties (THA) at 10 years. Long-term follow-up has shown survival at 25 years to be 81% (Berry et al. 2002), and 55–68% at ~30 years (Wroblewski et al. 2002, Callaghan et al. 2004). Important reasons for implant revision are aseptic loosening, dislocation, pain, infection, osteolysis, and implant wear (Havelin et al. 2000). Clinical investigations have indicated that aseptic loosening of the acetabular cup is closely linked to polyethylene wear (Oparaugo et al. 2001), which may be more affected by the number of motion cycles than by the magnitude of load (Schmalzried and Callaghan 1999). Conversely, the cemented stem may be affected only minimally by smaller loads, whereas heavy loads can cause debonding and fractures at the cement-metal interface (O'Connor et al. 1996, Race et al. 2003).

We investigated the association between physical activity and body mass index in middle age, and later revision hip arthroplasty due to aseptic loosening of the cup or stem. Assuming that these

risk factors do not change to any great extent from before to after primary hip surgery, we also wanted to determine whether activity and weight influence the loosening of acetabular and femoral components in different ways.

Patients and methods

Data registers

The Norwegian Arthroplasty Register (NAR) was started in 1987 (Havelin et al. 1993). Reporting to the register increased throughout the first 2 years, and since 1989, 97% of all primary total hip arthroplasties and revision hip arthroplasties in Norway have been recorded (Havelin et al. 2000). The form used for reporting to the Register was modified slightly in 1993, but both versions of the form recorded the type of implant and type of fixation. In the register, a revision is defined as surgery involving the removal or exchange of any or all parts of a total hip arthroplasty. For the present study, we identified participants who had undergone a THA for any reason before January 1, 2001. Primary hip surgery performed before the start of the Norwegian Arthroplasty Register could only be identified in participants with revision hip surgery performed after the start of the register (as the registration form used at revision also contained information concerning primary surgery).

We matched the data on hip surgery with screening data collected by the National Health Screening Service (now the Norwegian Institute of Public Health). During 1977–1983, the service screened the inhabitants of 3 Norwegian counties who were born between 1925 and 1942 for risk factors in cardiovascular disease (National Health Screening Service 1988). Specially trained screening nurses measured body height and weight. They also checked a questionnaire that the participants had received along with the screening invitation, which included questions on physical activity at work and during leisure (Saltin and Grimby 1968), and smoking habits.

Of 56,818 individuals invited, to the cardiovascular screening, 52,143 (92%) attended (Flugsrud et al. 2002). We also included data from the Norwegian Registry of Vital Statistics on marital status, death, and emigration.

Table 1. Basic characteristics stratified according to sex

	Men	Women
Participants, n	566	969
Revisions for aseptic loosening of cup and/or stem, n	72	93
<i>Mean (SD)</i>		
Age at screening	49 (4.2)	48 (4.4)
Body weight (kg)	81 (11)	70 (12)
Height (m)	1.76 (0.065)	1.63 (0.063)
BMI (kg/m ²)	26.3 (3.1)	26.5 (4.4)
Age at primary THA	63 (5.4)	63 (5.8)
Age at event/censoring	68 (4.6)	68 (4.9)

Study group

We identified 1,535 participants (969 females) who had received a THA before the end of follow-up (Table 1). Of these, 798 patients (52%) had valid data on all covariates while 1,489 patients (97%) had valid data on both anthropometry and physical activity. In the study group 121 participants died with an unrevised THA during follow-up. During follow-up, 165 participants were revised for aseptic loosening (49 for cup, 59 for stem, and 57 for both). 13 of these patients underwent revision for infection, 6 for dislocation, 2 for fracture, 3 for pain, and 9 for other indications. Of the 165 revisions for aseptic loosening, 93 involved female patients. Of the participants who were revised, 90 had their primary hip surgery fully documented in the NAR, while the other 75 underwent THA before the NAR started, and information on their primary hip surgery was recorded at the revision. Mean age at screening was 49 years. Mean age at primary operation for all participants was 63 years, and for patients who were eventually revised it was 57 years. Of the participants included, 1,025 (67%) had undergone THA due to primary osteoarthritis. Other indications for primary hip surgery were sequelae of hip dysplasia with or without dislocation (159), or of a hip fracture (147), and rheumatoid arthritis (48). The indication for THA was not available in 113 (7.4%) of the participants.

