Obese patients may have more soft tissue impingement following primary total hip arthroplasty

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Abstract

Purpose Several studies have reported a risk of dislocation in obese patients after total hip arthroplasty. In this study, we evaluated the interaction between obesity and dislocation by kinematic analysis using a navigation system.

Methods The intraoperative range of motion (ROM) and postoperative impingement-free ROM were measured in 38 patients, and we compared the impingement-free ROM in obese and non obese patients.

Results The postoperatively simulated ROM was similar in the obese and non obese groups. The intraoperative ROM was smaller in the obese group. The difference values between the intraoperative ROM and postoperatively simulated ROM were larger in the obese group. These results indicate that obese patients have less ROM following primary total hip arthroplasty even when the implant positioning is performed correctly.

Conclusions Dislocations are multifactorial problems including soft tissue impingement. Therefore, the risk of dislocation caused by soft tissue impingement in obese patients may be increased.

Introduction

The prevalence of obesity is estimated to be 30 % in the general population in the United States [1, 2], where obesity contributes to an estimated 300,000 premature

deaths annually [3]. Even in Japan, 23 million people were identified as obese in 2008 [4]. These numbers have increased more significantly in women than men and more prominently in older age groups in comparison to data collected a decade ago [2]. A high prevalence rate of hip osteoarthritis [5–7] and a subsequent increase in total hip arthroplasty (THA) [8, 9] have been observed in obese patients. Mechanical factors such as increased load, malalignment, and muscle weakness and metabolic factors, have been proposed to explain the effect of obesity on osteoarthritis [10–12].

There has been great concern that obesity is associated with anaesthetic and operative complications after THA [13]. Several studies have attempted to clarify the interaction between obesity and dislocation following THA [14–16]. Azodi et al. demonstrated that a high body mass index (BMI) increased the risk of dislocation after THA [16]. In particular, morbidly obese patients (BMI >40) had a statistically significant higher risk of dislocation [3, 15]. By contrast, other studies did not find evidence of an increased rate of dislocation caused by obesity after THA [14, 15].

Recently, navigation systems have been developed that can provide correct component positioning and anatomical hip angular information intraoperatively [17]. Further, three-dimensional (3D) template software has been recently developed and used for preoperative planning and postoperative evaluation.

Impingement is one cause of dislocation [18–21]. Therefore, to clarify the interaction between obesity and dislocation after THA, we performed kinematic analysis using a navigation system intraoperatively and 3D template software postoperatively. The intraoperative ROM measured with a computer navigation system was compared to the maximal impingement-free ROM calculated by simulation based on postoperative CT images. Measurements were

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made in flexion, internal rotation, abduction and external rotation. The differences between non obese and obese patients are reported.

Materials and methods

Patients and surgery

Thirty-eight hips (nine male and 29 female subjects) were analysed in this study. Each patient's BMI was calculated by dividing their weight in kilograms by their height in metres squared. The WHO definition of obesity is BMI greater than 30. It is more uncommon for the Western population to find patients in the normal weight group. However, it is uncommon for the Japanese to find patients in the overweight group. Therefore, the patients were categorised into two groups: nonobese (BMI <25) and obese groups in this study. There were 24 hips in the non obese group, and the patients in this group had a mean BMI of $21.5 \pm 1.8 \text{ kg/m}^2$. There were 14 hips in the obese group, and the patients in this group had a mean BMI of $27.8 \pm 2.4 \text{ kg/m}^2$ (Table 1). The mean ages of patients at the time of surgery in the non obese and obese groups were 65.2 ± 11.2 and 66.6 ± 10.6 years, respectively. The mean heights of patients in the non obese and obese groups were 154.9 ± 7.9 and 155.8 ± 11.1 cm, respectively. There were no significant differences in age and height between the non obese and obese groups. However, the mean weights of patients in the non obese and obese groups were 51.7 ± 7.3 and 67.9 ± 12.8 kg, respectively. There were significant differences in weight and BMI between the non obese and obese groups ($P < 0.001$; Table 1).

All patients underwent THA with the use of a computed tomography (CT)-based fluoro-matched navigation system (VVHIP3.5; BrainLAB, Feldkirchen, Germany) between January 2010 and May 2012 for osteoarthritis (32 joints in 32 patients) or idiopathic osteonecrosis of the femoral head (six joints in six patients). The surgeon followed the registration procedures by using fluoroscopic imaging with reference landmarks on the patient's anatomy relative to the tracked reference arrays.

