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ORIGINAL REPORT

EFFECTS OF POSTOPERATIVE WEIGHT-BEARING ON BODY COMPOSITION AND BONE MINERAL DENSITY AFTER UNCEMENTED TOTAL HIP ARTHROPLASTY

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Objective: **To investigate whether a postoperative weight-bearing regimen affects changes in bone mineral density and body composition after uncemented total hip arthroplasty, and to investigate the changes over a 5-year period after the surgical procedure.**
Design: **Secondary analysis of a previous randomized controlled trial.**
Methods: **A total of 39 patients were randomized to immediate full weight-bearing or partial weight-bearing for 3 months. Dual-energy X-ray absorptiometry was used to measure bone mineral density of the contralateral hip and both heels and to measure body composition.**
Results: **The weight-bearing regimen had no effect on change in bone mineral density or body composition after 3 and 12 months. At 5 years, there was a decrease in bone mineral density of 3% in the total body and 2–3% in the contralateral hip regions. At 5 years we found a decrease in total body bone mineral content of 5%, but no changes in fat mass or lean mass compared with preoperative values.**
Conclusion: **The postoperative weight-bearing regimen had no effect on changes in body composition or bone mineral density. Five years after total hip arthroplasty there was a decrease in bone mineral content and bone mineral density, but no changes in lean mass or fat mass.**

Key words: osteoarthritis of the hip; uncemented total hip arthroplasty; DXA; weight-bearing; body composition; bone mineral density.

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INTRODUCTION

Osteoarthritis of the hip (OAH) results in pain, which, in advanced OAH, limits everyday physical function, reduces walking ability and distance, makes walking aids necessary, and consequently limits the patient in several ways. Total hip arthroplasty (THA) is one of the most effective surgical procedures regarding physical function and pain relief. The benefits of THA are well documented, through the use of disease-specific and generic health-related quality of life instruments, e.g. the Western Ontario and McMaster Universities Osteoarthritis Index and the Short-Form 36 (1, 2).

Several randomized studies have reported no adverse effects on implant stability with early rehabilitation and full weight-bearing following uncemented THA (3–6). This is supported by a recent review of postoperative weight-bearing regimens after uncemented THA (7). There are several reports of periprosthetic bone loss after uncemented THA (5, 8, 9). The bone loss is apparent around the whole stem, but is most marked in the calcar region. There is usually a restoration towards baseline values around the stem after 12 months; however, the calcar area continuously loses bone even in stems designed for proximal load transfer, regardless of postoperative weight-bearing regimen (5).

To our knowledge there are no reports on body composition and bone body mineral density (BMD) changes following THA. A return to a more active daily life would theoretically lead to changes in body composition, or at least counteract inactivity changes induced by disease, e.g. OAH. Fatty infiltration into muscle increases with age (10), but can be diminished with regular physical activity (11). High-resistance training has been shown to have a positive effect on muscle mass (12), strength, size and function in patients as old as 90 years (13).

We have previously conducted a randomized controlled trial (RCT) on full vs partial weight-bearing after THA with femoral stem stability assessed with radiostereometry as the primary outcome and periprosthetic BMD changes as the secondary outcome (5). The aim of this paper was to make a secondary analysis of body composition and BMD changes following uncemented THA. Our aim was to investigate: whether the postoperative weight-bearing regimen made a difference in body composition changes; and to follow the changes over a 5-year period after the THA procedure. We also examined the impact of the surgical procedure and/or the implant on the baseline measurements.

PATIENTS AND METHODS

A total of 42 patients were included in this RCT at the visit to the pre-assessment clinic by the senior authors (PM, JM and HM). Inclusion criteria were strictly unilateral radiographically verified hip osteoarthritis, age between 25 and 65 years (age group in which we

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would routinely use an uncemented THA), and weight less than 110 kg. Exclusion criteria were: patients receiving steroids or other medication known to affect bone metabolism; malignancy; previous hip surgery; body mass index (BMI) above 35; patients living outside the Uppsala municipality. All patients gave informed consent before entering the study, which was approved by the local ethics committee (Ups 99242). Enrolment took place between April 2000 and April 2003, prior to the start of the randomized controlled trial registration.