Statistics

Simple survival was computed using the Kaplan-Meier method. We used the Cox proportional

hazard regression model to compute hazard ratios, estimating relative risks. Analyses were performed defining “event” as revision for aseptic loosening of cup or stem, or both. Censoring occurred at death, end of follow-up, or revision for indications other than aseptic loosening. In the Cox analysis, time was measured as years from primary THA to event or censoring. We included the same covariates in the model as we have previously studied in relation to primary osteoarthritis requiring total hip replacement (Flugsrud et al. 2002, 2003). Log-minus-log survival curves for each of the risk factors under investigation confirmed the proportional hazards assumption of the Cox model. Data were analyzed using SPSS version 12.0 software.

Age at primary THA was used as a continuous variable, except in specified analyses where it was categorized according to quartiles. For some analyses the study group was divided according to age at primary THA, with cut-off at 60 years (men) or 55 years (women). Body weight and height, and body mass index (BMI) were categorized according to quartiles. When specifically stated, weight rather than BMI was included in the model. Otherwise, BMI is used in the regression model rather than body weight. Physical activity at work and during leisure were independently classified as sedentary, moderate, intermediate or intensive; participants were asked to choose the alternatives that best described their level of activity during the 12 months that preceded screening (Flugsrud et al. 2002). Due to small numbers in the group with most intensive physical activity during leisure (8 men and no women), intermediate and intensive physical activity during leisure were analyzed as one group. Smoking habits were classified as current smoker, ex-smoker, or never smoker. Marital status was classified as unmarried, married, widow, divorced, or separated. At primary THA only one diagnosis was recorded in the National Arthroplasty Register, but at revision surgery one or more indications for surgery could be given.

Based on previous publications from the Norwegian Arthroplasty Register, the prosthetic implant used at primary hip surgery was classified as Cemented – good cement (Havelin et al. 1995a); Cemented – inferior cement (Havelin et al. 1995a, Espehaug et al. 2002); Hybrid: cementless HA or porous-coated cup with cemented stem, good

cement; Uncemented implant with hydroxyapatite or porous coating (Havelin et al. 1995b); Uncemented without hydroxyapatite or porous coating; or Expired.

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

Results

Age at screening, at THA and at event/censoring were similar between men and women (Table 1). The group of revised participants had a lower mean age at THA (56 years) than the unrevised participants (63 years). As most censorings occurred at end of follow-up, mean age at censoring (unrevised cases) was somewhat higher than at event (revised cases). The median time from screening to primary THA was 15 years, and in 95% of cases more than 6 years had elapsed between screening and THA. Survival to revision for any indication at 10 years for all THAs implanted after the Arthroplasty Register started was 82% (95% CI 78–86). 10-year survival of cemented implants using good cement, to revision due to aseptic loosening of cup or stem or both, was 88% (95% CI 84–93).

Age and sex

Comparing sexes, in the multivariate analysis men had twice the risk of revision due to aseptic loosening of the stem (RR 2.0, 95% CI 1.3–3.2). There was no significant difference for the cup (RR 1.3, 95% CI 0.8–2.3). There was no significant association between age and the risk of revision in men after adjusting for covariates (Table 2), but women had a 28% reduced risk of revision due to a loose cup for every 5 years of increase in age at primary THA (Table 3). Categorizing age at THA into age groups did not alter the results of the analyses (data not shown).

