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Original article

The influence of obesity on primary total hip arthroplasty outcomes: A meta-analysis of prospective cohort studies

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ABSTRACT

Background: Whether or not, obesity negatively influencing the outcomes of primary total hip arthroplasty (THA) remains a controversial issue. Though observational studies focused on this topic, the reported conclusions remain inconsistent. Therefore, we performed a meta-analysis of prospective cohort studies to evaluate if obesity negatively affects: (1) the overall complication rate (incidence of dislocation, deep infection and osteolysis); (2) functional outcome; (3) operative time and stay duration in hospital for the primary THA.

Methods: We searched the PubMed, Embase, Web of Science, and the Cochrane Library until July 2014 to identify the eligible prospective studies. The Newcastle Ottawa Scale (NOS) was used for quality assessment of the included studies. We extracted and pooled the data. As for continuous data, mean difference (MD) was calculated; for dichotomous variables, we calculated a weighted relative risk (RR) with its 95% confidence interval. Heterogeneity was evaluated using I^2 statistics. $P \leq 0.05$ was thought to be significant. **Results:** Fifteen studies were eligible for data extraction, which involved 11,271 total hip arthroplasties. The pooled data of complication rate demonstrated that obese patients suffered higher rates of complication (RR: 1.68, 95% CI 1.23 to 2.30, $P=0.0004$), dislocation (RR: 2.08, 95% CI 1.54 to 2.81, $P<0.0001$) and deep infection (RR: 2.92, 95% CI 0.74 to 11.49, $P=0.13$). For the functional result, obese patients acquired relatively lower Harris Hip Score than non-obese patients (MD: -2.75 , 95% CI -4.77 to -0.6), no difference was found regarding Oxford Hip Score (MD: -0.46 , 95% CI -2.18 to 1.26 , $P=0.60$). Obese patients compared to non-obese patients showed an increase duration of operation (MD: 10.67, 95% CI 3.00 to 18.35, $P=0.006$). However, no significant difference was found in the length of stay in hospital between obese and non-obese patients (MD: -0.16 , 95% CI -0.34 to 0.02 , $P=0.08$).

Conclusions: This meta-analysis of prospective cohort studies demonstrates that obesity negatively influences the overall complication rate, dislocation rate, functional outcome and operative time of primary total hip arthroplasty.

Level of evidence: Level II. Low-powered prospective randomized trial.

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1. Introduction

More than one million patients undergo total hip arthroplasty (THA) every year, and this number is estimated to double within the next two decades [1,2]. It is clear that obesity is a risk for arthritis, increasing need for arthroplasties can be predicted [3]. With the obesity epidemic, the proportion of obese patients needing THA is on ascension. Studies focusing on the influence of obesity in THA also gain its popularity. However, different conclusions were reported regarding whether obesity has a negative influence on primary THA [4,5]. Some centers have already refused to perform

THA for obese patients considering the high forces acting on the prosthesis and polyethylene wear unless an acceptable body mass index (BMI) is obtained [6,7]. Thus, an improved understanding of the influence of obesity on THA seems to be necessary. According to the World Health Organization guideline, BMI > 30 kg/m² is considered obese [8]. We performed this meta-analysis to compare outcomes in different groups (BMI < 30 , 30–40, > 40 kg/m²) using the PRISMA protocol. This meta-analysis of 15 prospective studies was designed to evaluate if obesity negatively affects:

- the overall complication rate (incidence of dislocation, deep infection and osteolysis);
- functional outcome;
- operative time and length of stay in hospital of the primary THA?

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2. Methods

2.1. Search strategy

Our search strategy was performed in the databases of PubMed/Medline, Embase, Web of Science, and the Cochrane Library until July 2014 to identify the eligible prospective cohort studies. The search strategy combined free keywords with Mesh Terms as following words:

- obesity, obese, body mass index, BMI, overweight, overweighed;
- hip arthroplasty, hip replacement, THA;
- prospective study(ies), cohort study(ies), longitudinal study(ies).

Only English articles were included. Furthermore, the references lists of retrieved studies were also checked for additional studies that met the criteria but not found by the electronic search.

2.2. Study inclusion and exclusion criteria

Studies that were included in this meta-analysis should meet the following criteria:

- include patients undergoing a primary THA;
- include an obese group ($BMI > 30 \text{ kg/m}^2$) and a non-obese ($BMI < 30 \text{ kg/m}^2$) group, the cutoff point of obesity should be $BMI > 30 \text{ kg/m}^2$;
- the study design must be a prospective cohort study;
- useful outcomes should be reported such as complication rate, operative time and function score.

Studies were excluded if:

- the definition of obese group was not $BMI > 30 \text{ kg/m}^2$;
- it was impossible to extract or pool the necessary data from the published results (not absolutely data but column chart, for example);
- no interested outcome was reported and non-prospective study design.

