

Research Article

Body Mass Profiles among Younger and Older Hip Osteoarthritis Cases Requiring Surgery: Do this Matter Clinically?

Running title: Hip osteoarthritis and body mass

Ray Marks^{1*}

¹Department of Health, Physical Education, Gerontological Studies and Services, School of Health & Behavioral Sciences, City University of New York, York College, USA and Department of Health and Behavior Studies, Columbia University, Teachers College, USA.

*Corresponding author: Dr. Marks R, Department of Health and Behavior Studies, Teachers College, Columbia University Box 114, 525W 120th Street, New York, NY 10027. Email: rm226@columbia.edu

Received: 04-24-2015

Accepted: 05-22-2015

Published: 06-08-2015

Copyright: © 2015 Ray

Abstract

The prevailing literature is inconsistent concerning the relationship of excess body mass to the onset and progression of disabling hip osteoarthritis, often deemed an age associated disease. We examined the distribution of body mass indices among a sample of severely disabled hip osteoarthritis patients relative to age, and surgical status. Data from the available records of 997 severely disabled hip osteoarthritis cases undergoing surgery subjected to correlational analyses showed more cases among the sample had body mass indices indicative of being overweight or obese than underweight or normal weight ($p=.001$). Those younger than 65 years of age were more likely on average to have higher body mass indices, than those over age 65 ($p=.001$), especially in the obese category. Those who were heavier were more likely to have one or more metabolic health conditions ($p=.001$), and those in the morbidly obese range were more likely to require surgery for severe complications ($p=.001$). Men were more likely to be overweight or obese than women in the sample ($p=.001$). These findings imply adults with severe disabling hip osteoarthritis, especially men, are more likely to exhibit high, rather than low or normal body weights, and these rates of obesity are negatively associated with age ($p= 0.001$). It also appears those who are heavier have a stronger chance of adverse outcomes and of having 1 or more metabolic health conditions. Efforts to prevent obesity at a young age, especially among males, may consequently help to delay, as well as allay, the extent of the disability experienced by the severely compromised hip osteoarthritis patient.

Keywords: Age; Body Mass; Disability; Hip Joint; Obesity; Osteoarthritis; Outcomes; Surgery

Abbreviations

BMI: Body mass index

Introduction

Understanding the factors that influence the onset and progression of hip osteoarthritis, a highly painful disabling disease with no known cure, is currently of high importance given that one in four adults will develop this condition in his or her lifetime [1]. One potentially preventable factor strongly linked to several forms of osteoarthritis is obesity. Yet, this is controversial with respect to osteoarthritis of the hip.

For example, although Murphy et al. [1], and Grotie et al. [2] found no association between body mass and the lifetime risk for hip osteoarthritis, Holliday et al. [3] showed becoming overweight early on in life increased the risk of developing hip osteoarthritis. Moreover, even though Kessler et al. [4] found body weight had no influence on short term outcomes of hip replacement surgery, Chee et al. [5] who examined the five year outcomes of patients receiving hip replacement surgery, found those who were morbidly obese had higher rates of complications than those who were non-obese, a similar finding to Houdeck et al. [6]. Lubbeke et al. [7] too found those osteoarthritis cases who were overweight and underwent hip joint arthroplasty surgery had an increased rate of adverse health outcomes.

To provide some additional data to support or refute the role of obesity in the context of hip osteoarthritis, we elected to carefully examine and detail the body weight characteristics of a reasonably large sample of community dwelling adults with end-stage hip osteoarthritis requiring surgery.

We also conducted sub category age related observations of the distribution of body weights among the sample, conjecturing that if obesity is a risk factor for severe hip osteoarthritis, a high proportion of younger cases in such a sample would exhibit high rather than normal or low body weights, as represented by a body mass index (BMI) higher than 25.

Moreover, we conjectured that if body weight impacts the severity or progression of hip osteoarthritis, those experiencing severe complications would exhibit high rather than normal body weights, on average.