Body weight and height, and BMI

Both men and women in the highest quartile of body weight were at increased risk of stem loosening (Tables 2 and 3). In men the increase in risk from lowest to highest quartile of body weight suggested a dose-response relationship between body

Table 2. Rates and relative risks of aseptic loosening in 566 men

	A	B	Acetabular component				Femoral component			
			C	D	E	F	C	D	E	F
Age at primary THR, per 5 years	566	2,811				0.8 (0.5–1.4)				1.0 (0.6–1.5)
BMI (kg/m ²)										
< 24.3	141	683	11	16.1	1	1	12	17.6	1	1
24.3–26.1	137	647	6	9.3	0.6	0.9 (0.3–2.6)	14	21.6	1.2	2.3 (1.0–5.4)
26.1–28.2	138	741	9	12.2	0.8	0.5 (0.2–1.5)	9	12.2	0.7	0.9 (0.4–2.4)
> 28.2	129	636	12	18.9	1.2	1.1 (0.4–2.8)	17	26.7	1.5	2.3 (1.0–5.5)
545	2,707	38	14.0	0.9		52	19.2	1.1		
Body weight, kg										
< 74	137	734	9	12.3	1	1	11	15.0	1	1
74–80	149	698	7	10.0	0.8	0.7 (0.2–2.0)	12	17.2	1.2	1.4 (0.6–3.4)
80–88	136	708	8	11.3	0.9	0.9 (0.3–2.6)	12	17.0	1.1	1.5 (0.6–3.7)
> 88	124	571	14	24.5	2.0	1.5 (0.5–4.4)	17	29.8	2.0	2.5 (1.0–6.3)
546	2,711	38	14.0	1.1			52	19.2	1.3	
Body height (m)										
< 1.72	162	866	10	11.6	1	1	12	13.9	1	1
1.72–1.75	120	607	7	11.5	1.0	1.4 (0.5–3.9)	6	9.9	0.7	1.0 (0.4–2.8)
1.75–1.80	145	695	12	17.3	1.5	1.2 (0.5–3.0)	24	34.5	2.5	2.5 (1.2–5.2)
> 1.80	118	539	9	16.7	1.5	1.3 (0.5–3.7)	10	18.6	1.3	1.1 (0.45–2.7)
545	2,707	38	14.0	1.2			52	19.2	1.4	
Physical activity at work										
Sedentary	116	547	9	16.5	1	1	13	23.8	1	1
Moderate	131	670	12	17.9	1.1	0.6 (0.2–1.8)	14	20.9	0.9	0.8 (0.3–2.0)
Intermediate	135	614	8	13.0	0.8	0.6 (0.2–2.0)	12	19.5	0.8	0.7 (0.3–1.9)
Intensive	180	966	10	10.4	0.6	0.6 (0.2–1.6)	14	14.5	0.6	0.6 (0.3–1.5)
562	2,797	39	13.9	0.9			53	19.0	0.8	
Physical activity during leisure										
Sedentary	99	536	4	7.5	1	1	11	20.5	1	1
Moderate	277	1,418	20	14.1	1.9	3.1 (0.8–11.8)	25	17.6	0.9	0.9 (0.4–2.2)
Intermediate	180	821	14	17.1	2.3	4.8 (1.3–18.2) b	16	19.5	1.0	1.1 (0.5–2.8) a
Intensive	8	25	1	40.0	5.4	a	1	40.0	2.0	a
564	2,800	39	13.9	1.9			53	18.9	0.9	

^a In the regression model intermediate and intensive levels of physical activity during leisure were analyzed as one group.

A No. of participants with valid data

B Person-years

C No. of events

D Events per 1,000 person-years

E Crude risk

F Multivariate relative risk (95% CI). All analyses were adjusted for age at screening, body height, body mass index (BMI), physical activity at work, physical activity during leisure, marital status, smoking habits, and implant category except those explicitly analyzing body weight, where BMI was omitted.

weight and stem revision, but the test for trend was not significant ($p = 0.2$). The association was less regular in women. Stratification according to age did not change this impression (data not shown). In women the estimated relative risk increased with increasing BMI, but the results did not reach significance for any of the endpoints investigated. No association between BMI and revision risk could be seen among men. Men who were 1.75–1.80 m tall had an increased risk of stem revision relative

to those shorter than 1.72 m. Our results did not indicate a dose-response relationship, and the finding may have been spurious.