Review articles, expert opinions, surgical techniques, and abstracts from meetings were excluded.

2.3. Data Extraction and Quality Assessment

The studies selection and data extraction were independently assessed by two reviewers (WL and TW). Studies were not blinded regarding author, affiliation, or source [9]. Disagreement was resolved by discussion and eventually determined by a senior author (TC). Outcomes of interest in this study were overall complication rate, incidence of dislocation, deep infection, and osteolysis, blood loss, functional score (Harris Hip Score and Oxford Hip Score), operative time and length of stay in hospital. The data in different groups were finally pooled into three groups ($BMI < 30$, $30\text{--}40$, $> 40 \text{ kg/m}^2$). Besides, the characteristics of each study were also recorded as follows: first author's last name, year of publication, study population, country of origin, study period and duration of follow-up.

Quality assessment of the prospective cohort studies included in this meta-analysis was assessed by the Newcastle Ottawa Scale (NOS) as recommended by the Cochrane non-randomized studies methods working group, which was composed of three sections (selection, comparability and assessment of outcome) [10]. Consensus was reached on study quality assessment through reviewing

the study and discussing the discrepancy. Studies were considered of high quality if at least 5 of 9 criteria were met.

2.4. Subgroup analysis

It was reported by some studies that patients with $BMI > 40 \text{ kg/m}^2$ suffered a worse outcome of the primary THA [5,11–13]. We performed a subgroup analysis for the outcomes (overall complication rate, incidence of dislocation, deep infection, Harris Hip Score, operative time, length of stay in hospital) that contained enough data to be divided into two subgroups (obesity $BMI 30\text{--}40 \text{ kg/m}^2$ and super-obesity $BMI > 40 \text{ kg/m}^2$).

2.5. Statistical analysis

We used Revman 5.3 software (The Nordic Cochrane Centre, Copenhagen, Denmark) to pool data, $P \leq 0.05$ was thought to be significant. Relative risk (RR) and its 95%CI were used to assess the association between obesity and its influence on THA complication rate, incidence of dislocation, deep infection and osteolysis across studies. For continuous data, which was reported with a range, the SD was calculated using the method described by Walter and Yao [14]. Finally, the data was pooled as mean difference (MD) and its 95%CI. The I^2 statistic was used to measure inconsistency across studies [15]. The data was pooled using fixed-effect (Mantel-Haenszel test) when no statistical heterogeneity was detected between studies ($P > 0.10$; $I^2 < 50\%$). Otherwise, the random-effect (DerSimonian-Laird method) model was used. We also performed a sensitivity analysis to explore possible explanations for heterogeneity.

3. Results

3.1. Study collection

One thousand and seventeen articles were identified through databases search, 654 records were left after the removal of duplicates, and finally, 625 were excluded after the screening of title and abstract. The remaining 29 articles were carefully viewed full-text, subsequently, 14 were excluded because of inconsistent with the inclusion or exclusion criteria. Finally, 15 studies were eligible for this meta-analysis including 11,271 THA [4,9,11–13,16–25]. Among the whole included studies, only four studies had a cut-off point of $BMI > 40 \text{ kg/m}^2$ [5,11–13]. More details were shown in Fig. 1.

3.2. Study characteristics

Fifteen prospective studies were included in this meta-analysis, which were published ranging from 1999 to 2013. Among the included studies, 5 were performed in UK [5,13,17,20,24], 2 in Germany [16,22], 2 in USA [11,23], 2 in Switzerland [18,21], 3 in Australia [4,12], 1 in Swedish [19]. As for the follow-up time, it ranged from 3 months to 18 years. More detailed information about the study characteristics was presented in Table 1.

Not all of the studies contain the defined interest of outcomes: 10 studies for complication rate (2 for super-obese group), 6 studies for dislocation (2 for super-obese group), 3 for deep infection, 3 for osteolysis, 4 for blood loss, 2 for Oxford Hip Score, 6 for Harris Hip Score (2 for super-obese group). Regarding operative time, 7 studies were pooled (2 for super-obese group), 6 studies for length of stay in hospital (2 for super-obese group). Because the number of included studies about the complication rate reached 10, we performed a funnel plot to assess the publication bias.

