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Obesity does not impact complications and conversion to total knee arthroplasty after high tibial osteotomy: A systematic review

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Abstract

Purpose: The purpose of this systematic review is to consolidate outcomes of obese patients undergoing high tibial osteotomy and to investigate the effect of obesity on postoperative outcomes, including symptomatic relief and time to conversion to arthroplasty.

Methods: Medline, Embase and Cochrane Library were searched from database inception up to April 2023 according to PRISMA guidelines by two reviewers. Search terms including 'obesity', 'BMI', 'osteotomy' and 'high tibial osteotomy (HTO)' were included to identify all relevant articles. Only studies that explicitly reported outcomes for obese patients were included. Disagreements in study inclusion or quality assessment were resolved by a senior third reviewer. Metrics compared include time to arthroplasty, preoperative and postoperative mechanical tibiofemoral angle (mTFA), patient-reported satisfaction scores and postoperative complications.

Results: Nine studies comparing 973 patients were included. The mean age was 52.7 ± 4.2 years old and 38.4% were male. Six studies performed the medial opening-wedge HTO, and three utilized the medial wedge closing technique. Most studies indicated significant improvement following surgical intervention with satisfactory outcomes in obese and nonobese patients. In addition, differences in complication rates were minimal between obese and nonobese patients (n.s.), while functional scores did not vary significantly. Conversion to total knee arthroplasty was not found to increase in obese patients (n.s.).

Conclusion: Obesity does not appear to carry a greater complication risk or worse outcomes following high tibial osteotomies, and surgeons should consider HTO a viable option for young obese patients with symptomatic unicompartmental chondral wear with coronal limb malalignment.

Level of Evidence: Level IV.

Abbreviations: BMI, body mass index; CI, confidence interval; CW-HTO, closed-wedge high tibial osteotomy; DTT-HTO, distal tibial tuberosity high tibial osteotomy; HSS, hospital for special surgery; HTO, high tibial osteotomy; ICC, interclass correlation coefficient; KSS, knee society score; MINORS, methodological index for non-randomized studies; mTFA, mechanical tibiofemoral angle; NS, not significant; OA, osteoarthritis; OKS, Oxford knee score; OW-HTO, opening wedge high tibial osteotomy; PRISMA, preferred reported items for systematic reviews and meta-analyses; PROMs, patient reported outcome measures; SD, standard deviation; SMD, standardized mean difference; SPSS, Statistical Package for the Social Sciences; TKA, total knee arthroplasty; WOMAC, Western Ontario and McMaster Universities.

KEYWORDS
high tibial osteotomy, HTO, knee, obesity, osteoarthritis

INTRODUCTION

High tibial osteotomy (HTO) is an operative option that can provide symptomatic relief and delay the progression of early-onset knee osteoarthritis (OA) in patients with unicompartmental disease. HTO is utilized to correct coronal misalignment and restore neutral biomechanics of the knee [7, 19]. However, patient selection for HTO remains dependent on specific patient criteria, such as age, gender, body mass index (BMI) and preoperative varus angles and has been utilized primarily in young, active, nonobese patients with isolated medial compartmental OA [7, 19].

While studies have shown that obesity (BMI > 30 kg/m^2) may be associated with inferior outcomes after HTO, with several reporting postoperative complication rates up to 10 times higher in obese patients [2, 8], it is unclear if obesity should be a strict contraindication to HTO and what effect it has on outcomes across multiple studies [8]. With the increasing incidence of obesity worldwide, determining its influence on outcomes will lend itself to improving decision-making regarding appropriate surgical interventions for this patient population.

The purpose of this study is to perform a systematic review investigating the effect of patient obesity on HTO surgical outcomes and complication rates. While the role of obesity has been previously investigated for orthopaedic operations [8], there has not been a systematic review that specifically investigates obesity's impact on HTO outcomes. Investigating whether obesity impacts surgical outcomes will allow surgeons to better consider the suitability of obese patients for HTO operations. It was hypothesized that obese patients would have worse long-term outcomes in patient-reported outcome measures (PROMs), higher rates of complications and greater percentages of patients requiring revision to total knee arthroplasty (TKA) following HTO than nonobese patients.

METHODS

This review was performed according to the PRISMA guidelines for reporting systematic reviews.

Search strategy

Prior to beginning the literature search, a search protocol was created and published online at the PROSPERO International Prospective Register of Systematic Reviews (CRD42023418155). A search strategy was used to query three electronic databases: Medline, Embase and Cochrane Library from database inception until April 2023. The search strategy aimed to identify all studies that investigated the role of BMI in HTO outcomes, and the reference lists of selected articles were also screened to identify other relevant studies. Search terms including 'obesity', 'BMI', 'osteotomy' and 'HTO' were included to identify all relevant articles. The exact search strategy can be sourced in the supplement (Appendix 1). There was no restriction on years of publication. Inclusion criteria were as follows: (1) primary studies of high tibial osteotomies in humans (level of evidence I–IV), (2) published in a peer-reviewed journal, (3) full text available and (4) published in English. Exclusion criteria were (1) less than 6-month average follow-up, (2) lack of differentiation between obese and nonobese patient groups and (3) lack of clinically reported outcomes.