Physical activity

Men with intermediate or intensive physical activity during leisure had a fourfold increase in risk of revision for aseptic loosening of the cup, compared to men with sedentary activity during leisure (Table 2). In this analysis the test for trend was positive

Table 3. Rates and relative risks of aseptic loosening in 969 women

			Acetabular component				Femoral component			
	A	B	C	D	E	F	C	D	E	F
Age at primary THR, per 5 years	969	5,140				0.7 (0.5; 1.0)				0.8 (0.6; 1.2)
BMI, kg/m ²										
<23.3	244	1,269	16	12.6	1	1	17	13.4	1	1
23.2–25.8	233	1,270	18	14.2	1.1	1.2 (0.6; 2.4)	16	12.6	0.9	1.0 (0.5; 2.2)
25.8–28.9	232	1,244	18	14.5	1.6	1.3 (0.6; 2.8)	14	11.3	0.8	1.1 (0.5; 2.4)
>28.9	231	1,181	12	10.2	0.8	1.3 (0.6; 3.1)	13	11.0	0.8	1.7 (0.7; 3.9)
	940	4,964	64	12.9	1.0		60	12.1	0.9	
Body weight, kg										
<62	251	1,378	18	13.1	1	1	16	11.6	1	1
62–68	221	1,138	19	16.7	1.3	2.1 (0.9; 4.5)	19	16.7	1.4	2.3 (1.1; 5.2)
68–77	251	1,342	14	10.4	0.8	1.0 (0.4; 2.3)	11	8.2	0.7	1.2 (0.5; 2.8)
>77	217	1,105	13	11.8	0.9	1.7 (0.7; 4.3)	14	12.7	1.1	2.7 (1.1; 6.9)
	940	4,964	64	12.9	1.0		60	12.1	1.0	
Body height (m)										
<1.59	268	1,480	22	14.9	1	1	22	14.9	1	1
1.59–1.63	237	1,318	17	12.9	0.9	1.1 (0.5; 2.20)	12	9.0	0.6	0.7 (0.3; 1.5)
1.63–1.67	213	1,046	9	8.6	0.6	0.76 (0.3; 1.7)	12	11.5	0.8	1.0 (0.5; 2.2)
>1.67	222	1,121	16	14.3	1.0	1.7 (0.8; 3.4)	14	12.5	0.8	1.2 (0.6; 2.5)
	940	4,964	64	12.9	0.9		60	12.1	0.8	
Physical activity at work										
Sedentary	121	674	13	19.3	1	1	9	13.4	1	1
Moderate	544	2,876	37	12.9	0.7	0.7 (0.3; 1.5)	42	14.6	1.1	1.3 (0.5; 3.0)
Intermediate	218	1,094	12	11.0	0.6	1.0 (0.4; 2.4)	8	7.3	0.6	0.9 (0.3; 2.7)
Intensive	81	465	5	10.8	0.6	0.9 (0.3; 3.0)	3	6.5	0.5	0.6 (0.1; 2.5)
	964	5,109	67	13.1	0.7		62	12.1	0.9	
Physical activity during leisure										
Sedentary	191	1,106	16	14.5	1	1	17	15.4	1	1
Moderate	635	3,349	42	12.5	0.9	0.7 (0.4; 1.5)	36	10.8	0.7	0.6 (0.3; 1.2)
Intermediate	142	674	9	13.4	0.9	1.6 (0.6; 4.1) ^b	11	16.3	1.1	1.3 (0.5; 3.4) ^a
Intensive	0	–	–	–	–	^a	–	–	–	^a
	968	5,130	67	13.06	0.9		63	12.3	0.8	

For abbreviations, see Table 2

($p = 0.04$), indicating a dose-response relationship. The association was similar when we restricted the study group to participants with records of both primary and revision hip surgery in the NAR (1,433 participants with 54 events), though the test for trend did not reach significance ($p = 0.05$). Separate analyses of men with age at THA that was (1) greater or equal to, or (2) less than 60 years showed the same association for both groups. No association between physical activity during leisure and revision could be seen in women.

Women appeared to have less risk of revision the more physically demanding they reported their work to be at the screening. This was most prominent in women who were over 55 at primary THA. The same tendency could be seen to a lesser degree in men, irrespective of age at THA.

Marital status and smoking habits

No consistent association was found between these parameters and the risk of later revision surgery (data not shown).

