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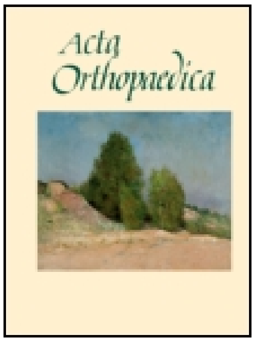

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Does BMI influence hospital stay and morbidity after fast-track hip and knee arthroplasty?

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Background and purpose — Body mass index (BMI) outside the normal range possibly affects the perioperative morbidity and mortality following total hip arthroplasty (THA) and total knee arthroplasty (TKA) in traditional care programs. We determined perioperative morbidity and mortality in such patients who were operated with the fast-track methodology and compared the levels with those in patients with normal BMI.

Patients and methods — This was a prospective observational study involving 13,730 procedures (7,194 THA and 6,536 TKA operations) performed in a standardized fast-track setting. Complete 90-day follow-up was achieved using national registries and review of medical records. Patients were grouped according to BMI as being underweight, of normal weight, overweight, obese, very obese, and morbidly obese.

Results — Median length of stay (LOS) was 2 (IQR: 2–3) days in all BMI groups.

30-day re-admission rates were around 6% for both THA (6.1%) and TKA (5.9%), without any statistically significant differences between BMI groups in univariate analysis ($p > 0.4$), but there was a trend of a protective effect of overweight for both THA ($p = 0.1$) and TKA ($p = 0.06$).

90-day re-admission rates increased to 8.6% for THA and 8.3% for TKA, which was similar among BMI groups, but there was a trend of lower rates in overweight and obese TKA patients ($p = 0.08$ and $p = 0.06$, respectively). When we adjusted for preoperative comorbidity, high BMI in THA patients (very obese and morbidly obese patients only) was associated with a LOS of > 4 days ($p = 0.001$), but not with re-admission. No such relationship existed for TKA.

Interpretation — A fast-track setting resulted in similar length of hospital stay and re-admission rates regardless of BMI, except for very obese and morbidly obese THA patients.

Body mass index (BMI) might possibly influence outcome after total hip arthroplasty (THA) and total knee arthroplasty (TKA). Underweight may be associated with malnutrition and comorbidities. In a large Danish study it was found (after hip replacement and knee replacement) be a risk factor for post-operative ischemic stroke, acute myocardial infarction, and cardiovascular death—with higher mortality than in patients with normal BMI (Thornqvist et al. 2014). Also, underweight has been associated with re-admission after THA or TKA in general, and specifically for infection and hip dislocation (Alfonso et al. 2008, Zhang et al. 2012).

Obesity of varying severity in TKA operations has been found to result in more complications and inferior objective and functional Knee Society scores (McElroy et al. 2013, Issa et al. 2013, Adhikary et al. 2015), but without any difference in length of hospital stay (LOS) (Issa et al. 2013).

Also, in THA operations, obesity has resulted in smaller improvements in outcome scores and quality of life and more wound complications compared to normal weight, and higher BMI has also resulted in more re-admissions and reoperations (Haverkamp et al. 2011, Jameson et al. 2014, Liu et al. 2015).

Prescribed weight loss may be difficult or impossible for patients to achieve and maintain, with or without arthroplasty (Ast et al. 2015), and even successful weight loss preoperatively—with or without bariatric surgery—may not reduce the possible complications associated with the subsequent arthroplasty operation (Inacio et al. 2014 a, b). Thus, the risk profile appears to be increased with THA or TKA in overweight or obese patients, and even in previously obese patients. As some overweight/obese patients still need arthroplasty operations and because high BMI may only (to some extent) compromise the clinical outcome (Foster et al. 2015) or implant survival (Tai et al. 2014), it is important to assess the risks in different

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weight classes. As fast-track THA and TKA may offer the best available treatment, combining evidence-based clinical features with organizational optimization and reduced morbidity and mortality (Husted 2012, Husted et al. 2014, Jørgensen et al. 2013, 2015), we determined perioperative morbidity and mortality levels in patients with BMIs outside the normal range who were operated with the fast-track methodology, and compared these levels to those in patients with normal BMI.

Material and methods

This study was based on an ongoing study registry of preoperative patient characteristics run by the Lundbeck Foundation Center for Fast-track Hip and Knee Replacement Collaboration (www.fthk.dk), and parts of the cohort have featured previously in other studies focusing on other aspects of postoperative morbidity and risk factors (Jørgensen et al. 2013, 2015). The current study cohort had surgery between January 2010 and November 2013 in 8 large arthroplasty departments, each of which performed more than 400 primary arthroplasties a year.