Finally, because obesity is linked to metabolic syndrome, we anticipated that obese hip osteoarthritis cases, that is those with BMIs greater than 29.9 would be more likely than not to exhibit one or more of these diseases than those who were normal weight or underweight.

To examine these premises objectively, the present analysis examined:

1. The body mass distribution patterns among the present cohort of severely disabled hip osteoarthritis cases requiring primary or secondary surgeries.

2. The body mass distribution patterns among those younger and older than 65 years of age.
3. The body mass distribution patterns among those with no prior surgical history, and those requiring surgery for revision or severe post-surgical complications.

Selected analyses were also conducted to examine gender related body mass distribution patterns, as well as metabolic syndrome related patterns of presentation.

Materials and Methods

Records of a sample of 1040 patients hospitalized for some form of hip replacement or revision surgery due to the presence of severe disabling end-stage hip osteoarthritis of one or both hips collected prospectively as part of an approved parent study of hip joint surgical outcomes were examined. After excluding those with rheumatologic health conditions, as well as those with acute hip fractures, there were 997 available records of men and women between 23-89 years of age, among whom 823 had no history of prior surgical complications requiring either revision or restorative secondary surgeries. In addition to demographic data, body mass indices, and evidence of diabetes, cardiovascular disease, depression, and numbers of comorbid health conditions were extracted from the records. Body mass index (an indicator of body mass derived from the formula $\text{weight} \cdot \text{height}^2$), was categorized into underweight (BMI less than 20), normal weight (BMI 20-24.9), overweight (BMI 25-29), and obese (>29) categories. Type of surgical condition was categorized as unilateral primary hip joint replacement, bilateral primary hip joint replacement, revision replacement surgery with no complications, revision surgery with severe complications such as infection, dislocation, or periprosthetic fractures. Data were systematically entered into SPSS version 17.0 files to examine trends in the data as regards body mass index, along with selected demographic and clinical variables using chi-square tests, cross-tabulations, and analysis of variance. An a priori significance level of 0.05 was adopted.

Results

The baseline descriptive characteristics of the sample are shown in Table 1. The mean age of the sample was 65.5 ± 12.98 years (range 23-94) and 57% were women, and 42% were men.

The mean body mass index of the sample of 27.6 ± 5.7 (range 15-68, median 27), showed most or 67% were overweight, on average, and males were more likely to be overweight, obese, or excessively obese with a body mass index >40 than females ($p=0.001$). The 390 cases under age 65 tended to be heavier on average than those 599 cases over age 65 ($p=0.001$) (28.8 ± 6.4 vs 26.9 ± 5.2). The correlation between body mass index and age

was an inverse one, $r=.18$; $p=.001$, suggesting that those who were younger tended to be heavier than those who were older. Unsurprisingly, among those in the excessively obese range ($BMI > 40$), 23% had diabetes compared to 5% among those in the overweight or moderately obese categories, and 43% of these excessively obese cases had comorbid hypertension histories ($p < .001$). Among the 39 excessively obese cases, 23 or about 54% were 65 years or younger.

Table 1. Characteristics of cohort of hip osteoarthritis patients requiring primary or secondary surgery (n=997)

Variable	Finding
Age (years), mean \pm SD	65.5 \pm 12.98, range 23-94
Age range, (n,%)	
<65 yrs	391(39.2)
>65 yrs	599(60)
Gender, (n,%)	
Male	424(42)
Female	568(57)
Health condition, (n)	
Cardiovascular disease	217
Diabetes	47
Hypertension	329
Surgical category, (n)	
Unilateral hip replacement	770
Bilateral hip replacement	54
Revision surgery no complications	122
Severe complications	48
BMI ($kg.m^{-2}$), mean \pm SD	27.6 \pm 5.7
median	27
range	15-68
BMI category, (n,%)	
Non-obese ($BMI < 25$)	307(30.8)
Mild obesity ($25 > BMI < 29.9$)	391(39.2)
Mod.obesity ($30 > BMI < 39.9$)	256(25.7)
Severe obesity ($BMI > 40$)	39(3.9)

BMI=body mass index

The relationship between gender and body mass, and between age and body mass category is shown in Tables 2 and 3. As indicated, those categorized as obese were generally younger than those who were not, and males tended to present with higher overall rates of obesity, in general, than females.