Primary implant and method of fixation

Of the 1,535 implants investigated, 930 were cemented using well-documented cement, 284 were cementless, and 174 were cemented with inferior cement. It was essential to control for primary implant, otherwise the analyses grossly overestimated the effect of age at THA—as inferior implants were mainly used in younger patients. Subanalysis including only participants who received a cemented primary implant with good cement generally gave the same impression as analysis of the whole study group. There were too

few participants with other implants to make comparisons of implants meaningful.

Indication for primary THA

Controlling for the indication for primary hip surgery in the Cox model did not strengthen the model, and had no effect on the results.

Discussion

We found that high weight at middle age was associated with revision for aseptic loosening of the femoral stem in both sexes. A high level of physical activity entailed an increased risk of revision due to aseptic loosening of the acetabular cup in men. Even after controlling for anthropometry and physical activity at middle age, we found that men had a higher risk of revision due to aseptic loosening of the femoral stem than women, and that the risk of revision due to cup loosening in women decreased with increasing age at primary THA.

Validation of questionnaire

The questions concerning physical activity were introduced in Sweden (Saltin and Grimby 1968), and similar questions were used in the World Health Organization study Monitoring of Trends and Determinants in Cardiovascular Disease (Stender et al. 1993). Both questions have been validated against maximum oxygen uptake during exertion (Wilhelmsen et al. 1976). The question concerning physical activity during work has been validated against a 7-day diary (Stender et al. 1991), and the question concerning leisure activity has been validated against maximum work capacity (Løchen and Rasmussen 1992).

Strengths of the study

The present investigation was strengthened by the prospective gathering of data and the high attendance at screening. A comparison of the Norwegian Arthroplasty Register (NAR) with the Norwegian Patient Register showed a completeness of registration in the NAR during 1999–2002 of 97% for primary hip arthroplasty. In the same interval, more exchange revision procedures were recorded in the NAR than in the Patient Register (Espehaug et al. 2006). Comparing the NAR with the records

from 1987–2003 of one (very dedicated) hospital showed that 0.2% of primary arthroplasties and 1.2% of revisions had not been recorded in the NAR (Arthursson et al. 2005).

Weaknesses of the study

The inclusion algorithm allowed the inclusion of some participants for whom only revision (and not primary THA) had been recorded in the NAR. This meant that participants for whom primary hip surgery had been performed before the start of the NAR were only included if they had been revised later. We were thus unable to include screened participants who underwent THA before NAR started, and who did not have revision surgery after January 1, 1987. Redoing all the analyses on a study group restricted to those with primary operation after start-up of NAR did not give any significant results, but the patterns were largely the same as in the total study group.

We were mainly interested in the exposure to risk factors after primary THA, but our exposure data were all recorded before primary hip surgery. This is discussed in greater detail below, for each risk factor. We did not assess the immediate post-operative results, and could not evaluate whether, for example, there was a preponderance of inferior surgery in patients with high body weight that could have influenced revision rates. Obese people profit as much from joint replacements as others do (Stickles et al. 2001), and the prevalence of improper cup positioning has been as low among obese patients as among patients of normal weight (Paterno et al. 1997).

The still somewhat young age of the study group at the end of follow-up represents a weakness in that there will be many instances of both primary and revision surgery in the screened cohort after the end of follow-up. Stratifying the analyses according to age at primary THA had little effect on the results.

It is not obvious that different hip implants and different methods of fixation entail the same risk factors for revision. Cemented implants using good cement had been used in 61% of all participants, but only in 22% of the participants who underwent revision due to aseptic loosening during follow-up. Restricting the analyses to participants with THA using good cement showed the same pattern as

when analyzing the whole study group, but it was less distinct due to few endpoints. The number of participants in our study group with other kinds of THA was too low to allow one to discern possible differences in revision risk. Due to the many different implants employed, we could not control for implant size in a standardized way.