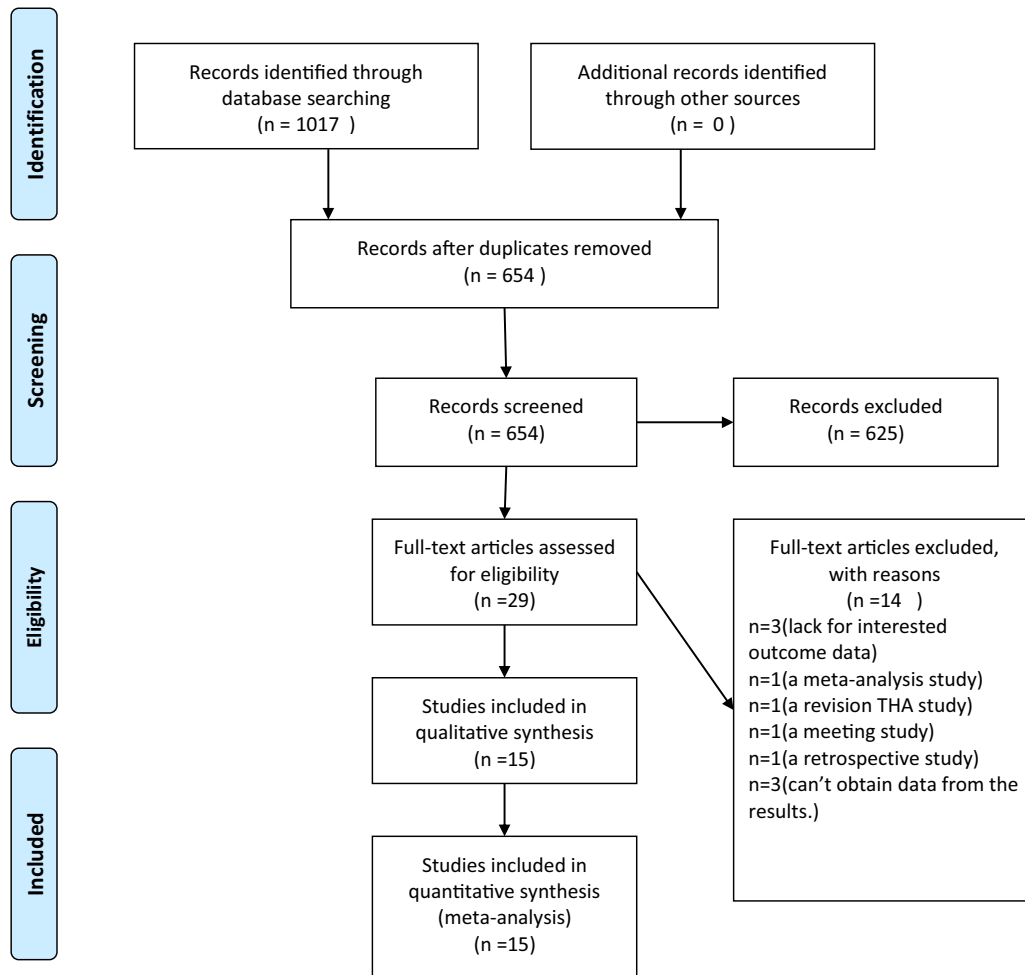


Fig. 1. Flowchart detailing the selection of studies.

Table 1
Characteristics of studies included in the meta-analysis.

Study	Setting	Enrolment time	Group (BMI kg/m ²)	N	Follow-up (year)
Dienstknecht et al., 2013 [16]	Germany	2010	< 30, ≥ 30	134	< 1
Raphael et al., 2013 [11]	USA	2011	< 25, 25–30, 30–39.9, ≥ 40	50	< 1
Michalka et al., 2012 [4]	Australia	2005 to 2007	< 30, 30–35, > 35	191	< 1
Davis et al., 2011 [17]	UK	1998 to 2005	< 25, 25–30, 30–34.9, ≥ 35	1617	5
Lubbeke et al., 2010 [18]	Switzerland	1996 to 2003	< 25, 25–29.9, ≥ 30	503	5 to 10
Chee et al., 2010 [13]	UK	1998 to 2003	< 30, 30–39.9, ≥ 40	110	5
Dowsey et al., 2010 [12]	Australia	2005 to 2007	< 30, 30–39.9, ≥ 40	471	1
Jackson et al., 2009 [25]	Australia	1997 to 2006	< 30, ≥ 30	1659	0 to 11
Andrew et al., 2008 [5]	UK	1999 to 2007	< 30, 30–39.9, ≥ 40	1059	5
Sadr Azodi et al., 2008 [19]	Swedish	1997 to 2004	< 25, 25–29.9, ≥ 30	2085	3
Lubbeke et al., 2007 [21]	Switzerland	1996 to 2005	< 30, ≥ 30	2495	5
Kessler et Kafer, 2007 [22]	Germany	2005	< 25, 25–29.9, ≥ 30	67	< 1
Patel and Albrizio, 2007 [20]	UK	2002 to 2005	< 25, 25–29, 30–34, > 34	550	1
McLaughlin and Lee, 2006 [23]	USA	1983 to 1987	< 25, 25–30, 30–34.9, ≥ 35	198	10 to 18
Bowditch and Villar, 1999 [24]	UK	Not mentioned	< 26, 25–30, > 30	82	< 1
Total				11,271	