The software associates the positions of the registered anatomical landmarks relative to the reference arrays, with the 3D representations of the patient's bones calculated from

segmentation of the patient's CT scans, and provides the surgeon with real-time information on the location of surgical instruments relative to the patient's anatomy.

All patients underwent THA with a Pinnacle cup and Summit stem (DePuy, Warsaw, IN) by anterolateral approach. There was no case of dislocation after surgery in this series during the study period. Preoperative planning was performed using the navigation system. The study protocol was approved by Kobe University Graduate School of Medicine Ethics Committee, and all patients provided informed consent.

Registration of navigation THA

Registration of the pelvis was performed by 2D–3D image matching. First, fluoroscopic images of the pelvis including the femoral head and pubic symphysis were taken and matched with preoperative CT data. Second, the matched image was confirmed by touching the anterior superior iliac spine with a pointer. Finally, verification was completed by denoting the surface of the iliac crest, and registration was finished prior to the skin incision.

Similarly, registration of the femur was performed by 2D–3D image matching. First, fluoroscopic images of the proximal femur including the femoral head were taken and matched with preoperative CT data. Second, the matched image was confirmed by touching the femoral epicondyles with a pointer. Finally, verification was completed by denoting the proximal femur.

Intraoperative measurement of ROM

The maximal hip flexion, internal rotation, abduction, and external rotation were measured after implantation of the prosthesis by the measuring tool of the navigation system. The endpoint for the maximal ROM measurement was estimated by that the system detected a separation between the centre of rotation of cup and centre of rotation for the femoral head.

The axes for postoperative ROM simulation were based on the mechanical axis of the femur and anterior pelvic plane of the pelvis. The mechanical axis of the femur was estimated by the centre of the bilateral epicondyles of the femur and the centre of the femoral head.

Postoperative measurement of ROM

Regarding the preparation for planning, CT of the pelvis to the knee joint was performed, and the images were transferred to the 3D template software (ZedHip; Lexi, Tokyo, Japan). The simulative ROMs of maximal flexion, internal rotation, abduction, and external rotation were measured using the computer algorithm of the implant impingement

Table 1 Demographic data of the study group

Parameter	Age	Height (cm)	Weight (kg)	BMI
Non-obese	65.2	154.9	51.7	21.5
Obesity	66.6	155.8	67.9	27.8
<i>P</i> -value	N.S.	N.S.	$P < 0.001$	$P < 0.001$

N.S. not significant, BMI body mass index

detection system with the 3D template from postoperative CT data. The estimated mechanical axis in the 3D template was the same as that of the navigation system.

Statistical analysis

All data are expressed as the mean $\pm$ standard deviation (SD) unless otherwise indicated. Statistical analysis was performed using one-way analysis of variance with Tukey's post hoc test for multiple comparisons of paired samples. Correlations between the ROM and age, height, weight, or BMI were examined by Pearson's chi-squared test. In all cases, $p < 0.05$ was considered significant.

Results

Postoperatively simulated ROM did not differ between the nonobese and obese groups

The simulative impingement-free ROMs of flexion, internal rotation, abduction, and external rotation were measured by the 3D template software with postoperative CT data. In the non obese group, mean flexion was $109.4 \pm 8.0^\circ$, internal rotation was $69.9 \pm 11.0^\circ$, abduction was $60.0 \pm 6.8^\circ$, and external rotation was $52.1 \pm 8.9^\circ$. In the obese group, mean flexion was $114.1 \pm 10.0^\circ$, internal rotation was $73.8 \pm 13.7^\circ$, abduction was $60.5 \pm 6.5^\circ$, and external rotation was $51.5 \pm 12.9^\circ$. There was no significant difference in the mean values of maximal ROM between the non obese and obese groups (Table 2). The simulated maximal ROM might be dependent on implant positioning of both cup and stem. Therefore, these data suggested the positioning of implants was almost the same between the non obese and obese groups.