Directly after the operation the patients were randomized, with consecutively numbered sealed envelopes, to either full weight-bearing (FWB) or partial weight-bearing (PWB). The patients in the FWB group were instructed to bear full weight directly after surgery and, in addition, were enrolled in a strictly controlled and active physiotherapeutic programme, with exercises to be performed at home after instruction by the study physiotherapist. The home exercises were intensified after 4 weeks by adding training in a pool twice a week for 4–7 weeks postoperatively. Subsequently, 7 weeks intensive training in the physiotherapist's gym was added and this continued until 3 months after surgery. The patients in the PWB group were instructed to bear weight partially, approximately 15 kg, for 3 months, which was the routine at the department at that time. In addition, they received a short written home-exercise programme, based on mobility through supported flexion and extension exercises. Typically, the patients in both groups were treated as in-patients for 7 days following surgery.

In order to evaluate compliance with the instructions regarding weight-bearing, snapshots of weight-bearing were assessed at every visit to the outpatient clinic, using the F-scan system (Tekscan™ Inc., South Boston, USA). Mean weight-bearing, expressed as peak load in kilograms, was calculated on the basis of 3 recordings, each of which included 5 steps. This was carried out by the same physiotherapist and with the same equipment before surgery and 1 week, and 3, 6, 12, and 24 months after surgery, as described previously (14).

Three of the initial 42 patients had undergone contralateral THA because of OAH within the follow-up period and were thus excluded from the present study (Consolidated Standards of Reporting Trials; CONSORT, Fig. 1). Thus, 39 patients (20 men, 19 women) with strictly unilateral OAH were available for the present study.

All patients received an uncemented total hip replacement with the grit-blasted titanium CLS hip stem (Centerpulse/Zimmer Inc., Warsaw, IN, USA). The design, described as a press fit stem, allows proximal load transfer and is thought to give no stress shielding (15). The original study included the uncemented Interop acetabular cup. For reasons of manufacturing problems with oil-contaminated shells (16), the product was withdrawn from the market. Thus, only 15 Interop acetabular cups were inserted. The remaining patients were operated on with an uncemented Allofit acetabular cup without screw holes ($n=23$), or an uncemented Trilogy cup with cluster holes ($n=1$) (all cups by Centerpulse, Bern, Switzerland, acquired by Zimmer Inc., Warsaw, IN, USA). All 3 cups are press fit cups and no additional screws were used for stability. All patients received a modular 28-mm cobalt-chrome femoral head. Five experienced surgeons performed the operations in a standardized manner in accordance with the manufacturer's manual, using an anterolateral approach with the patient in the lateral position.

Total body composition measurements and areal bone densitometry at the proximal femur on the unaffected side (preoperatively bilaterally) were performed with a pencil-beam total body dual-energy X-ray absorptiometry (DXA) scanner, DPX-L (Lunar Co., Madison, WI, USA). The heels were measured with a cone-beam DXA-equipment, PIXI (Lunar Co.).

The same DXA machines were used throughout the study. The baseline DXA measurement was performed 1–2 weeks before surgery for 35 patients, according to the initial study protocol. After study onset the suspicion arose that the implant and/or the surgery itself might artificially alter the baseline values. Hence, 22 patients were also scanned within 1 week after surgery. The follow-up DXA measurements were carried out after 3, 12, 24 and 60 months. The heels were followed to 24 months. A spine phantom was scanned regularly during the study period and the long-term precision, expressed as coefficient of variance (CV%) for L2–L4 BMD, was < 1.5%.

Body composition

The total body scan was manually adjusted for regions of interest (ROI), i.e. head, trunk, spine, arms and legs (Fig. 2). The DXA scan measured fat mass (FM), lean mass (LM) (i.e. muscle mass) and bone mineral content