Age and sex

We found an inverse relationship between age at THA and risk of revision for cup loosening in women. Otherwise, there was no association between age at THA and later revision for aseptic loosening. An investigation of 2,000 Charnley hip arthroplasties that had been followed for 25 years showed a significant increase in implant survival with increasing age at THA (Berry et al. 2002). The effect was most pronounced for the cups. The Swedish Arthroplasty Register reported better survival with increasing age at THA for cemented arthroplasties (Swedish National Hip Arthroplasty register. Annual Report 2004). Neither of these investigations included information on physical activity or anthropometry. Our relatively short observation time after THA, and narrow age-span at THA, may have reduced the sensitivity to an effect of age at THA. It is, however, probable that the negative effect of young age found by other authors was influenced by higher activity levels among younger patients.

After controlling for anthropometry, physical activity, primary diagnosis and type of implant, we found men to be at increased risk of revision due to aseptic stem loosening compared to women. In The Swedish National Hip Arthroplasty Register, it was found that men with cemented prostheses were at increased risk, except in patients who were younger than 50 years at THA (2004). It is conceivable that more detailed knowledge about the amount and kind of physical activity (and other lifestyle factors) would have reduced the difference in risk between men and women. Even so, the possibility remains that biological gender differences have also put men at a greater risk of aseptic loosening of a hip arthroplasty.

Body weight, height, and BMI

Both men and women in the highest weight quartile had more than double the risk of aseptic stem loosening than those in the lowest weight quartiles.

A longitudinal investigation in the Norwegian city of Tromsø that measured BMI repeatedly found that men aged 45–49 years had a mean BMI of 24.6 kg/m², which had increased to 25.7 kg/m² 20 years later. Women aged 45–49 years had a mean BMI at inclusion of 24.3 kg/m², which had increased to 26.0 kg/m² 15 years later (Jacobsen et al. 2001). One study of patients undergoing primary hip arthroplasty found no difference in body weight from before to after surgery (Utvoll et al. 2002). It therefore seems that in our population, BMI at screening was a good predictor of BMI after hip surgery, but that during this time the population had a mean increase in BMI of 1–2 kg/m².

In our investigation we found no evidence of an association between BMI at middle age and later risk of revision. A follow-up study of 426 primary Charnley hip arthroplasties found revisions after 10 years to be more frequent among patients with a BMI of greater than 25 kg/m², apparently measured at the latest follow-up (Fuchs and Wieder 2000). The authors reported an overall 10-year survival of only 78%, however, and their results may not be generally applicable. Our results are in accordance with a case-control study that measured participants' anthropometrics at the time of admission for prosthetic revision surgery, in which they found no association between BMI and revision risk (Wendelboe et al. 2003). It appears that while the strains on a hip implant—and thus the risk of stem revision—increase with body weight, it does not matter whether the body mass is spread thinly out on a long body, or packed densely on a short one.

Physical activity at work

We found no significant associations between physical activity at work and risk of revision for loosening, but the data suggest a lower revision risk the more physically demanding work the participant reported at screening. A previous report found patients with THAs who returned to heavy work to be at increased risk of revision (Kilgus et al. 1991), and it is difficult to see how strenuous work in the fifth decade of life should protect against aseptic loosening of a THA implanted later. One possible explanation is that the Norwegian public sick-leave pension provides adequately for patients who leave

work. Most patients with heavy physical labor probably stop working permanently after their hip arthroplasty. There may thus be a weak—or even inverse—relationship between physical activity at work at screening and after primary hip surgery in our study group. There were no data available to allow us to verify this relationship.

Physical activity during leisure

We found that a high level of physical activity during leisure at an average age of 42 years was a predictor of early revision for loosening of the cup, particularly among men. There appeared to be a dose-response relationship, but the confidence intervals were wide. This can best be explained if the level of physical activity during leisure as recorded at screening correlates with the activity level after primary THA. In a case-control investigation, participants were asked whether they were doing regular exercise before and after THA. Of 261 who exercised before THA, 167 also did so after surgery, while of 193 who did not exercise before THA, only 65 had started regular exercise after THA ($p < 0.001$) (Espehaug, personal communication 2004). In an investigation of 194 THA patients describing participation in 5 specific sports activities before and after total hip arthroplasty, 87% of the answers indicated unchanged participation, 10% indicated increased and 3% indicated decreased participation (Ritter and Meding 1987). These findings substantiate the assumption that there was a high correlation in our study group between the level of physical leisure activity the participants reported at the screening, and the amount of physical exercise they were performing after THA.