Table 2. Distribution of patients according to age, gender and body mass (n=993)

Variable	Non-obese < 25	Body Mass Category		
		Obese Grade 1 25-29.9	Grade 2 30-30.9	Grade 3 > 40
Number of patients (n)	307	391	256	39
Mean age (yrs)	66.8 \pm 13.9	67.1 \pm 11.9	62.6 \pm 12.6	58.2 \pm 12.1*
Females (n=568)	227	202	117	22
Males (n=423)	80	187	139	17
Female (%)	40	35.6	20.6	3.9
**Male (%)	18.9	44.2	32.9	4.0

*** significant body mass distribution differences observed among sub-groups

In terms of body mass distributions among the sub-group of patients undergoing primary or secondary surgeries, those who experienced serious complications following prior hip surgery tended to be heavier on average than those with no

complications, or those requiring standard revision procedures ($F=2.78$; $df=3$; $p=.04$). Conversely, those in the normal body mass or underweight category experienced proportionately fewer severe complications than those who were obese ($p=.001$) (See Table 4). Those requiring bilateral hip joint replacement surgery were almost 10 years younger than those requiring any other form of surgery ($p=.001$), and 62.5% of those requiring surgery for complications such as periprosthetic fractures were male ($p=.001$).

Table 3. Distribution of all patients by age range according to obesity groupings (n=993)

	Non-obese < 25	BMI index Grade 1 25-29.9	Grade 2 30-30.9	Grade 3 > 40
Number of patients (n)	307	391	256	39
Overall (%)	30.8	39.2	25.7	3.9
< 65 years (n=391)	106	132	127	25
>65 years (n=599)	198	259	128	14
< 65 years (%)	27.2	33.8	32.6	6.4*
>65 years (%)	33.1	43.2	21.4	2.3

*significant body mass distribution differences occurred among those younger or older than 65 years of age, $p < 0.001$

Table 4. Distribution of body mass among the 4 different operative conditions showing those with severe complications were more likely to be obese than underweight or of normalweight.

	Underweight < 20	BMI Category Normal 20-24.9	Overweight 25-29.9	Obese 30+
Number of patients (n,%)	35(3.5)	275(27.6)	376(37.7)	307(30.8)
Unilateral surgery	26(3.4)	211(27.4)	299(38.8)	233(30.3)
Bilateral surgery	1(1.9)	18(33.3)	16(29.6)	19(35.2)
Revision surgery	7(5.7)	37(30.3)	44(36.9)	34(27.9)
Complications	1(2.1)	9(18.8)	17(35.4)	21(43.8)*

*significant body mass distribution differences occurred among those requiring surgery for severe complications, $p < 0.001$

Among those with 3 comorbid health conditions, hypertension, cardiovascular disease, and diabetes, no subject was observed to be at a healthy weight. Of those with BMIs greater than 40, 9% were healthy, while almost 28% had a metabolic syndrome related comorbid health condition ($p=.025$). Among the 44 cases with a diabetes diagnosis, almost 50% were obese, and 19.1% were morbidly obese ($p=.001$). Being overweight or obese was related to the presence of a high blood pressure diagnosis ($p=.001$), but not to cardiovascular health ($p=.117$).

Discussion

Although the relationship between overweight and hip joint osteoarthritis is not definitive, results of this present analysis suggest overweight is an important hip joint osteoarthritis correlate.