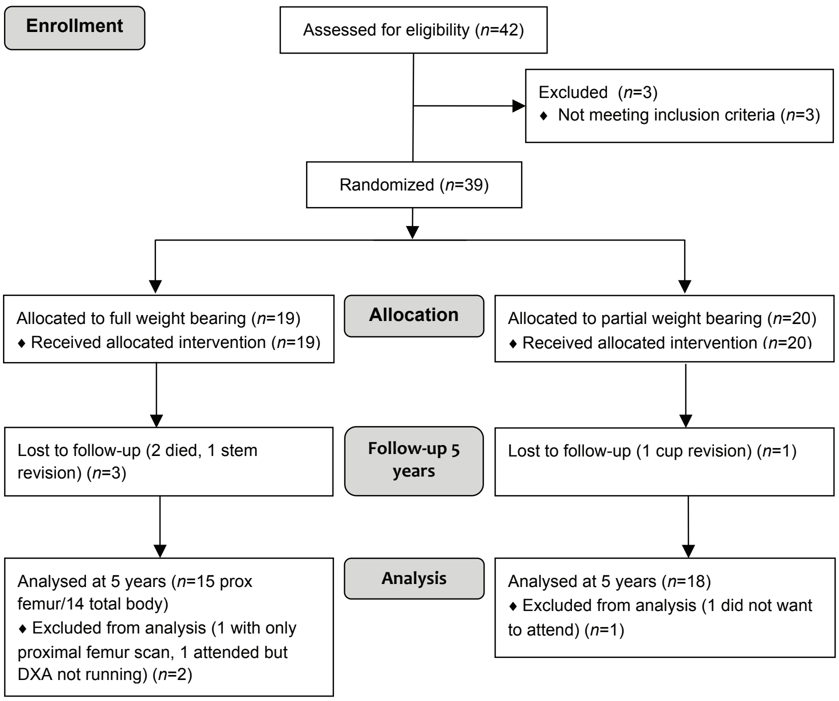

Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) flow diagram. DXA: dual x-ray absorptiometry.

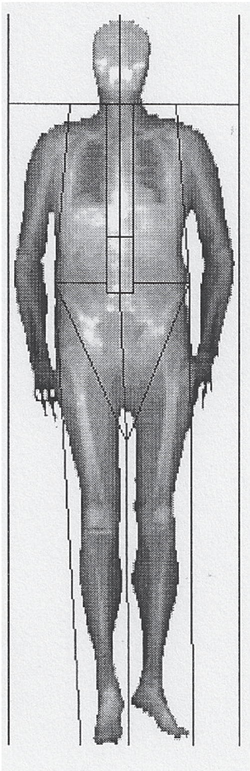

Fig. 2. Total body DXA scan displaying the manually adjusted regions for measurement of body composition, i.e. fat mass, lean mass, and bone mineral content.

(BMC) in grams. Regional analyses gave us the operated and non-operated leg's figures. In order to allow for comparisons between FWB and PWB groups, the FM, LM and BMC proportion of each leg's total weight was calculated, i.e. the FM%, LM%, and BMC% in each leg. By using the proportions rather than the absolute values we minimized the possible difficulties in this longitudinal study with manually adjusted ROIs.

Bone mineral density

The proximal femur was scanned bilaterally preoperatively, and the unaffected contralateral hip was followed for 5 years. Three ROIs at the proximal femur were analysed for areal bone mineral density (g/cm^2), i.e. femoral neck (FN), total hip (TH), and trochanter region (TR).

A manufacturer-defined ROI of the heels was analysed for areal BMD (g/cm^2) of the calcaneus bilaterally (followed for 2 years).

In order to assess the effect of postoperative weight-bearing regimen we compared:

- changes in body composition proportions from baseline to 3 and 12 months;
- effects on BMD at 3 and 12 months.

In order to assess the changes over 5 years following the unilateral THA procedure we pooled the data for both groups and analysed:

- total body composition of FM% (TB FM%), LM% (TB LM%) and BMC% (TB BMC%);
- changes in the operated and non-operated leg's FM%, LM% and BMC%;
- BMD of the contralateral hip, and BMD of the heels (for 2 years after surgery);
- total body weight assessed by DXA.

Twenty-two patients were also scanned within a few days after the operation. This allowed for assessment of the influence of the surgical procedure and the implant on the distribution of tissues compared with the preoperative values (19 patients had both pre- and post-operative scans).

Statistical analysis

Statistical analysis was performed with Statistica 9.1 (StatSoft, Inc., Tulsa, OK, USA). Study groups were compared with Student's *t*-test or Mann-Whitney *U* test, depending on whether they were normally distributed. Likewise, within-group comparisons were made using paired *t*-test or Wilcoxon signed-rank test. Differences were considered significant when $p < 0.05$. Values are given as means with standard deviations (SD).

The primary study parameter of this RCT was the effect of FWB on the stability of an uncemented femoral stem, Thus, the power analysis for this study was made for radiostereometric analysis (RSA) (3, 5, 17) to estimate the sample size necessary to detect a significant difference in linear micromotion along the y-axis, i.e. subsidence, between the two groups with alpha 0.05 and beta 0.20 (i.e. a power of 0.8), and groups of 20 patients were found sufficient. The aim of this paper was to make a secondary analysis on the effects of weight-bearing and changes in body composition and BMD.