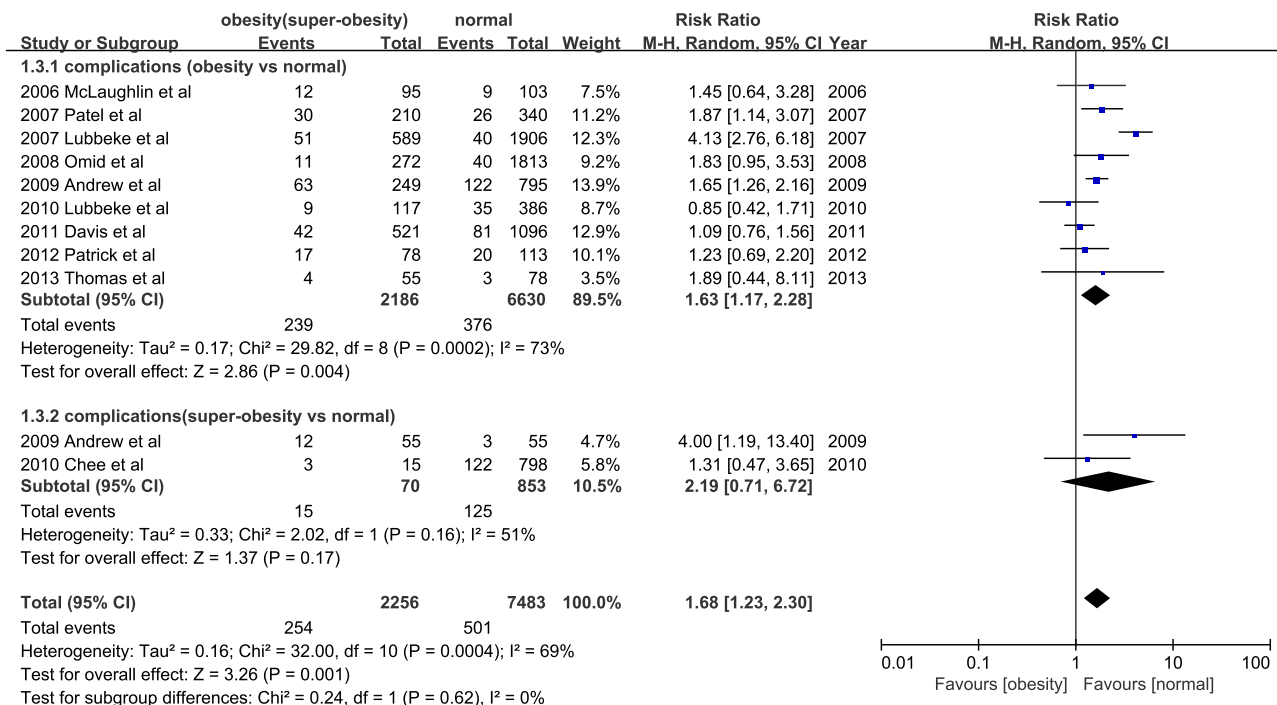


Fig. 2. Complications – Forest plot.

3.3. Overall complications

Ten articles reported overall complications. To be specific, the interested data of this outcome included major and minor complications (such as deep infection, dislocation, osteolysis, aseptic loosening et al, minor such as wound healing, hematoma, superficial infection et al). A random-effect model was employed in pooling the data about the overall complications, since high heterogeneity was observed among the 10 studies ($P=0.0004$, $I^2=69\%$). The calculated results demonstrated that obese patients had a significant higher complication rate than non-obese patients (RR: 1.68, 95% CI 1.23 to 2.30, $P=0.0004$) (Fig. 2). Besides, because of the relative high heterogeneity, we performed a sensitivity analysis. One included study [21] was found to strongly increase the heterogeneity, and the I^2 decreased from 69% to 12% when excluding this study [21], but the overall result didn't reverse (RR: 1.45, 95% CI 1.20 to 1.76, $P<0.0001$). As to the subgroup, 2 studies reported overall complications about super-obese patients, the pooled result didn't reveal negative influence of super-obesity on the complications (RR: 2.19, 95% CI 0.71 to 6.72, $P=0.17$) (Fig. 2).

3.4. Dislocations

Six included studies recorded the dislocation incidences. No significant heterogeneity was found for the overall dislocation analysis ($P=0.99$, $I^2=0\%$). The overall result for dislocation displayed a higher dislocation rate in obese patients than non-obese patients (RR: 2.08, 95% CI 1.54 to 2.81, $P<0.0001$). Contrast to the overall outcome, the subgroup result of super-obese patients didn't show a higher dislocation rate than non-obese patients (RR: 3.27, 95% CI 0.67 to 15.91, $P=0.14$), which probably resulted from the lack of power in the super-obese group (Fig. 3).