That is, obesity as defined by a body mass index of 29.9 or higher was a consistent feature of this present cohort, especially among those younger than 65 years of age. Moreover, consistent with Changulani et al. [8], those in the morbidly obese range were almost 10 years younger on average than those in the normal weight category, and those with higher body weights were more likely to experience adverse surgical outcomes than those who were not. The finding that younger cases with no other identifiable disease cause had high rates of obesity, especially morbid obesity rates, is consistent with findings of Tai et al. [9] and Guetner et al. [10]. As in Guetner et al.'s study, it appears younger adults, especially those who suffer from morbid obesity may be quite prone to developing osteoarthritis in both hips, as well as other disabling health conditions such as diabetes and cardiovascular disease. They may also require early hip joint replacement surgery, while incurring an increased risk of poor surgical outcomes, due to their lack of physical activity and possible hormonal imbalances that produce poorer bone quality [10].

Liu et al. [11] reported 27% of hip replacements in middle age women were attributable to obesity, as outlined in 2007. Although our data do not support that of Jacobsen and Holm [12] who found total hip replacement was predicted solely by body mass indices at baseline, the present data do support a strong obesity influence in this disease, with similar rates to Liu et al. [11] of approximately 25% for women. This relationship currently appeared even stronger for men, where approximately 36% were obese, and being obese was especially evidenced among those men 65 years of age or younger.

In line with Vinequerra et al. [13] who examined 149 patients over 5 years for risk of future total hip replacement, and found a three-fold risk in those with body mass indices greater than 27, almost 70% of those younger than 65 years of age in the present study had body mass indices greater than 25, when considered as a whole. That is, they had an average BMI of 28.8 ± 6.3 , and 64.1% of those in the excessively obese category were 65 years of age or less versus 35.9% who were older than 65 years of age. As well, younger cases experienced the same rate of severe complications as the older cases, even though Wallace et al. [14] reported no similar major adverse impact of body mass index on risk of post-operative complications six months after total hip replacement surgery, as did Tai et al. [9] after 10 years, but this group did not examine morbidly obese patients cases independently.

While Grotle et al. [2] found no association between body mass and hip osteoarthritis, obesity, an independent predictor of pain [16], can undoubtedly place excess biomechanical stress on the hip joint. It can also increase chances of adopting a sedentary lifestyle, and hence not unsurprisingly, greater body weight and body mass index during early and middle adulthood [15].

Since being overweight could render individuals of any age subject to abnormal hip joint loading forces that can initiate early joint destruction processes along with increases in pro-inflammatory enzymes that degrade cartilage matrix [17], hip joint destruction may not depend solely on age. Moreover, associated high rates of pain, as well as joint destruction and postural changes in those who are excessively obese can be expected to impact the pathogenesis of hip joint osteoarthritis both before and after surgery more profoundly than non obese situations [18, 19]. Alternately, the constellation of obesity, immobility and pain can independently raise the risk for hip joint osteoarthritis, and its disability.

Although a causal link between obesity and hip joint osteoarthritis cannot be confirmed on the basis of this retrospective cross sectional study, and its small sample size and makeup, plus limited mode of assessing body mass, it is difficult to refute the hypothesis that obesity can independently impact the onset of hip osteoarthritis and its severity. The results do however comport with others such as Guenther et al. [10], and hence to more ably support this hypothesis, prospective studies that utilize underwater weighing and bioelectrical impedance measures of body mass along with radiographic scans may be helpful.