The Lundbeck Foundation Center database (LCDB) prospectively registers preoperative patient characteristics through a patient-reported questionnaire, with staff available for assistance, and is registered at ClinicalTrials.gov (NCT01515670). The questionnaire is completed by all patients who are to have surgery at the participating departments. The only requirements for being one of the collaborating hospitals are having a documented median LOS of ≤ 3 days, including transfer to other departments, and discharge planned to the patient's own home.

Data from the LCDB were subsequently merged with data from the Danish National Database of Reimbursed Prescriptions for information on prescribed drugs before and after surgery, while information on LOS, 90-day re-admission, and mortality was acquired from the Danish National Patient Registry (DNPR). Reporting to the DNPR is mandatory and necessary in order to receive reimbursement from the government, and it is independent of patient insurances, income, and geographic location, thus assuring complete follow-up.

Optimized clinical features included using spinal anesthesia whenever possible, using small standard incisions (the medial parapatellar approach for TKA and the posterior approach for THA), using tranexamic acid, using local infiltration analgesia (LIA) in TKA, not using drains, mobilization within a few hours after surgery, using multimodal opioid-sparing analgesia, having fixed functional discharge criteria, and discharging directly to home (Husted 2012).

As suggested by the World Health Organisation, patients can be classified according to their BMI as being underweight (BMI < 18.5), of normal weight (> 18.5 and < 25), overweight (> 25 and < 30), obese (> 30 and < 35), very obese (> 35 and < 40), and morbidly obese (> 40).

Study objectives

The main study objective was to determine the influence of different BMI groups on LOS of > 4 days, re-admissions within 30 and 90 days, and specified complications resulting in either LOS of > 4 days or re-admission. Secondarily, we evaluated the association between BMI groups and the same outcomes, but adjusting for differences in baseline characteristics using multiple logistic regression.

Specified complications of interest that resulted in re-admissions were defined according to the existing literature (Husted et al. 2008, 2015, Jørgensen et al. 2013, 2014, 2015) and comprised: thromboembolic episodes (DVT, PE, arterial embolism), myocardial infarction, acute coronary syndrome, angina pectoris, ischemic stroke/TCI, deep infection (requiring surgery), wound/superficial infection (managed without surgery below the fascia), any intraoperative complications including fracture and arterial lesions, any early prosthesis-related complications, and periprosthetic fractures with or without trauma—and for THA, also dislocation. Mortality within 90 days was registered based on the nationwide civil registry.

Statistics

All percentages are reported, including 95% confidence intervals (CIs). Continuous data are reported as median and interquartile ranges (due to skewing of the data). Comparisons of categorical data were done using chi-squared test. Comparisons of re-admission rates were done on a per-procedure basis, regardless of whether patients had multiple re-admissions. However, evaluation of specific complications of interest included all cases with LOS of > 4 days or re-admission. For multiple logistic regression analysis, we included variables previously found to influence outcome after fast-track THA and TKA (use of walking aids, preoperative anemia etc.) or related to increased BMI (hypertension, diabetes etc.). The model included 11 variables, with hospital of surgery added as a random effect. Analyses were done with SPSS version 20. 95% CI values for percentages were calculated at http://vassarstats.net/. Any p-value of < 0.05 was considered significant.

Ethics

No approval from the National Ethics Committee was necessary, as this was a non-interventional observational study. Permission to store and review patient data was obtained from the Danish National Board of Health (entry no. 3-3013-56/1/HKR) and the Danish Data Protection Agency (entry no. 20047-58-0015).

Results

The total cohort involved 13,775 procedures, 45 of which (0.3%) had data on BMI missing in the LCDB and were therefore excluded. Thus, the study analysis was done on 13,730 procedures: 7,194 THAs and 6,536 TKAs. Most patients were

Table 1. Distribution of grouped BMI on type of procedure

Joint of surgery/BMI	Number of patients	Fraction
Hip, median: 26.6, IQR: 24.0–29.7		
<18.5	77	1.1
18.5–24.9	2,396	33.3
25.0–29.9	3,008	41.8
30.0–34.9	1,329	18.5
35.0–39.9	299	4.2
>39.9	85	1.2
Total	7194	100
Knee, median: 28.9, IQR: 25.8–32.6		
<18.5	29	0.4
18.5–24.9	1,250	19.1
25.0–29.9	2,524	38.6
30.0–34.9	1,745	26.7
35.0–39.9	699	10.7
>39.9	289	4.4
Total	6,536	100

IQR: Interquartile range

overweight with a trend of knee patients being more obese than hip patients, and with only a small proportion of each being underweight (1.1% for THA and 0.4% for TKA) (Table 1).