3.5. Deep infection and osteolysis

Meta-analysis for incidence of deep infection and osteolysis were performed using random-effect model ($P=0.10$, $I^2=52\%$) and

fixed-effected model ($P=0.35$, $I^2=4\%$) respectively. Overall result demonstrated that obese patient appeared to undergo a higher deep infection rate than non-obese patients (RR: 2.92, 95% CI 0.74 to 11.49, $P=0.13$) (Fig. 4), no significant difference was observed about the osteolysis (RR: 1.32, 95% CI 0.95 to 1.82, $P=0.09$) (Appendix A: Fig. A). A sensitivity analysis was done to the incidence of deep infection. Exclusion of the included study by McLaughlin and Lee [23], which had a relatively less patients than other studies [5,21] included in the analysis of deep infection, resolved the heterogeneity and reversed the results ($I^2=0\%$, RR = 5.06, 95% CI 2.46 to 10.43, $P<0.0001$).

3.6. Blood loss

Four studies were included for the analysis of blood loss. A random-effect model was employed owing to heterogeneity ($P=0.0003$, $I^2=84\%$). The obese patients bled more during the operation than non-obese patients (MD: 207.43, 95% CI 6.80 to 408.05, $P=0.04$) (Fig. 5). However, when exclusion of the study by Dienstknecht et al. [16], which was performed through minimal invasive surgical techniques compared to other included studies, the I^2 decreased from 84% to 0%. The MD changed from 207.43 to 315.49 ($I^2=0\%$, MD: 315.49, 95% CI 242.90 to 388.08).

3.7. Functional score

As to functional score, the data of Oxford Hip Score and Harris Hip Score were pooled. Only 2 studies were included for Oxford Hip Score, 6 studies for Harris Hip Score. A fixed-effect model was employed to Oxford Hip Score, the results demonstrated that no heterogeneity between the groups ($P=0.65$, $I^2=0\%$) and no difference was observed between the obese and non-obese patients on Oxford Hip Score (MD: -0.46 , 95% CI -2.18 to 1.26 , $P=0.60$) (Appendix A: Fig. B). However, the overall data for Harris Hip Score was pooled using the random-effect model ($P=0.02$, $I^2=60\%$), a slight lower Harris Hip Score was observed in the obese patients than non-obese groups (MD: -2.75 , 95% CI -4.77 to -0.6 , $P=0.07$)

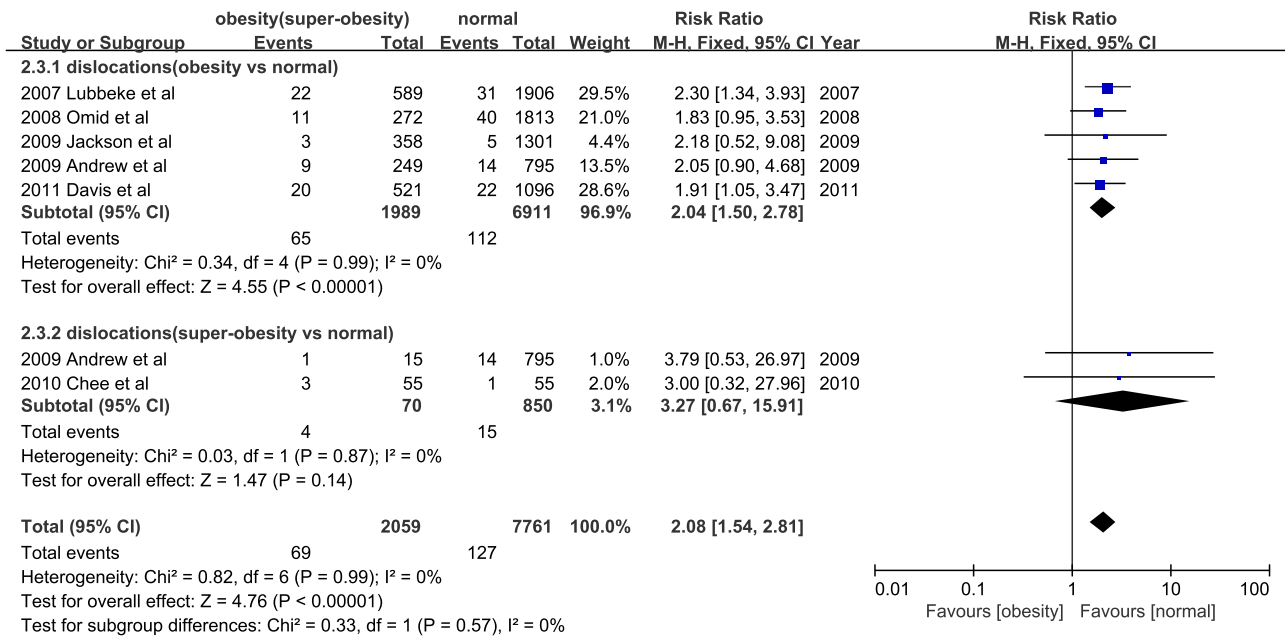


Fig. 3. Dislocations – Forest plot.