RESULTS

The mean age of the 39 patients (20 men, 19 women) was 54 years (SD 9) (range 25–63). Their mean weight (DXA derived for 35 patients with preoperative scan) was 79 kg (SD 13), mean height 172 cm (SD 9) and mean body mass index 27 (SD 3). Four patients were lost to follow-up. One patient died of pulmonary embolism 3 months postoperatively; 1 patient (PWB) had a cup revision within 20 months because of loosening (no data after 1 year); 1 patient (FWB) had a stem revision after 1.5 years because of aseptic loosening (no data after 1 year); and 1 patient died of unrelated causes after 2 years (no data at 5 years).

At 5 years 3 patients could not attend the follow-up examination (1 only had the proximal femur scan). Thirty-two of the 39 patients completed a total body scan at 5 years, 33 completed a proximal femur scan, and 36 patients had their heels scanned after 2 years. Nineteen of the 38 patients were scanned both pre- and post-operatively.

Compliance with weight-bearing

As previously reported, the patients in the PWB group put almost twice the recommended weight on the operated side (26 kg at 1 week and 32 kg at 3 months) (14). The PWB group, however, put substantially less load on the operated leg at 1 week and 3 months than the FWB group (14). Not surprisingly, the FWB group was unable to perform full weight-bearing during the first postoperative week.

Effect of postoperative weight-bearing

The prescribed postoperative weight-bearing regimen had no effect on either the change of FM%, LM% or BMC% in either leg at 3 months (Table I) or at 12 months (data not shown) or on the BMD at the contralateral hip or heels from baseline to 3 months (Table I) or 12 months (data not shown).

Changes over 5 years following unilateral total hip arthroplasty (Table II)

There was a 5% decrease in TB BMC% at 5 years. The TB FM% and TB LM% did not change during the 5 years. There

Table I. *Changes in body composition of the legs and bone mineral density (BMD) of the heels and the contralateral hip from baseline to 3 months. Full weight-bearing (FWB) vs partial weight-bearing (PWB) after uncemented total hip arthroplasty*

		Change in percentage from baseline to 3 months			
		FWB Mean (SD)	PWB Mean (SD)	*p*	*n*
Fat mass, %	Op	+11 (12)	+16 (21)	0.7	16/18
	Non-op	+9 (13)	+10 (17)	0.8	
Lean mass, %	Op	–4 (5)	–4 (4)	0.6	
	Non-op	–3 (4)	–2 (6)	0.9	
BMC, %	Op	–13 (5)	–9 (7)	0.06	
	Non-op	–2 (6)	0 (8)	0.6	
BMD, g/cm^2	FN	0 (3)	–1 (3)	0.07	17/20
	TR	+1 (3)	–1 (4)	0.1	
	TH	+1 (2)	–1 (2)	0.07	
	Heels op	–1 (4)	–1 (4)	0.7	16/20
	Heels non-op	–1 (5)	+1 (2)	0.3	15/20

p=body composition changes compared with Mann-Whitney *U* test, BMD compared with *t*-test.
n=patients in FWB/PWB. Non-op: non-operated side; BMC: bone mineral content; FN: femoral neck; TR: trochanter; TH: total hip.

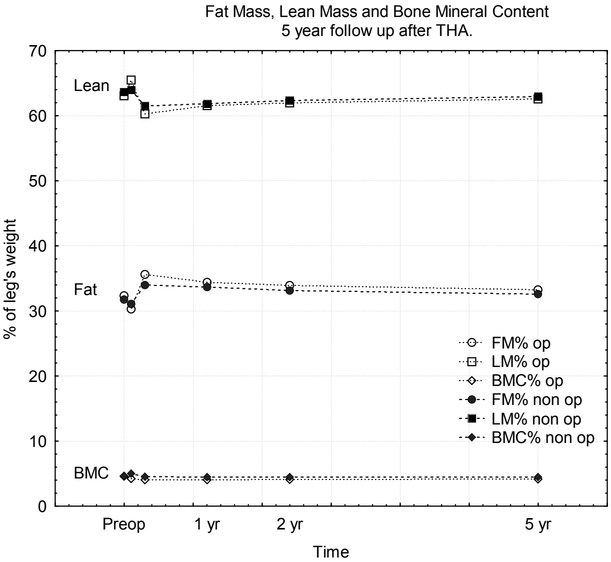

Fig. 3. Body weight and distribution of fat mass (FM), lean mass (LM) and bone mineral content (BMC) (operated vs non-operated leg) following total hip arthroplasty. Preoperative to 5-year follow-up.

was a decrease of 9% in BMC% in the operated leg and of 4% in the non-operated leg from baseline, and the decrease was larger on the operated side ($p<0.01$). FM% reaches its highest value, and LM% its lowest, at 3 months (Fig. 3). From then on the values normalized towards the baseline values and there was no change from baseline to 5 years.