Median LOS was 2 (IQR: 2–3) days in all BMI groups, with slightly higher mean values for outliers being underweight or morbidly obese for both THA and TKA (p = 0.5 and p = 0.1, respectively). The proportion of THA patients with a LOS of more than 4 days increased (from that in patients with normal weight; around 8%) with increasing BMI, although this was only statistically significant for very obese patients (around 13%; p = 0.03). In other overweight patients, a smaller fraction had a LOS of ≤ 4 days (6%; p < 0.02). The same trend was seen for TKA patients: in the group of patients with normal weight, 11% had a LOS of > 4 days as opposed to only 8% in the overweight and obese group (p = 0.01).

The greatest proportion of patients with a LOS of > 4 days—for both THA (17%) and TKA (13%)—was found in the underweight group, but this was not statistically significant (with small numbers; p > 0.1). For both procedures, the median LOS for underweight patients with a LOS of > 4 days was similar (p > 0.5).

30-day re-admission rates were 6.1% for THA and 5.9% for TKA, without any significant differences between BMI groups in univariate analysis (p > 0.4), but there was a trend of a protective effect of overweight for both THA (p = 0.1) and TKA (p = 0.06).

90-day re-admission rates increased to 8.6% for the THA group and to 8.3% for the TKA group. This was similar between BMI groups, but there was a maintained trend of lower values for overweight and obese TKA patients (p = 0.08 and p = 0.06, respectively).

No increased risk of the specified complications of interest (thromboembolic episodes, myocardial infarction, acute coronary syndrome, angina pectoris, ischemic stroke/TCI, deep or superficial infection, periprosthetic fractures, and dislocation) was found with increasing BMI. The distribution of BMI groups with all specified reasons for a LOS of > 4 days and re-admission can be seen in Table 2 (see Supplementary data). Table 3 shows the combined proportions of patients in each BMI group with a LOS of more than 4 days, with re-admission within 90 days, and with specific complications.

After adjusting for differences in relevant preoperative characteristics, higher BMI (very obese and morbidly obese only) was found to be associated with a LOS of > 4 days, but not with re-admission for THA. In contrast, no associations with LOS of > 4 days, re-admission within 90 days, or specific complications were found for TKA (Tables 4 and 5).

Overall 90-day mortality was 0.2% following THA and 0.1% following TKA, with the small numbers not allowing detailed statistical analysis between BMI groups.

Table 3. Fractions of patients with a LOS > 4 days , 90 days readmissions and specific conditions according to BMI group. Values are n (%; 95% confidence intervals)

Joint BMI	LOS > 4 days	p-value	90–days readmissions	p–value	Specific complications	p-value
THA						
< 18.5	10 (13.0; 7.2–22.3)	0.1	3 (3.4; 1.3–11)	0.2	2 (2.6; 0.7–9.0)	0.6
18.5–24.9	189 (7.9; 6.9–9.0)	–	209 (8.7; 7.7–9.9)	–	113 (4.7; 3.9–5.6)	–
25.0–29.9	188 (6.3; 5.4–7.2)	0.02	237 (7.9; 7.0–8.9)	0.3	135 (4.5; 3.8–5.3)	0.7
30.0–34.9	98 (7.4; 6.1–8.9)	0.6	125 (9.4; 8.0–11)	0.5	83 (6.3; 5.1–7.7)	0.05
35.0–39.9	35 (11.7; 8.5–15.9)	0.02	35 (11.7; 8.5–16)	0.09	21 (7.0; 4.6–10.5)	0.08
≥ 40.0	11 (12.9; 7.4–21.7)	0.09	9 (10.6; 5.7–19)	0.6	7 (8.2; 4.1–16.0)	0.2
TKA						
< 18.5	5 (17.2; 7.6–34.6)	0.3	4 (5.2; 2.0–13)	0.5	0 (0.0; 0.0–4.8)	1
18.5–24.9	141 (11.3; 9.6–13.2)	–	120 (9.6; 8.1–11)	–	33 (2.6; 1.9–3.7)	–
25.0–29.9	213 (8.4; 7.4–9.6)	0.005	200 (7.9; 6.9–9.0)	0.08	47 (1.9; 1.4–2.5)	0.2
30.0–34.9	145 (8.3; 7.1–9.7)	0.006	133 (7.6; 6.5–9.0)	0.06	29 (1.7; 1.2–2.4)	0.06
35.0–39.9	70 (10.0; 8.0–12.5)	0.4	66 (9.4; 7.5–12)	0.9	16 (2.3; 1.4–3.7)	0.6
≥ 40.0	35 (11.7; 8.6–15.9)	0.7	22 (7.4; 4.9–11)	0.3	11 (3.7; 2.1–6.5)	0.3