Conclusion

Having a high body mass appears more characteristic than not of individuals hospitalized for purposes of total hip replacement, revision surgery, or severe complications from prior surgery. Whether this is a consequence of the disease, rather than a cause or risk factor it is important to consider:

1. A high percentage of end stage hip osteoarthritis cases are obese, especially when compared to current publicized rates among adults of approximately 33% [36].
2. Forty percent of those younger than 65 years of age, and approximately 24 percent of those 65 years of age or older were categorized as being obese, suggesting obesity is not necessarily a consequence of the duration of the disease.
3. Men were more likely to be obese, as well as overweight in this sample compared to women, especially in the younger age group.
4. Excessively obese cases with BMIs > 40 were more likely to be under age 65 than over 65 years of age, and were equally represented by men and women.
5. Being hospitalized for a severe post-surgical joint replacement complication was associated with being excessively obese, especially among males.
6. Being overweight or obese was statistically correlated with the presence of one or more metabolic health condition, regardless of gender, and no subject with three comorbid conditions was reported to be at a healthy weight.

In accord with Guenther et al. [10] and Cimmino et al. [21] who implied obesity is likely to heighten the osteoarthritis disease severity, pain, and dysfunction, it appears reasonable to conclude that excess body mass can raise the risk for early onset of hip joint osteoarthritis, plus early referral for hip osteoarthritis surgery. Regardless of age [22], excess obesity can also increase the likelihood of post-surgical complications and smaller than desirable outcome benefits. It can increase readmissions rates, and need for reoperations, plus surgical duration and hospital length of stay [24]. Hence despite the limitations of an observational study for pinpointing causation, along with the present mode of assessing obesity, in absence of a cure for hip osteoarthritis, this present study implies efforts to minimize the onset and progression of obesity across the lifespan may prove highly beneficial, despite the lack of consensus of a distinct correlation of these factors [25].

This lack of consensus is however declining, and past lack of clarity on this issue may have stemmed in part, from the fact that in some earlier studies, obesity was not the prevalent problem it is today [eg 26], and the magnitude of obesity may have been lower, and the population not as sedentary as a whole. Consequently, there was less distinction in older case control studies between subjects, in the context of body mass estimates and a lower likelihood of a connection between these variables. The tendency to operate on much younger patients today, may also reveal new trends in the risk attributable to obesity versus age in the case of hip osteoarthritis. Newer data are clearly more consistent in identifying a reasonably strong association between excess body mass and the onset and progression of hip osteoarthritis [15, 27, 28], especially the early onset of this condition. [29, 30]. Weight gain also clearly raises the risk of later total hip replacement surgery [31], and this relationship is stronger in younger men and women, and absent in older men and weaker in older women [32]. Since the prevalence of overweight is increasing in the general population [10], and body mass is a modifiable risk factor [32], the need to focus on weight control in early life, as well among those who are already diagnosed with hip osteoarthritis is clearly of potential clinical significance. This primary prevention approach may especially help to attenuate the immense personal burden experienced among young people with hip osteoarthritis [27], as well as older cases who are at increased risk of adverse events after surgery [33, 34], plus those with a BMI of 35kg.m^{-2} , and comorbid health conditions [37]. Indeed, despite past conjecture concerning the importance of obesity as a hip osteoarthritis risk factor, it is our view that this present analysis, plus an increasing number of current as well as past studies [eg 38] are providing compelling evidence that obesity prevention and intervention is imperative in any meaningful effort to stem the tide of increasing disability attributable to hip osteoarthritis anticipated in the aging population.