There was a decrease in BMD of the contralateral hip by 3% at the FN, by 3% at the TH, and by 2% at TR, and also a decrease of 3% in total body BMD at 5 years. There was no change in BMD of the heels at 2 years. The 29 patients with both preoperative and 5 years examinations showed no change in body weight (+1% over 5 years, $p=0.5$).

Timing of baseline examination (19 pre- vs post-operative scans)

The operated hip displayed a 13% decrease in BMC% (4.87 vs 4.25; $p<0.05$) after surgery. There was no difference in FM% or LM% when comparing the 19 pre- and post-operative examinations (data not shown).

Table II. *Baseline, 5-year values, and changes in total body composition, weight, and bone mineral density (BMD) from pre-operative to 5 years (2 years for heels) after unilateral uncemented total hip arthroplasty*

		Baseline Mean (SD)	*n*	5-year Mean (SD)	*n*	Change, % Mean (SD)	*n*	*p*	*p*[a]
Total body	FM%	32.9 (7.8)	35	33.9 (8.9)	32	2 (14)	29	0.3	
	LM%	63.3 (7.4)		62.5 (8.5)		–1 (7)		0.7	
	BMC%	3.8 (0.5)		3.6 (0.5)		–5 (6)		<0.001	
Weight, kg		78.8 (13)		79.8 (13)		1 (6)	0.5		
BMD, g/cm^2	TB	1.233 (0.1)		1.202 (0.1)		–3 (3)		<0.001	
	FN	1.001 (0.1)	38	0.967 (0.1)	33	–3 (6)	33	<0.01	
	TH	1.055 (0.1)		1.021 (0.1)		–3 (4)		<0.001	
	TR	0.885 (0.1)		0.866 (0.1)		–2 (5)		<0.05	
Regional analysis of lower extremities, operated and non-operated side									
FM, %	Op	32.3 (11)	35	33.2 (11)	32	+3 (16)	29	0.8	
	Non-op	31.7 (11)		32.6 (11)		+3 (17)		0.8	0.7
LM, %	Op	63.1 (10)		62.6 (11)		0 (7)		0.8	
	Non-op	63.6 (10)		62.9 (10)		0 (7)		0.9	0.8
BMC, %	Op	4.6 (0.8)		4.2 (0.7)		–9 (8)		<0.001	
	Non-op	4.6 (0.8)		4.4 (0.7)		–4 (7)		<0.05	<0.01
BMD Heels	Op	0.547 (0.1)	37	0.548 (0.1)	36	0 (7)	35	0.9	
	Non-op	0.555 (0.1)	36	0.561 (0.1)		+1 (6)	34	0.4	0.3

p=Wilcoxon signed-rank test/paired *t*-test (DXA) baseline to 5 years ([a]between op and non-op side).
TB: total body; FN: femoral neck; TH: total hip; TR: trochanter; op: operated side; non-op: non-operated side.

DISCUSSION

To our knowledge, the present paper is the first to investigate the effect of postoperative weight-bearing on changes in body composition and BMD. Most studies of FWB vs PWB following THA compare periprosthetic BMD and we have previously reported our data on that (5). In this paper we focus on a secondary analysis of changes in body composition of the lower extremities and BMD of the heels and contralateral hip following a unilateral THA procedure.

Our patients were randomized to partial weight-bearing for 3 months (PWB group) with the instruction to load 15 kg on the operated leg, or to full immediate weight-bearing (FWB group) combined with intensive supervised physiotherapy. Compliance with the weight-bearing instruction was measured at visits to the physiotherapist, using the F-scan system. The PWB group had problems in complying with the set weight-bearing limits, which is in line with other findings of difficulties in staying within the prescribed weight-bearing limits (18). Others have used an auditory feedback device calibrated to between 10% of body weight to 30 kg of loading to instruct the patients (4, 19).