BMI: body mass index THA: total hip arthroplasty TKA: total knee arthroplasty. Comparisons are vs. BMI of 18.5–24.9

Table 4. Multiple logistic regression THA (n = 6,809)

Variable	LOS > 4 days (n = 502) OR	95%CI	p-value	90-days readmission (n = 584) OR	95%CI	p-value	Specific complications (n = 336) OR	95%CI	p-value
BMI			< 0.001			0.1			0.01
< 18.5	1.19	0.55–2.59	0.7	0.4	0.11–1.20	0.1	0.47	0.11–2.00	0.3
18.5–24.9	1	–	–	1	–	–	1	–	–
25.0–29.9	0.96	0.76–1.21	0.7	0.93	0.75–1.14	0.5	1.02	0.78–1.35	0.9
30.0–34.9	1.28	0.97–1.21	0.09	1.17	0.91–1.50	0.2	1.55	1.13–2.11	0.006
35.0–39.9	2.10	1.37–3.23	0.001	1.30	0.85–1.96	0.2	1.83	1.10–3.04	0.02
> 39.9	3.23	1.58–6.59	0.001	1.24	0.57–2.70	0.6	1.65	0.64–4.29	0.3
Age/year	1.05	1.03–1.06	< 0.001	1.03	1.02–1.04	< 0.001	1.03	1.01–1.04	< 0.001
Male vs female	0.90	0.72–1.11	0.3	1.10	0.91–1.33	0.3	0.97	0.77–1.24	0.8
Living			< 0.001			0.8			0.7
With others	1	–	–	1	–	–	1	–	–
Alone	1.78	1.45–2.20	< 0.001	1.05	0.86–1.27	0.6	1.10	0.86–1.34	0.5
Institution	1.86	0.87–4.00	0.1	1.18	0.53–2.62	0.7	1.31	0.50–3.45	0.6
Walking aid	2.31	1.87–2.85	< 0.001	1.59	1.31–1.93	< 0.001	1.26	0.97–1.62	0.08
Pre-op. anemia	1.98	1.58–2.48	< 0.001	1.44	1.15–1.80	0.002	1.48	1.12–1.20	0.007
Diabetes			0.4			0.4			0.3
No DM	1	–	–	1	–	–	1	–	–
IDDM	1.48	0.85–2.58	0.1	1.40	0.83–2.37	0.2	1.15	0.58–2.28	0.7
NIDDM	1.07	0.75–1.53	0.7	0.99	0.72–1.38	1	0.70	0.44–1.12	0.1
Hypertension	0.80	0.65–0.99	0.04	1.13	0.94–1.37	0.2	1.10	0.86–1.39	0.5
Anticoagulants	1.20	0.81–1.78	0.4	1.33	0.93–1.90	0.1	0.57	0.33–0.80	0.04
Cardiac disease	1.53	1.15–2.04	0.003	1.42	1.10–1.85	0.008	1.72	1.25–2.36	0.001
Pulmonary disease	1.40	1.04–1.87	0.03	1.42	1.10–1.85	0.008	1.20	0.83–1.74	0.3
Psychiatric disorder	1.82	1.44–2.31	< 0.001	1.54	1.22–1.93	< 0.001	1.31	0.97–1.77	0.08

THA: total hip arthroplasty, LOS: length of stay, OR: odds ratio, CI: confidence interval, BMI: body mass index DM: diabetes mellitus, IDDM: insulin dependent diabetes mellitus, NIDDM: non-insulin dependent diabetes mellitus.

Table 5. Multiple logistic regression TKA (n = 6,123)