References

1. Murphy LB, Helmick CG, Schwartz TA, Renner JB, Tudor G et al. One in four people may develop symptomatic hip osteoarthritis in his or her lifetime. *Osteoarthritis Cartilage*. 2010, 18(11): 1372-1379.
2. Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: an epidemiological study in the general population with 10 years follow-up. *BMC MusculoskeletDisord*. 2008, 9: 132.
3. Holliday KL, McWilliams DF, Maciewicz RA, Muir KR, Zhang W et al. Lifetime body mass index, other anthropometric measures of obesity and risk of knee or hip osteoarthritis in the GOAL case-control study. *Osteoarthritis Cartilage*. 2011, 19(1): 37-43.
4. Kessler S, Käfer W. Overweight and obesity: two predictors for worse early outcome in total hip replacement? *Obesity*. 2007, 15(11): 2840-2845.
5. Chee YH, Teoh KH, Sabnis BM, Ballantyne JA, Brenkel IJ. Total hip replacement in morbidly obese patients with osteoarthritis: results of a prospectively matched study. *J Bone Joint Surg Br*. 2010, 92(8): 1066-1071.
6. Houdek MT, Wagner ER, Watts CD, Osmon DR, Hanssen AD et al. Morbid obesity: a significant risk factor for failure of two-stage revision total hip arthroplasty for infection. *J Bone Joint Surg Am*. 2015, 97(4): 326-332.
7. Lübbeke A, Stern R, Garavaglia G, Zurcher L, Hoffmeyer P. Differences in outcomes of obese women and men undergoing primary total hip arthroplasty. *Arthritis Rheum*. 2007, 57(2): 327-334.
8. Changulani, M; Kalairajah, Y; Peel, T; Field, RE. The relationship between obesity and the age at which hip and knee replacement is undertaken. *J Bone Joint Surg (Br)*. 2008, 90B: 360-363.
9. Tai SM, Imbuldeniya AM, Munir S, Walter WL, Walter WK et al. 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): 1758-1762.
10. Guenther D, Schmidl S, Klatt TO, Widhalm HK, Omar M et al. Overweight and obesity in hip and knee arthroplasty: evaluation of 6078 cases. *World J Orthop*. 2015, 6(1): 137-144.
11. Liu B, Balkwill A, Banks E, Cooper C, Green J, Beral V. Relationship of height, weight and body mass index to the risk of