Our findings lend support to the hypothesis that physical activity after THA increases the risk of aseptic cup loosening *in vivo*. The fact that physical activity during leisure did not increase the risk of loosening of the stem may indicate that the alternatives used to describe leisure activity were more sensitive to the number of hip motion cycles irrespective of load, than to the number of episodes with high hip load.

To summarize, we found that body weight and physical activity affect the survival of total hip arthroplasties. Controlling for these variables weakened the association between age at pri-

mary surgery and aseptic loosening. Men were at increased risk of loosening of the femoral stem, also after controlling for lifestyle factors. The unequal impact of body weight and physical activity on cup and stem loosening that we have found here is in keeping with separate mechanisms of loosening (Harris 1994).

Contributions of authors

GBF, LN and HEM: conceived the idea. All authors designed the study. BE and HEM: prepared the data and did the database linkage. GBF: carried out the statistical analyses and the literature search and wrote the draft of the paper. BE and HEM: gave advice on statistical methodology, and all authors critically reviewed and contributed to the final paper.

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- Arthursson A, Furnes O, Espehaug B, Havelin L I, Søreide J A. Validation of data in the Norwegian Arthroplasty Register and the Norwegian Patient Register 5,134 primary total hip arthroplasties and revisions operated at a single hospital between 1987 and 2003. *Acta Orthop* 2005; 76: 823-8.
- Berry D J, Harmsen W S, Cabanela M E, Morrey B F. Twenty-five-year survivorship of two thousand consecutive primary Charnley total hip replacements: factors affecting survivorship of acetabular and femoral components. *J Bone Joint Surg (Am)* 2002; 84: 171-7.
- Callaghan J J, Templeton J E, Liu S S, Pedersen D R, Goetz D D, Sullivan P M, et al. Results of Charnley Total Hip Arthroplasty at a Minimum of Thirty Years. A Concise Follow-up of a Previous Report. *J Bone Joint Surg (Am)* 2004; 86: 690-5.
- Charnley J. *Low friction arthroplasty of the hip. Theory and practice.* Berlin, Germany: Springer Verlag 1979.
- Espehaug B, Furnes O, Havelin L I, Engesaeter L B, Vollset S E. The type of cement and failure of total hip replacements. *J Bone Joint Surg (Br)* 2002; 84: 832-8.
- Espehaug B, Furnes O, Havelin L I, Engesaeter L B, Vollset S E, Kindseth O. Registration completeness in the Norwegian Arthroplasty Register. *Acta Orthop* 2006; 77: 49-56.
- Flugsrud G B, Nordsletten L, Espehaug B, Havelin L I, Meyer H E. Risk factors for total hip replacement due to primary osteoarthritis: A cohort study in 50,034 persons. *Arthritis Rheum* 2002; 46: 675-82.
- Flugsrud G B, Nordsletten L, Espehaug B, Havelin L I, Meyer H E. Weight change and the risk of total hip replacement. *Epidemiology* 2003; 14: 578-84.
- Fuchs S, Wieder J. Survival rate of the cemented Charnley total hip endoprosthesis and modifying parameters. *Biomed Tech (Berl)* 2000; 45: 362-9.
- Harris W H. Osteolysis and particle disease in hip replacement. A review. *Acta Orthop Scand* 1994; 65: 113-23.