Variable	LOS > 4 days (n = 559) OR	95%CI	p-value	90–days readmission (n = 499) OR	95%CI	p-value	Specific complications (n = 122) OR	95%CI	p-value
BMI			0.2			0.1			1
< 18.5	1.96	0.66–5.85	0.2	1.94	0.64–5.89	0.2	0.67	0.06–6.99	0.7
18.5–24.9	1	–	–	1	–	–	1	–	–
25.0–29.9	0.78	0.60–0.99	0.049	0.84	0.66–1.09	0.2	0.93	0.65–1.32	0.7
30.0–34.9	0.85	0.65–1.12	0.3	0.76	0.57–1.01	0.06	0.91	0.62–1.35	0.6
35.0–39.9	1.08	0.76–1.53	0.7	0.93	0.66–1.33	0.7	1.02	0.62–1.67	0.9
> 39.9	1.04	0.64–1.69	0.9	0.57	0.33–0.99	0.046	1.19	0.62–2.26	0.6
Age/year	1.04	1.02–1.05	< 0.001	1.01	1.00–1.02	0.04	1.01	0.99–1.02	0.2
Male vs female	1.01	0.82–1.24	< 0.001	1.31	1.07–1.59	0.008	1.10	0.84–1.44	0.5
Living			< 0.001			0.8			0.7
With others	1	–	–	1	–	–	1	–	–
Alone	1.60	1.31–2.00	< 0.001	1.05	0.85–1.28	0.7	0.98	0.74–1.30	0.9
Institution	1.21	0.37–3.97	0.7	3.15	1.20–8.25	0.02	0.64	0.07–6.35	0.7
Walking aid	2.43	1.98–2.98	< 0.001	1.66	1.34–2.06	< 0.001	1.27	0.93–1.73	0.1
Pre–op. anemia	1.70	1.34–2.15	< 0.001	1.41	1.10–1.82	0.007	0.96	0.65–1.43	0.8
Diabetes			0.4			0.4			0.3
No DM	1	–	–	1	–	–	1	–	–
IDDM	1.48	0.94–2.33	0.09	1.62	1.04–2.53	0.03	1.24	0.63–2.44	0.5
NIDDM	1.23	0.91–1.65	0.2	1.23	0.92–1.66	0.2	0.98	0.63–1.53	0.9
Hypertension	1.08	0.89–1.32	0.4	1.10	0.90–1.34	0.4	0.92	0.70–1.23	0.6
Anticoagulants	1.60	1.10–2.35	0.02	1.25	0.84–1.86	0.3	0.97	0.52–1.79	0.9
Cardiac disease	1.26	0.95–1.67	0.1	1.23	0.93–1.63	0.2	1.17	0.78–1.77	0.4
Pulmonary disease	1.35	0.99–1.83	0.05	1.18	1.36–2.41	< 0.001	1.29	0.84–1.98	0.2
Psychiatric disorder	2.11	1.70–2.62	< 0.001	1.47	1.16–1.85	0.001	1.26	0.91–1.75	0.2

For legends, see Table 4

Discussion

Fast-track hip and knee arthroplasty reduces morbidity and mortality compared to longer and more conventional hospital stays (Malviya et al. 2011, Khan et al. 2014). It also results in favorable safety profiles regarding LOS, morbidity, and re-admissions in particular high-risk patients (Husted et al. 2015, Jørgensen et al. 2013, 2015).

The distribution of BMI in this large multicenter cohort of unselected patients operated with the fast-track methodology showed that one-third of hip arthroplasty patients and only one-fifth of knee arthroplasty patients had a normal BMI with the latter being heavier. We found that the median LOS was 2 days in all BMI groups, but the proportion of patients who stayed more than 4 days was significantly higher in the very obese THA patients—whereas being a little overweight appeared to be protective, as this group of patients generally had a shorter LOS. The same trend was seen in TKA patients, as the proportion of patients in the overweight and obese groups who stayed more than 4 days was less than in the normal-BMI group. A possible explanation for this finding would be higher muscle volume in the slightly to moderately overweight patients, facilitating earlier fulfillment of the strictly functional discharge criteria (Husted 2012)—whereas the very obese patients might be limited in this by having too much body weight, as one study found postoperative improvements in quadriceps function following TKA to be slower in patients with higher BMIs (Pua et al. 2015) and a similar underlying mechanism could explain the same finding in THA. As strictly functional discharge criteria were used, and reduced muscle strength has been identified as being 1 of 3 main reasons for delayed discharge (the other 2 being pain and dizziness), the slower regaining of quadriceps strength may result in delayed functional recovery and therefore in a longer time to discharge (Husted et al. 2011).

Of the BMI groups, the underweight group of patients had the greatest (but statistically insignificant) proportion of patients who stayed longer than 4 days, although over 80% still managed a median LOS of 2 days. No large studies have involved this group before. In the literature there has only been 1 study, in 20 patients, on the outcome in underweight THA patients with the finding of an increased risk of dislocation (Alfonso et al. 2008). We found no association between being underweight and having a LOS of > 4 days, re-admission after < 90 days, or mortality—for either fast-track THA or fast-track TKA—and no correlation with any particular complication, including dislocation. A registry study found U-shaped risk associations between BMI and perioperative cardiovascular events and mortality, which were highest in the underweight group, in THA and TKA, suggesting that this was a subpopulation at risk (Thornqvist et al. 2014).

In the present fast-track study, multiple logistic regression analysis showed an association between BMI of THA patients and a LOS of more than 4 days, manifested by a higher odds ratio (OR) for longer stays in the very obese (where OR was doubled) and in the morbidly obese (where OR was 3 times higher). This contrasts with the results of a smaller fast-track study, where BMI was not associated with LOS (den Hartog et al. 2015), but it is in accordance with findings in other studies (Bradley et al. 2014, Inneh et al. 2015).