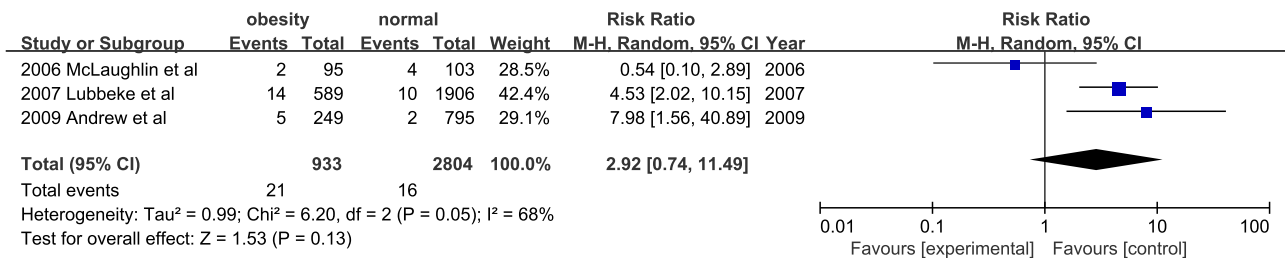


Fig. 4. Deep infection – Forest plot.

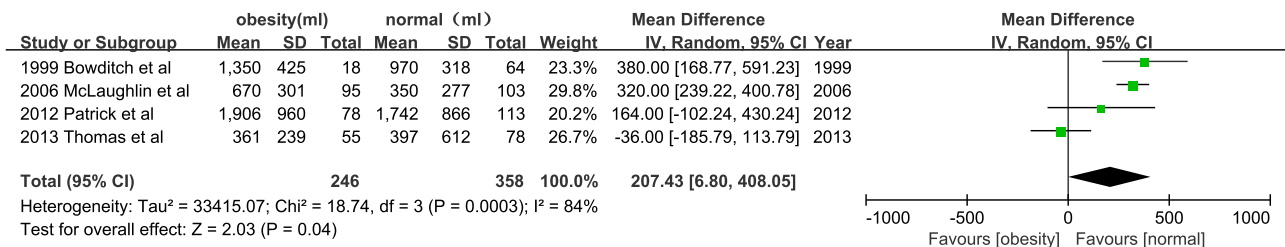


Fig. 5. Blood loss – Forest plot.

(Fig. 6). The heterogeneity couldn't be changed from high to low or moderate by exclusion of any single study. A relative lower Harris Hip Score was observed in the subgroup of super-obesity (MD: -6.74, 95% CI -10.66 to -2.82, P=0.0008).

3.8. Operative time

Seven articles were eligible for the data extraction of operative time. A random-effect model was used to pool the data owing to the heterogeneity (P<0.00001, I² = 87%). The overall pooled results of the 7 studies showed a significant difference between obese patients and non-obese patients (MD: 10.67, 95% CI 3.00 to 18.35, P=0.005) (Appendix A: Fig. C). Obese patients appeared to undergo a longer duration of operation. Sensitivity analysis revealed that exclusion of any single study didn't alter the high heterogeneity.

Regarding the subgroup of super-obesity, the pooled data exhibited a significant increase time of the operation for super-obese patients (MD: 37.59, 95% CI 22.99 to 52.19, P<0.0001).

3.9. Length of stay in hospital

Regarding the length of stay in hospital, there were 6 studies employed in the data analysis. The overall heterogeneity was not significant (P=0.12, I² = 12%), the pooled result was calculated using the fixed-effect model. In contrast to results mentioned above, the length of stay in hospital pooled data showed neither significant difference in the overall result nor the super-obesity group (respectively MD: -0.16, 95% CI -0.34 to 0.02, P=0.08, MD: -0.43, 95% CI -1.91 to 1.05, P=0.09) (Appendix A: Fig. D).