- Havelin L I, Espehaug B, Vollset S E, Engesaeter L B, Langeland N. The Norwegian arthroplasty register. A survey of 17,444 hip replacements 1987-1990. *Acta Orthop Scand* 1993; 64: 245-51.
- Havelin L I, Espehaug B, Vollset S E, Engesaeter L B. The effect of the type of cement on early revision of Charnley total hip prostheses. A review of eight thousand five hundred and seventy-nine primary arthroplasties from the Norwegian Arthroplasty Register. *J Bone Joint Surg (Am)* 1995a; 77: 1543-50.
- Havelin L I, Vollset S E, Engesaeter L B. Revision for aseptic loosening of uncemented cups in 4,352 primary total hip prostheses. A report from the Norwegian Arthroplasty Register. *Acta Orthop Scand* 1995b; 66: 494-500.
- Havelin L I, Engesaeter L B, Espehaug B, Furnes O, Lie S A, Vollset S E. The Norwegian Arthroplasty Register: 11 years and 73,000 arthroplasties. *Acta Orthop Scand* 2000; 71: 337-53.
- Jacobsen B K, Njølstad I, Thune I, Wilsgaard T, Lochen M L, Schirmer H. Increase in weight in all birth cohorts in a general population: The Tromsø Study, 1974-1994. *Arch Intern Med* 2001; 161: 466-72.
- Kilgus D J, Dorey F J, Finerman G A, Amstutz H C. Patient activity, sports participation, and impact loading on the durability of cemented total hip replacements. *Clin Orthop* 1991; (269): 25-31.
- Løchen M L, Rasmussen K. The Tromsø study: physical fitness, self reported physical activity, and their relationship to other coronary risk factors. *J Epidemiol Community Health* 1992; 46: 103-7.
- National Health Screening Service. The cardiovascular disease study in Norwegian counties: results from second screening. Oslo, Norway: National Health Screening Service; 1988.
- O'Connor D O, Burke D W, Jasty M, Sedlacek R C, Harris W H. In vitro measurement of strain in the bone cement surrounding the femoral component of total hip replacements during simulated gait and stair-climbing. *J Orthop Res* 1996; 14: 769-77.
- Oparaugo P C, Clarke I C, Malchau H, Herberts P. Correlation of wear debris-induced osteolysis and revision with volumetric wear-rates of polyethylene: a survey of 8 reports in the literature. *Acta Orthop Scand* 2001; 72: 22-8.
- Paterno S A, Lachiewicz P F, Kelley S S. The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. *J Bone Joint Surg (Am)* 1997; 79: 1202-10.
- Race A, Miller M A, Ayers D C, Mann K A. Early cement damage around a femoral stem is concentrated at the cement/bone interface. *J Biomech* 2003; 36: 489-96.
- Ritter M A, Meding J B. Total hip arthroplasty. Can the patient play sports again? *Orthopedics* 1987; 10: 1447-52.
- Saltin B, Grimby G. Physiological analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. *Circulation* 1968; 38: 1104-15.
- Schmalzried T P, Callaghan J J. Current Concepts Review. Wear in total hip and knee replacements. *J Bone Joint Surg (Am)* 1999; 81: 115-36.
- Stender M, Döring A, Hense H W, Schlichtherle S, M'Harzi S, Keil U. Comparison of 2 methods for the assessment of physical activity. *Soz Präventivmed* 1991; 36: 176-83.
- Stender M, Hense H-W, Döring A, Keil U. Physical activity at work and cardiovascular disease risk: results from the MONICA Augsburg study. *Int J Epidemiol* 1993; 22: 644-50.
- Stickles B, Phillips L, Brox W T, Owens B, Lanzer W L. Defining the relationship between obesity and total joint arthroplasty. *Obes Res* 2001; 9: 219-23.
- Swedish National Hip Arthroplasty register Annual Report 2004. Gotheburgh, Sweden: Department of Orthopaedics, Sahlgrenska University Hospital; <http://www.jru.orthop.gu.se/>
- Utvoll J, Flugsrud G B, Nordsletten L. Weight change from before to after primary hip arthroplasty. In: Vasli L (ed.), 2002 Congress of the Norwegian Surgical Associations. Proceedings. Oslo, Norway; 2002.
- Wendelboe A M, Hegmann K T, Biggs J J, Cox C M, Portmann A J, Gildea J H, et al. Relationships between body mass indices and surgical replacements of knee and hip joints. *Am J Prev Med* 2003; 25: 290-5.
- Wilhelmsen L, Tibblin G, Aurell M, Bjure J, Ekström-Jodal B, Grimby G. Physical activity, physical fitness and risk of myocardial infarction. *Adv Cardiol* 1976; 18: 217-30.
- Wroblewski B M, Siney P D, Fleming P A. Charnley low-frictional torque arthroplasty in patients under the age of 51 years. Follow-up to 33 years. *J Bone Joint Surg (Br)* 2002; 84: 540-3.