In fast-track TKA, high BMI was not associated with longer LOS. This is in accordance with the results of most previously published studies on conventional stays (Issa et al. 2013), and shows that BMI does indeed not affect LOS—as the studies with longer stays may have concealed a "hidden" difference that was not apparent because all patients were staying longer. A nationwide study involving 1,777,068 primary TKAs found a slightly but statistically significantly longer LOS in morbidly obese TKA patients (3.6 days) than in non-obese patients (3.5 days) in non-fast-track settings (D'Apuzzo et al. 2015).

In light of the previously published meta-analyses showing more complications and re-admissions in the obese patients, it is both interesting and reassuring that in this large, multicenter cohort of unselected patients who were operated in the fast-track setting, we found that BMI did not affect 30-day re-admission rates, which were around 6% for both THA and TKA. Also, BMI did not affect 90-day re-admission rates, although there was near-statistical significance in overweight and obese TKA patients, whereas the groups of very obese and morbidly obese patients did not have more re-admissions than the other BMI groups. This contrasts with most of the published studies, where more conventional pathways were followed without strict adherence to fast-track principles with optimization of both evidence-based clinical features and logistics (see Material and methods). A meta-analysis on the potential influence of a BMI of greater than 30 on outcome after TKA has found substantially higher complication rates in obese and morbidly obese patients than in non-obese patients (15% and 22% as compared to 9%) (McElroy et al. 2013). Also, a cohort study on the clinical outcome of TKA patients (comparing those with a BMI of between 30 and 40 with those with a BMI of less than 30) found higher complication rates in the former group (11% vs. 4%), but without any significant difference in LOS (Issa et al. 2013). Also, in obese THA patients, smaller improvements in outcome scores and more wound complications have been found. In patients who were more obese, even reduced outcomes in function and quality of life, more wound complications, more re-admissions, and more reoperations were found (Jameson et al. 2014). A recent meta-analysis on the influence of obesity on the outcome of THA also found that obese patients have more complications in general and more dislocations and deep infections in particular—while having longer operations, similar LOS, and reduced functional outcome than non-obese patients (Liu et al. 2015). These findings in patients who are operated in more conventional settings contrast with our findings from a fast-track setting, where no difference in specific complications was found between different BMI groups.

Our study confirmed the well-known risk factors for prolonged hospital stay, re-admission, and specific complications that have been reported by other authors (Husted et al. 2008, Jørgensen et al. 2013, 2014, 2015, den Hartog et al. 2015, Husted et al. 2015). Age, preoperative use of walking aids, anemia, diabetes, hypertension, use of anticoagulants, and cardiopulmonary and psychiatric disease may influence both LOS and re-admission rates; these considerations are outside the scope of the present study and have been evaluated and discussed in previous articles from our group (Husted et al. 2008, 2015, Jørgensen et al. 2013, 2014, 2015).

We found no association between BMI and 90-day re-admission in fast-track THA in general, and only an association in obese and very obese patients regarding particular complications, though not dislocation. This contrasts with the results of other studies where there was an increased risk of dislocation with increasing BMI (Liu et al. 2015).

Specifically, we found no increased risk of DVT/PE, infection/wound problems, or periprosthetic fracture associated with increasing BMI. This is in contrast to most—but not all (D'Apuzzo et al. 2015)—other studies using more conventional pathways, which have found associations between higher BMI and a higher incidence of venous thromboembolic episodes (Haverkamp et al. 2011, Zhang et al. 2015) and of infection/wound problems (McElroy et al. 2013, Jameson et al. 2014, D'Apuzzo et al. 2015, Liu et al. 2015). Although technical errors in the obese TKA patients (due to difficult exposure and procedure) could be expected to result in more periprosthetic fractures, we found no association between higher BMI and periprosthetic fracture, as did others also not (Haverkamp et al. 2011). Other studies have found increased mortality associated with higher BMI, especially in morbidly obese patients (Thornqvist et al. 2014, D'Apuzzo et al. 2015). We cannot confirm this finding in fast-track surgery, but the numbers were small, complicating interpretation.

For fast-track TKA patients, we found no association between BMI and a LOS of more than 4 days, re-admission within 90 days, or particular complications—although a curious protective effect of being morbidly obese was seen on re-admission. While we cannot explain the latter finding, it is reassuring to see that there is no safety signal for any BMI group in TKA patients undergoing fast-track surgery. This is not in line with other recently published studies, which have found increased morbidity with higher BMI (Issa et al. 2013, McElroy et al. 2013, Adhikary et al. 2015).