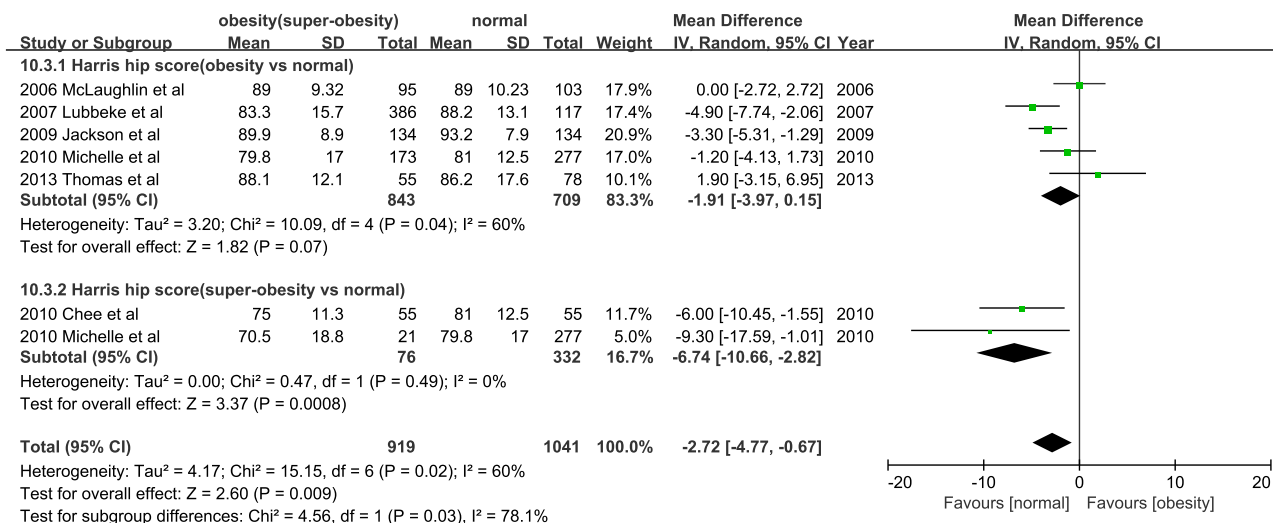


Fig. 6. Harris Hip Score – Forest plot.

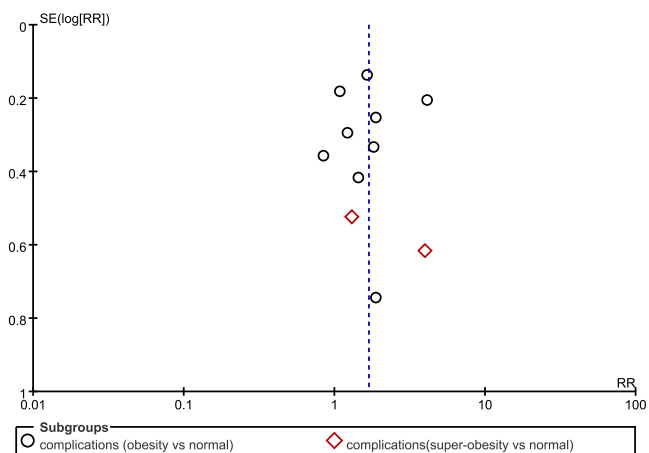


Fig. 7. Complications – Funnel plot.

3.10. Publication bias

The funnel plot of the overall complication rate was employed to evaluate publication bias. As the funnel plot showed, a mild asymmetry was exhibited which reflected a slight publication bias (Fig. 7). However, only 10 studies were included in the funnel plot, the result should be interpreted cautiously.

3.11. Quality assessment

The Newcastle Ottawa Scale (NOS) was used to assess the 15 eligible prospective studies. All the articles were scored according the three sections of NOS (selection, comparability and assessment of outcome). Finally, all the 15 studies were of high quality (meeting 5 or more NOS criteria) (Table 2).

4. Discussion

Obesity is on the rise, becoming a worldwide epidemic because of popularity in unhealthy diet and sedentary lifestyle. It is well known that obesity increases the likelihood of various diseases, particularly heart disease, diabetes, obstructive sleep apnea, certain types of cancer, and osteoarthritis in low limbs [26,27]. Obesity also draws the orthopedic community attention [28,29]. Some surgeons argued that obese patients seemed to suffer a longer

Table 2
Newcastle-Ottawa Scale for the included studies.

Study	Selection	Comparability	Exposure
Dienstknecht et al., 2013 [16]	※※※※	※※	※※
Raphael et al., 2013 [11]	※※※※	※	※※
Michalka et al., 2012 [4]	※※※※	※	※※
Davis et al., 2011 [17]	※※	※※	※※
Lubbeke et al., 2010 [18]	※※※※	※	※※
Chee et al., 2010 [13]	※※※	※※	※※
Downsey et al., 2010 [12]	※※	※	※※
Jackson et al., 2009 [25]	※※※※	※※	※※
Andrew et al., 2008 [5]	※※※	※	※※
Sadr Azodi et al., 2008 [19]	※※※	※	※※
Lubbeke et al., 2007 [21]	※※※※	※	※※
Kessler and Kafer, 2007 [22]	※※※※	※※	※※
Patel and Albrizio, 2007 [20]	※※※※	※	※
McLaughlin and Lee, 2006 [23]	※※※※	※	※※
Bowditch and Villar, 1999 [24]	※※※※	※	※

duration of operation and worse outcomes [30–32]. A meta-analysis and system review about the topic was published in 2011 [33], which included not only prospective studies but also retrospective studies, suggesting that obesity appeared to have a negative influence on the outcome of total hip replacement [33]. However, some recent prospective studies reported the controversial results [4,11,16]. Some studies argued that there is no difference in operative times, lengths of stay and complication rate between non-obese and obese patients [4,34,35]. A significant difference in the outcomes of THA was seen in other similar studies [5,11,35]. Some centers have already refused to perform THA for obese patients until a targeted body mass index (BMI) is obtained [6]. In order to clarify the influence of obesity on THA, we performed a meta-analysis of prospective cohort studies but not the retrospective studies for its latent bias. We included some new studies the former meta-analysis did not contain. We made cutoff points of BMI < 30, 30–40, > 40 kg/m². Studies which did not set a cutoff point of BMI > 30 were excluded in this meta-analysis. Finally, 15 studies were eligible for data analysis.