Intraoperative ROM was smaller in the obese group

The ROMs of flexion, internal rotation, abduction, and external rotation were measured intraoperatively by the navigation system. In the non obese group, mean flexion was $91.8 \pm 11.6^\circ$, internal rotation was $47.9 \pm 10.7^\circ$, abduction was $31.0 \pm 9.6^\circ$, and external rotation was $27.1 \pm 9.1^\circ$. In the obese group, mean flexion was $88.1 \pm 13.2^\circ$, internal

rotation was $37.5 \pm 13.6^\circ$, abduction was $36.6 \pm 9.4^\circ$, and external rotation was $35.1 \pm 14.0^\circ$. The trend is that intraoperative range of motion is always less than simulated ROM, because the endpoint of intraoperative ROM measurement is dependent on a separation between the centre of rotation of cup and centre of rotation for the femoral head, and the separation represents implant, bone or soft tissue impingement. The mean ROM of internal rotation was significantly smaller in the obese group than in the non obese group ($p = 0.01$; Table 3). The result may be dependent on soft tissue impingement, because internal rotation might be mostly affected by thickness of anterior soft tissue.

Obese patients had a larger average difference between their intraoperative and simulated ROM

We analysed the difference in values between the intraoperative ROM and the postoperatively simulated maximal impingement-free ROM. The mean difference values for flexion, internal rotation, abduction, and external rotation were 17.5 ± 12.5 , 22.7 ± 13.8 , 28.9 ± 12.3 , and $22.8 \pm 13.1^\circ$, respectively, in the non obese group. The corresponding values in the obese group were 28.1 ± 13.8 , 36.4 ± 12.4 , 23.8 ± 14.1 , and $28 \pm 17.9^\circ$, respectively. The mean difference values between the intraoperative ROMs and the postoperatively simulated maximal impingement-free ROMs for flexion and internal rotation were significantly larger in the obese group than in the non obese group (flexion: $p = 0.03$; internal rotation: $p = 0.03$; Table 3). The result may be dependent on soft tissue impingement, because flexion and internal rotation might be affected by thickness of anterior soft tissue. The difference of abduction and external rotation tended to be smaller in the obese group than in the non obese group. However, there were no significant differences. These results indicate that ROMs of abduction and external rotation are not affected by thigh soft tissue impingement.

BMI was strongly correlated with the difference between their intraoperative and simulated ROM of internal rotation

We analysed the correlations of age, height, weight, and BMI with the ROMs of maximal flexion, internal rotation,

Table 2 Mean values of range of motion

Parameter measured	Nonobese			Obese		
	Simulated	Intraoperation	Difference	Simulated	Intraoperation	Difference
Flexion	109	92	17	114	88	26*
Internal rotation	70	48	22	74	38*	36*
Abduction	60	31	29	61	37	24
External rotation	52	27	25	52	35	17

*Indicates p -value < 0.05

Table 3 (a) Correlations of clinical factors and intraoperative ROM measured by the navigation system after implantation. (b) Correlations of clinical factors and the difference between their intraoperative and simulated ROM of internal rotation. Upper values are correlation coefficients; lower values are *p*-values

Correlation <i>P</i> -value	Max flexion	Max IR	Max Abd	Max ER
(a) Intra-operative ROM				
Age	−0.11	−0.14	0.16	0.18
	N.S.	N.S.	N.S.	N.S.
Height	0.17	0.02	−0.27	0.04
	N.S.	N.S.	N.S.	N.S.
Weight	−0.31	−0.48	0.31	−0.37
	N.S.	0.032	N.S.	N.S.
BMI	−0.26	−0.65	0.26	−0.56
	N.S.	0.002	N.S.	0.019
(b) Difference of ROM				
Age	0.13	0.22	0.01	−0.10
	N.S.	N.S.	N.S.	N.S.
Height	0.06	0.29	0.26	0.09
	N.S.	N.S.	N.S.	N.S.
Weight	0.08	0.57	0.44	−0.03
	N.S.	N.S.	N.S.	N.S.
BMI	0.06	0.60	0.46	−0.15
	N.S.	0.009	N.S.	N.S.

Bold values indicate that the values have statistically significant correlations

N.S. not significant, *IR* internal rotation, *ER* external rotation

abduction, and external rotation. There were no significant correlations between these clinical factors and simulated ROMs (data not shown). However, there were significant correlations between BMI and the mean ROMs of internal/external rotation ($r=-0.65$, $p=0.002$; $r=-0.56$, $p=0.019$; Table 3). We further analysed the correlations of the difference values of ROM with age, height, weight, and BMI. There was a significant correlation between BMI and internal rotation ($r=-0.60$, $p=0.009$; Table 3). These findings also may be dependent on soft tissue impingement.

Discussion

Obesity has been linked to the development of osteoarthritis in the knee joint [6, 22]. Karlson et al. revealed an association between increased BMI and the risk of developing osteoarthritis of the hip of sufficient severity to warrant surgical intervention [9].