Thus, most studies on patients who were operated in more conventional settings have shown higher morbidity in the obese, the very obese, and the morbidly obese than in non-obese patients. Overall, it appears that the fast-track methodology may protect against the increased risk probably—due to a combination of improved perioperative care, pain treatment, and early mobilization.

We acknowledge that the present study had some limitations. First of all, no PROMs or objective data on function are reported, as we concentrated solely on LOS and complications necessitating re-admission. However, in Demark the unique registries ensure complete follow-up, and the basis of achieving a good functional result is to avoid severe complications that result in re-admission. Secondly, the numbers were small regarding underweight patients (77 THA patients (1.1%) and 29 TKA patients (0.4%)) and morbidly obese patients (85 THA patients (1.2%) and 289 TKA patients (4.4%)), making the statistical conclusions less robust and increasing the width of the confidence intervals. Nonetheless, we did have enough patients and events to justify adjustment for multiple variables previously found to influence outcome after fast-track THA and TKA. In conclusion, higher BMI (very obese patients and morbidly obese patients only) in THA is associated with a slightly higher risk of having a LOS of more than 4 days, but not with re-admissions, whereas no such relationship existed for TKA. The fast-track methodology therefore protects against the higher morbidity found with higher BMI in more conventional settings. Furthermore, BMI should not be a limiting factor for THA or TKA, and surgery in a fast-track setting is a safe way to reduce the risk of complications and re-admission, irrespective of BMI.

Supplementary data

Table 2 is available at the Acta Orthopaedica website (www.actaorthop.org), identification number 9979.

HH, CCJ, KG, and HK designed the study. CCJ gathered the data and HH, CCJ, KG, and HK analyzed it. HH wrote the initial draft and all the authors revised it.

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Adhikary S D, Liu W M, Memtsoudis S G, Davis C M 3rd, Liu J. Body mass index more than 45 kg/m^2 as a cutoff point is associated with dramatically increased postoperative complications in total knee arthroplasty and total hip arthroplasty. J Arthroplasty 2015; Nov 10 [E-pub ahead]

Alfonso D T, Howell R D, Caceres G, Kozlowski P, Di Cesare P E. Total hip arthroplasty in the underweight. J Arthroplasty 2008; 23(7): 956-9.

Ast M P, Abdel M P, Lee Y Y, Lyman S, Ruel A V, Westrich G H. Weight changes after total hip or knee arthroplasty: prevalence, predictors, and effects on outcomes. J Bone Joint Surg Am 2015; 97(11): 911-9.

Bradley B M, Griffiths S N, Stewart K J, Higgins G A, Hockings M, Isaac D L. The effect of obesity and increasing age on operative time and length of stay in primary hip and knee arthroplasty. J Arthroplasty 2014; 29(10): 1906-10.

D'Apuzzo M R, Novicoff W M, Browne J A. The John Insall Award: Morbid obesity independently impacts complications, mortality, and resource use after TKA. Clin Orthop Relat Res 2015; 473(1): 57-63.

den Hartog Y M, Mathijssen N M, Hannink G, Vehmeijer S B. Which patient characteristics influence length of hospital stay after primary total hip arthroplasty in a 'fast-track' setting? Bone Joint J 2015; 97-B(1): 19-23.

Foster S A, Hambright D S, Antoci V, Greene M E, Malchau H, Kwon Y M. Effects of obesity on health related quality of life following total hip arthroplasty. J Arthroplasty 2015; 30(9): 1551-4.

Haverkamp D, Klinkenbijl M N, Somford M P, Albers G H, van der Vis H M. Obesity in total hip arthroplasty--does it really matter? A meta-analysis. Acta Orthop 2011; 82(4): 417-22.

Husted H, Holm G, Jacobsen S. Predictors of length of stay and patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. Acta Orthop 2008; 79(2): 168-73.

Husted H, Lunn T H, Troelsen A, Gaarn-Larsen L, Kristensen B B, Kehlet H. Why still in hospital after fast-track hip and knee arthroplasty? Acta Orthop 2011; 82(6): 679-84.

Husted H. Fast-track hip and knee arthroplasty: clinical and organizational aspects. Acta Orthop 2012; 83 (Suppl 346): 1-39.

Husted H, Jørgensen C C, Gromov K, Troelsen A; Collaborative Group of the Lundbeck Foundation Center for Fast-Track Hip and Knee Replacement. Low manipulation prevalence following fast-track total knee arthroplasty. Acta Orthop 2015; 86(1): 86-91

Inacio M C, Kritz-Silverstein D, Raman R, Macera C A, Nichols J F, Shaffer R A, Fithian D C. The risk of surgical site infection and re-admission in obese patients undergoing total joint replacement who lose weight before surgery and keep it off post-operatively. Bone Joint J 2014a; 96-B(5): 629-35.