Effect of postoperative weight-bearing

The 2 different weight-bearing regimens had no effect on the change in FM%, LM% or BMC% in either leg 3 and 12 months after the surgical procedure. There was no difference in the change in BMD of either the operated or non-operated side's heels or of the contralateral hip. This could be in line with previous studies showing no adverse effect on the stability of femoral implants (3–5, 17) or on the periprosthetic BMD (5, 19) regarding the postoperative weight-bearing regimens after uncemented THA.

Changes over 5 years following unilateral total hip arthroplasty

Body composition. Five years after a unilateral THA we found no change in TB FM% or TB LM%, nor did we find any change in FM% or LM% in either leg. The percentage of body fat increases in both men and women with normal ageing, with higher values in women (20, 21). Our results are in contrast with the findings of an annual increase in TB FM of 2.4% for women and 7% for men older than 50 years, and a decrease of 1% and 1.9% in TB LM, in a cross-sectional study of 273 ethnic Swedish individuals re-measured after 3–4 years (22). The different findings might reflect the different study designs in terms of a selected OAH group in our case, and also perhaps be a matter of sample size. In our patients, however, there was a decrease in TB BMC% of 5%, as well as a decrease in BMC% in both legs. The BMC% decrease in the operated side was larger at 5 years than in the non-operated side, but there might be no real difference in loss of BMC with the extraction of the femoral head in mind.

Bone mineral density. The OAH patients displayed a decrease in BMD in all ROIs of the contralateral hip, as well as a decrease in total body BMD, which probably reflects the expected age-related reductions. At 5 years, the decrease in FN BMD was 3% in our OAH patients, i.e. an annual loss of 0.6%. This is in line with cross-sectional and longitudinal studies with reported annual losses of 0.3–1.5% in FN BMD (22–24). We found no change in BMD at the heels 2 years after THA.

Body weight. Pain resulting from OAH prevents ordinary physical activities and may therefore be a factor in weight gain. A decrease in pain following THA would be beneficial for these patients and could therefore lead to more physical activity and promote weight loss.

On the contrary, we found no change in weight during the 5 years following THA. Contrary to our finding, the median annual weight loss was 1 kg in a cohort study of 4,800 former male civil servants (age 40–69 years) from England with a median follow-up of 28 years (25). However, the patients in the latter study were younger at inclusion, and were all men. Our results are in line with the finding of no weight gain in a large cohort study of more than 6,000 men and women, who were older than 60 years and healthy at inclusion, from 6 European countries during a median follow-up of 4.3–4.6 years (26). However, both weight loss and weight gain (in the obese subjects only) of more than 1 kg per year was associated with increased mortality in a nested case-control analysis in this study population.

Does timing of baseline examination matter?

Since we became aware of the possible artificial effect of the implant and the surgical procedure on the total body scan, 22 patients were also scanned postoperatively. Comparisons between the preoperative and postoperative examinations clearly show a 13% decrease in BMC% of the operated side. This probably reflects the effect of the surgical procedure with extraction of a considerable amount of BMC, i.e. the femoral head. In addition, the software excluded the BMC anterior and posterior to the implant. We found no difference in FM% or LM%. Visser et al. (27) chose to use the results of only the non-fractured leg in a study of muscle mass and muscle strength after hip fracture, since the swelling after the surgical procedure would be measured as lean mass, and hence theoretically overestimate the muscle mass at baseline. With our findings at hand, we chose to use the preoperative examination as the baseline, but with the decrease in BMC in mind. For comparisons of soft tissues and weight the preoperative examinations offer a more reliable baseline; we found no differences in FM% and LM% between the pre- and postoperative examinations.

Our study has both strengths and limitations. We used a randomized design to study the effect of postoperative weight-bearing on body composition and BMD of the contralateral hip and of both heels. We used DXA to measure the proportion of FM, LM and BMC, which has been described as a method with excellent long-term precision (28). We also investigated the potential effect of the surgical procedure on the baseline values of body composition in half of the study group after study onset. Compliance with the prescribed weight-bearing was controlled with the F-scan system, although only at visits to our PT. The sample size in our study was much smaller than the cross-sectional studies on age-related BMD changes. Power analysis in this RCT was performed for the stability of the femoral implant assessed by RSA. We might lack the power to find small differences in BMD and body composition.

In conclusion, we found no differences between the varying postoperative weight-bearing regimens regarding effect on change in body composition or BMD of the legs after an uncemented THA. Five years after THA there was a decrease in BMC and BMD, but no changes in fat mass or lean mass (muscle) distribution in the total body or legs.

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