The current meta-analysis has limitations:

- though 15 prospective studies were included in the data extraction, not all of the studies allowed retrieval of pooling data for the defined outcomes. Ten studies were included in the data analysis of overall complications, which contained most studies among the interest of outcomes;
- the number of THA performed in the included studies varied from 50 to 2495, which may contribute to the outcomes bias and heterogeneity. Besides, the length of follow-up also ranged from 3 months to 18 years;
- some confounding factors (such as diabetes, denutrition, osteoporosis) that may affect the outcomes of THA were not adjusted in the included studies, which may influence the final results;
- we did try to contact the authors for some original data of some studies, no response was returned. Some data of the defined outcomes was unable to extract, resulting in missing for the data analysis.

Among the 15 included studies, only 4 had a cutoff point of BMI > 40, which resulted in relatively low power of the pooling data for super-obesity group. Furthermore, all the included studies did not contain the whole interested outcomes pooled in our studies. As to the overall complications, 10 studies were employed in analysis, 6 for Harris Hip Score, 7 for operative time, and 6 for length of stay in hospital. The confounding factors were adjusted in 5 included studies [13,16,17,22,25]. Obese patients were more likely to have comorbidity than non-obese patients, and the comorbidity may cause higher complication rate. So far, there was no evidence that obese patients without comorbidity had a lower risk of complications than the obese with comorbidity, which was also similar to the non-obese. Despite of the limitations, the whole 15 studies were in line with the inclusion criteria. We attentively reviewed and extracted data from the included studies, the main distinguished factor BMI was consistent in the included studies, all the patients underwent primary THA, and all the studies included were prospective. We demonstrated that the pooled results in our study were reliable.

The pooled result about the overall complications displayed that obese patients suffered higher complication rate than non-obese patients. To be specific, we also analyzed the incidence of dislocation, deep infection and osteolysis. Higher dislocation rate was found in the obese patients, which was in line with former studies [33,36]. The reasons of the higher complication rate in obese patients may focus on that patients with high weight owned a mass of adipose and muscle tissues, which may make the THA surgery more difficult and time-consuming, especially in the procedures of exposure and prosthesis insertion [37]. In addition, obese patients not only undergo more soft damage because of longer operative time but also have higher force on the prosthesis, which may increase the risk of early loosening, dislocation and prosthesis wear [36–39]. The difficulty of exposure, time-consuming operation, denutrition and micro-inflammation status (which is common in obese patients) [40–43] may enhance the possibility of contamination both in superficial and deep position. However, our result did not display a higher deep infection rate of obese patients, which may account for the powerless and heterogeneity of the included studies (Fig. 4).

For the functional score, the data of Oxford Hip Score and Harris Hip Score were extracted and pooled. No statically difference was observed between the obese and non-obese group regarding Oxford Hip Score. Contrast to Oxford Hip Score, obese patients addressed a minimal lower Harris Hip Score than non-obese patients. Six studies were included for analysis of Harris Hip Score, which was more powerful than Oxford Hip Score (2 studies included). Thus, we believed that the Harris Hip Score in the present study was more reliable for the functional score evaluation, obese

patients had a slightly lower subjective functional score than non-obese patients.

As for operative time, obese patients had a longer duration of operation than non-obese patients. The difficulty of operation exposure and prosthesis insertion may account for a longer duration of surgery in obese patients. On the contrary to operative time, there was no significant difference between obese and non-obese patients on length of stay in hospital. It was not surprising that the length of stay in hospital did not differ between the obese group and non-obese group, because patients in medical centers were usually admitted in the standard clinical pathway, all patients who underwent THA would go through the standard procedures from admission to discharge. Unless some major complications happened during hospitalization, the long of stay in hospital was similar between the obese and non-obese patients.

5. Conclusions

To our knowledge, this is the first meta-analysis and systematic review of prospective studies on the influence of obesity on primary THA. Fifteen prospective studies were included for this meta-analysis. The results suggest that obesity has a negative influence on the complication rate (incidence of dislocation), functional outcome and operative time of primary total hip arthroplasty.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.otsr.2015.01.011](https://doi.org/10.1016/j.otsr.2015.01.011).

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