Inacio M C, Paxton E W, Fisher D, Li R A, Barber T C, Singh J A. Bariatric surgery prior to total joint arthroplasty may not provide dramatic improvements in post-arthroplasty surgical outcomes. J Arthroplasty 2014b; 29(7): 1359-64.

Inneh I A, Iorio R, Slover J D, Bosco J A 3rd. Role of sociodemographic, comorbid and intraoperative factors in length of stay following primary total hip arthroplasty. J Arthroplasty 2015; 30(12): 2092-7.

Issa K, Pivec R, Kapadia B H, Shah T, Harwin S F, Delanois R E, Mont M A. Does obesity affect the outcomes of primary total knee arthroplasty? J Knee Surg 2013; 26(2): 89-94.

Jameson S S, Mason J M, Baker P N, Elson D W, Deehan D J, Reed M R. The impact of body mass index on patient reported outcome measures (PROMs) and complications following primary hip arthroplasty. J Arthroplasty 2014; 29(10): 1889-98.

Jørgensen C C, Kehlet H; Lundbeck Foundation Centre for Fast-track Hip and Knee Replacement Collaborative Group. Role of patient characteristics for fast-track hip and knee arthroplasty. Br J Anaesth 2013; 110(6): 972-80.

Jørgensen C C, Kjaersgaard-Andersen P, Solgaard S, Kehlet H; Lundbeck Foundation Centre for Fast-track Hip and Knee Replacement Collaborative Group. Hip dislocations after 2,734 elective unilateral fast-track total hip arthroplasties: incidence, circumstances and predisposing factors. Arch Orthop Trauma Surg 2014; 134(11): 1615-22.

Jørgensen C C, Madsbad S, Kehlet H; Lundbeck Foundation Centre for Fast-track Hip and Knee Replacement Collaborative Group. Postoperative morbidity and mortality in type-2 diabetics after fast-track primary total hip and knee arthroplasty. Anesth Analg 2015; 120(1): 230-8.

Khan S K, Malviya A, Muller S D, Carluke I, Partington P F, Emmerson K P, Reed M R. Reduced short-term complications and mortality following Enhanced Recovery primary hip and knee arthroplasty: results from 6,000 consecutive procedures. Acta Orthop 2014; 85(1): 26-31.

Liu W, Wahafu T, Cheng M, Cheng T, Zhang Y, Zhang X. The influence of obesity on primary total hip arthroplasty outcomes: A meta-analysis of prospective cohort studies. Orthop Traumatol Surg Res 2015; 101(3): 289-96.

Malviya A, Martin K, Harper I, Muller S D, Emmerson K P, Partington P F, Reed M R. Enhanced recovery program for hip and knee replacement reduces death rate. Acta Orthop 2011; 82(5): 577-81.

McElroy M J, Pivec R, Issa K, Harwin S F, Mont M A. The effects of obesity and morbid obesity on outcomes in TKA. J Knee Surg 2013; 26(2): 83-8.

Pua Y H, Seah F J, Seet F J, Tan J W, Liaw J S, Chong H C. Sex differences and impact of body mass index on the time course of knee range of motion, knee strength, and gait speed after total knee arthroplasty. Arthritis Care Res (Hoboken) 2015; 67(10): 1397-405.

Tai S M, Imbuldeniya A M, Munir S, Walter W L, Walter W K, Zicat B A. The effect of obesity on the clinical, functional and radiological outcome of cementless total hip replacement: a case-matched study with a minimum 10-year follow-up. J Arthroplasty 2014; 29(9): 1758-62.

Thornqvist C, Gislason G H, Køber L, Jensen P F, Torp-Pedersen C, Andersson C. Body mass index and risk of perioperative cardiovascular adverse events and mortality in 34,744 Danish patients undergoing hip or knee replacement. Acta Orthop 2014; 85(5): 456-62.

Zhang Z J, Zhao X Y, Kang Y, Zhang Z Q, Yang Z B, He A S, Fu M, Sheng P Y, Liao W M. The influence of body mass index on life quality and clinical improvement after total hip arthroplasty. J Orthop Sci 2012; 17(3): 219-25.

Zhang Z H, Shen B, Yang J, Zhou Z K, Kang P D, Pei F X. Risk factors for venous thromboembolism of total hip arthroplasty and total knee arthroplasty: a systematic review of evidences in ten years. BMC Musculoskelet Disord 2015; 16: 24.