Several studies demonstrated the interaction of obesity with ROM [23, 24]. Park et al. demonstrated that obesity significantly reduced the ROM for multiple joints [23]. Gadinsky et al. reported that patients with higher BMI values had lower ROMs of the knee joint after total knee arthroplasty [24]. However, there was no report that described the ROM in obese patients after THA. In this study, we first demonstrated that obese patients had significantly lower ROMs for flexion and internal rotation after THA, although the maximal ROM with postoperative simulation did not differ between obese and non obese patients. These results may be consistent with soft tissue impingement.

We also measured the difference in values between the intraoperative ROM and the postoperatively simulated maximal impingement-free ROM. The difference in values represent the safety range for avoiding implant impingement. These results indicated that implant impingement occurred much less frequently in obese patients because the safety range was wider in obese patients than in non obese patients. However, dislocations are multifactorial problems. Abductor strength/continuity, soft tissue and bony impingement, infections, fluid forces, and soft tissue tensioning may also play roles. Recently, Elkins et al. demonstrated that morbid obesity may increase dislocation because of thigh soft tissue impingement, independent of implant impingement [25]. Lubbeke et al. demonstrated the increased risk of dislocation in obese women but not in obese men relative to their non-obese counterparts, suggesting a differential effect of obesity on the perioperative outcomes of men and women after THA [26]. They suggested that the quality of soft tissue influences the dislocation rate and that the lower peripheral muscle strength described in obese women could be one possible mechanism leading to an increased dislocation rate in these patients [11, 26].

Azodi et al. demonstrated that a high BMI was significantly associated with an increased risk of implant dislocation following primary THA [16]. They indicated that the increased risk of implant dislocation in overweight and obese patients may reflect a more complicated surgical procedure; in these patients, excessive adipose and muscle tissue mass in the hip region can make the surgical procedure more difficult and result in suboptimal orientation of

the prosthetic components [16]. Our findings indicate that implant impingement occurred much less frequently in obese patients if implant positioning is correctly performed. However, obese patients have less intraoperative ROMs because of soft tissue impingement even when implants were correctly positioned.

Cup and stem alignment during THA is a critical factor for achieving an optimal ROM and avoiding implant impingement. Several studies have focused on cup orientation with positioning in the safe zone during navigation THA, as outlined by Lewinnek [27]. A computer-assisted navigation system with real-time adjustments for component positioning is critical for avoiding malpositioning, especially in obese patients.

In conclusion, obese patients have less implant impingement following primary total hip arthroplasty if the implant positioning is performed correctly, but soft tissue impingement may increase. Our findings might indicate the one reason why obese patients have increased rates of dislocation.