- hip and knee replacements in middle-aged women. *Rheumatol*. 2007, 46(5): 861-867.
12. Jacobsen S, Sonne-Holm, S. Increased body mass index is a predisposition for treatment by total hip replacement. *Int Orthop*. 2005, 29(4): 229-234.
13. Vinniciguerra C, Gueguen A, Revel M, Heuleu JN, Amor B et al. Predictors of the need for total hip replacement in patients with osteoarthritis of the hip. *Rev Rhum Engl Ed*. 1995, 62(9): 563-570.
14. Wallace G, Judge A, Prieto-Alhambra D, de Vries F, Arden NK et al. The effect of body mass index on the risk of post-operative complications during the 6 months following total hip replacement or total knee replacement surgery. *Osteoarthritis Cartilage*. 2014, 22(7): 918-927.
15. Wang Y, Wluka AE, Simpson JA, Giles GG, Graves SE et al. Body weight at early and middle adulthood, weight gain and persistent overweight from early adulthood are predictors of the risk of total knee and hip replacement for osteoarthritis. *Rheumatol*. 2013, 52(6): 1033-1041.
16. Singh JA, Lewallen D. Age, gender, obesity, and depression are associated with patient-related pain and function outcome after revision total hip arthroplasty. *Clin Rheumatol*. 2009, 28(12): 1419-1430.
17. Iannone F, Lapadula G. Obesity and inflammation--targets for OA therapy. *Curr Drug Targets*. 2010 11(5): 586-198.
18. Fabris de Souza SA, Faintuch J, Valezi AC, Sant'Anna AF, Gama-Rodrigues JJ et al. Postural changes in morbidly obese patients. *Obes Surg*. 2005, 15(7): 1013-1016.
19. Elson LC, Barr CJ, Chandran SE, Hansen VJ, Malchau H et al. Are morbidly obese patients undergoing total hip arthroplasty at an increased risk for component malpositioning?. *J Arthroplasty*. 2013, 28(8 Suppl): 41-44.
20. Magliano M. Obesity and arthritis. *Menopause Int*. 2008, 14(4):149-154.
21. Cimmino MA, Scarpa R, Caporali R, Parazzini F, Zaninelli A et al. Body mass and osteoarthritic pain: results from a study in general practice. *Clin Exp Rheumatol*. 2013, 31(6): 843-849.
22. Jameson SS, Mason JM, Baker PN, Elson DW, Deehan DJ et al. The impact of body mass index on patient reported outcome measures (PROMs) and complications following primary hip arthroplasty. *J Arthroplasty*. 2014, 29(10): 1889-1898.
23. Lübbecke A, Moons KG, Garavaglia G, Hoffmeyer P. Outcomes of obese and nonobese patients undergoing revision total hip arthroplasty. *Arthritis Rheum*. 2008, 59(5):738-745.
24. Maradit Kremers H, Visscher SL, Kremers WK, Naessens JM, Lewallen DG. Obesity increases length of stay and direct medical costs in total hip arthroplasty. *Clin Orthop Relat Res*. 2014, 472(4): 1232-1239.
25. Jones DG. Articular cartilage degeneration: etiologic association with obesity. *Ochsner J*. 2009, 9(3): 137-139.
26. Stürmer T, Günther KP, Brenner H. Obesity, overweight and patterns of osteoarthritis: the Ulm Osteoarthritis Study. *J Clin Epidemiol*. 2000, 53(3): 307-313.
27. Ackerman IN, Osborne RH. Obesity and increased burden of hip and knee joint disease in Australia: results from a national survey. *BMC Musculoskelet Disord*. 2012, 20: 13:254.
28. Jiang L, Rong J, Wang Y, Hu F, Bao C et al. The relationship between body mass index and hip osteoarthritis: a systematic review and meta-analysis. *Joint Bone Spine*. 2011, 78(2): 150-155.
29. Andrew JG, Palan J, Kurup HV, Gibson P, Murray DW et al. Obesity in total hip replacement. *J Bone Joint Surg Br*. 2008, 90(4): 424-429.
30. Teichtahl AJ, Wang Y, Smith S, Wluka AE, Urquhart D et al. Early cartilage abnormalities at the hip are associated with obesity and body composition measures - A 3.0T MRI community-based study. *Arthritis Res Ther*. 2015, 17(1): 107.
31. Flugsrud GB, Nordsletten L, Espehaug B, Havelin LI, Engeland A et al. The impact of body mass index on later total hip arthroplasty for primary osteoarthritis: a cohort study in 1.2 million persons. *Arthritis Rheum*. 2006, 54(3): 802-807.
32. Apold H, Meyer HE, Espehaug B, Nordsletten L, Havelin LI et al. Weight gain and the risk of total hip replacement a population-based prospective cohort study of 265,725 individuals. *Osteoarthritis Cartilage*. 2011, 19(7): 809-815.
33. Huddleston JI, Wang Y, Uquillas C, Herndon JH, Maloney WJ. Age and obesity are risk factors for adverse events after total hip arthroplasty. *Clin Orthop Relat Res*. 2012, 470(2): 490-496.
34. Marks R. Body mass characteristics of hip osteoarthritis patients experiencing aseptic loosening, periprosthetic fractures, dislocation, and infections after total hip replacement. *Clinicoecon Outcomes Res*. 2009, 1: 7-16.
35. Davis AM, Wood AM, Keenan AC, Brenkel IJ, Ballantyne JA. Does body mass index affect clinical outcome post-operatively and at five years after primary unilateral total hip replacement performed for osteoarthritis? A multivariate analysis of prospective data. *J Bone Joint Surg Br*. 2011, 93(9): 1178-1182.

36. Marks R, Allegrante JP. Comorbid disease profiles of adults with end-stage hip osteoarthritis. *Med Sci Monit.* 2002, 8(4): 305-309.

37. Adult obesity facts. Centers for Disease Control and Prevention. 2015.

38. Teichtahl AJ, Wang Y, Smith S, Wluka AE, Zhu M et al. Bone geometry of the hip is associated with obesity and early structural damage - a 3.0T magnetic resonance imaging study of community-based adults. *Arthritis Res Ther.* 2015 17: 112.