References

- Korner J, Eberle MA (2001) An update on the science and therapy of obesity and its relationship to osteoarthritis. *Curr Rheumatol Rep* 3(2):101–106
- Flegal KM, Carroll MD, Ogden CL, Johnson CL (2002) Prevalence and trends in obesity among US adults, 1999–2000. *JAMA* 288(14):1723–1727
- Grant JA, Viens N, Bolognesi MP, Olson SA, Cook CE (2008) Two-year outcomes in primary THA in obese male veterans administration medical center patients. *Rheumatol Int* 28(11):1105–1109. doi:10.1007/s00296-008-0575-y
- Ibrahim SA, Stone RA, Han X, Cohen P, Fine MJ, Henderson WG, Khuri SF, Kwok CK (2005) Racial/ethnic differences in surgical outcomes in veterans following knee or hip arthroplasty. *Arthritis Rheum* 52(10):3143–3151. doi:10.1002/art.21304
- Felson DT, Chaisson CE (1997) Understanding the relationship between body weight and osteoarthritis. *Baillieres Clin Rheumatol* 11(4):671–681
- Lievensen AM, Bierma-Zeinstra SM, Verhagen AP, van Baar ME, Verhaar JA, Koes BW (2002) Influence of obesity on the development of osteoarthritis of the hip: a systematic review. *Rheumatology (Oxford)* 41(10):1155–1162
- Oliveria SA, Felson DT, Cirillo PA, Reed JI, Walker AM (1999) Body weight, body mass index, and incident symptomatic osteoarthritis of the hand, hip, and knee. *Epidemiology* 10(2):161–166
- Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Meyer HE (2002) Risk factors for total hip replacement due to primary osteoarthritis: a cohort study in 50,034 persons. *Arthritis Rheum* 46(3):675–682. doi:10.1002/art.10115
- Karlson EW, Mandl LA, Aweh GN, Sangha O, Liang MH, Grodstein F (2003) Total hip replacement due to osteoarthritis: the importance of age, obesity, and other modifiable risk factors. *Am J Med* 114(2):93–98
- Felson DT (2004) Risk factors for osteoarthritis: understanding joint vulnerability. *Clin Orthop Relat Res* (427 Suppl):S16–S21
- Hulens M, Vansant G, Lysens R, Claessens AL, Muls E, Brumagne S (2001) Study of differences in peripheral muscle strength of lean versus obese women: an allometric approach. *Int J Obes Relat Metab Disord* 25(5):676–681. doi:10.1038/sj.ijo.0801560
- Hunter DJ, March L, Sambrook PN (2002) Knee osteoarthritis: the influence of environmental factors. *Clin Exp Rheumatol* 20(1):93–100
- Sturmer T, Dreinhofer K, Grober-Gratz D, Brenner H, Dieppe P, Puhl W, Gunther KP (2005) Differences in the views of orthopaedic surgeons and referring practitioners on the determinants of outcome after total hip replacement. *J Bone Joint Surg Br* 87(10):1416–1419. doi:10.1302/0301-620X.87B10.16702
- Moran M, Walmsley P, Gray A, Brenkel IJ (2005) Does body mass index affect the early outcome of primary total hip arthroplasty? *J Arthroplasty* 20(7):866–869. doi:10.1016/j.arth.2005.02.008
- Andrew JG, Palan J, Kurup HV, Gibson P, Murray DW, Beard DJ (2008) Obesity in total hip replacement. *J Bone Joint Surg Br* 90(4):424–429. doi:10.1302/0301-620X.90B4.20522
- Sadr Azodi O, Adami J, Lindstrom D, Eriksson KO, Wladis A, Bellocchio R (2008) High body mass index is associated with increased risk of implant dislocation following primary total hip replacement: 2,106 patients followed for up to 8 years. *Acta Orthop* 79(1):141–147. doi:10.1080/17453670710014897
- Miki H, Yamanashi W, Nishii T, Sato Y, Yoshikawa H, Sugano N (2007) Anatomic hip range of motion after implantation during total hip arthroplasty as measured by a navigation system. *J Arthroplasty* 22(7):946–952. doi:10.1016/j.arth.2007.02.004
- Chen PY, Wu CT, Hou CH, Hou SM (2005) Loosening of total hip arthroplasty with a prosthesis employing a skirted femoral head. *J Formos Med Assoc* 104(5):370–373
- Shon WY, Baldini T, Peterson MG, Wright TM, Salvati EA (2005) Impingement in total hip arthroplasty a study of retrieved acetabular components. *J Arthroplasty* 20(4):427–435. doi:10.1016/j.arth.2004.09.058
- Barrack RL (2003) Dislocation after total hip arthroplasty: implant design and orientation. *J Am Acad Orthop Surg* 11(2):89–99
- Gambera D, Carta S, Crainz E, Fortina M, Maniscalco P, Ferrata P (2002) Metallosis due to impingement between the socket and the femoral head in a total hip prosthesis. A case report. *Acta Biomed* 73(5–6):85–91
- Gelber AC (2003) Obesity and hip osteoarthritis: the weight of the evidence is increasing. *Am J Med* 114(2):158–159
- Park W, Ramachandran J, Weisman P, Jung ES (2010) Obesity effect on male active joint range of motion. *Ergonomics* 53(1):102–108. doi:10.1080/00140130903311617
- Gadinsky NE, Ehrhardt JK, Urband C, Westrich GH (2011) Effect of body mass index on range of motion and manipulation after total knee arthroplasty. *J Arthroplasty* 26(8):1194–1197. doi:10.1016/j.arth.2010.12.004
- Elkins JM, Daniel M, Pedersen DR, Singh B, Yack HJ, Callaghan JJ, Brown TD (2012) Morbid obesity may increase dislocation in total hip patients: a biomechanical analysis. *Clin Orthop Relat Res*. doi:10.1007/s11999-012-2512-3
- Lubbeke A, Stern R, Garavaglia G, Zurcher L, Hoffmeyer P (2007) Differences in outcomes of obese women and men undergoing primary total hip arthroplasty. *Arthritis Rheum* 57(2):327–334. doi:10.1002/art.22542
- Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR (1978) Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 60(2):217–220