Eligibility and study selection

Titles, abstracts and full text of retrieved studies were screened by two reviewers (C. H. and F. N.) following the establishment of search criteria. Disagreements at the title and abstract stages were automatically included. Full-text evaluation was independently performed by two reviewers who selected relevant studies based on pre-determined selection criteria. Full-text stage discrepancies were resolved by reaching a consensus between reviewers. If an agreement could not be reached regarding inclusion, the discrepancy was resolved by a third senior reviewer (C. C.). In addition, relevant reference lists of included studies were analysed to add articles that had not yet been reviewed. Inclusion criteria were as follows: patients who have undergone an HTO to treat medial compartment OA of any severity reported BMI of included patients, the inclusion of any reported patient outcome measure or biomechanical outcome, and written in the English language. Only studies that explicitly reported outcomes for obese patients were included. A PRISMA flowchart of the search strategy is illustrated in Figure 1. After screening and full-text evaluation, nine studies were included (Figure 1).

Three primary outcomes were analysed: PROMs, postoperative complications and conversion to TKA. The PROMs for knee function included the following: Knee society score, Lysholm knee score, Oxford knee score (OKS), hospital for special surgery (HSS) knee score and the Western Ontario and McMaster Universities (WOMAC) OA index. All postoperative and

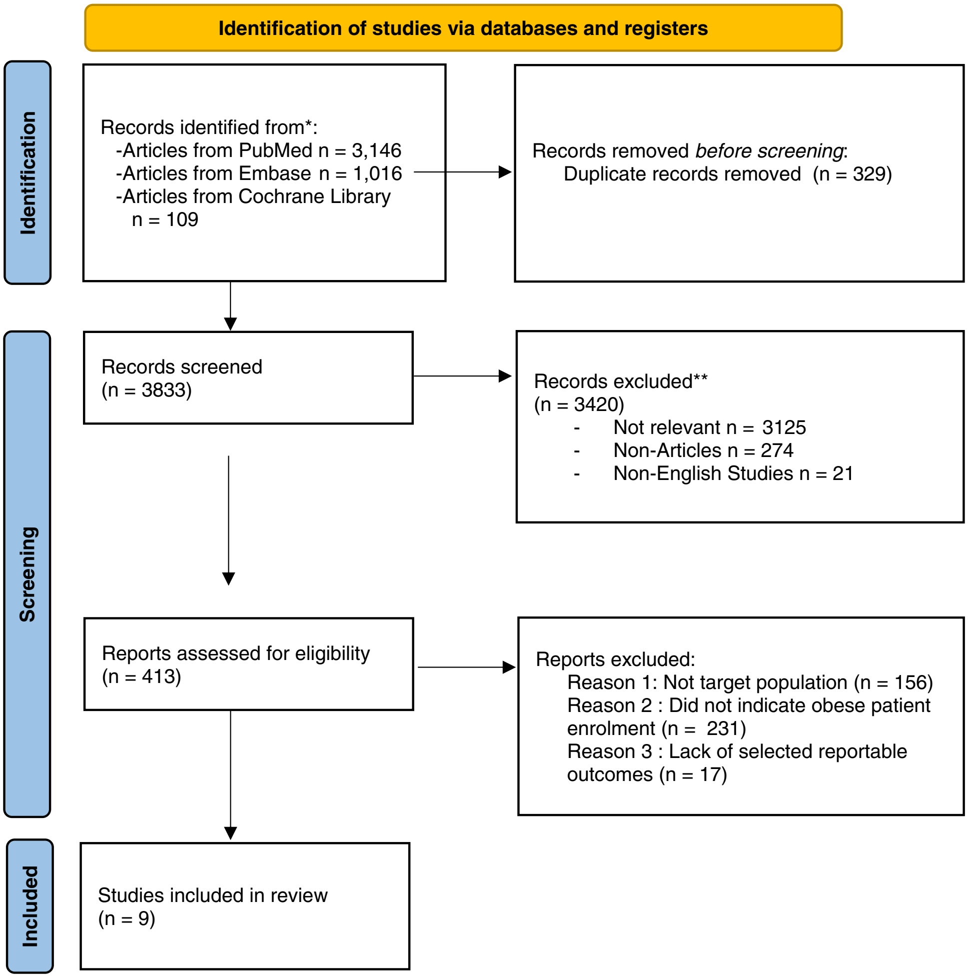

FIGURE 1 PRISMA flow diagram demonstrating the selection process of the nine included studies that investigated differences in high tibial osteotomy (HTO) outcomes between obese and nonobese patients.

surgical complications were included, along with the incidence and timeline of conversion to TKA. Secondary outcomes compiled included mechanical tibiofemoral angle (mTFA) angle, operative angle correction and osteoarthritic grading.

Data extraction

Data was extracted from the included studies by two authors (C. H. and F. N.). These data were cross-checked, and incongruencies were discussed and reviewed by the two reviewers discussed. The following data were extracted: (1) study information: author, publication year, country, study design, level of evidence; (2) follow-up period; (3) study population: number of participants, sex, BMI and age; (4) surgical technique (medial opening- or lateral closing wedge), knee operated on; (5) results of primary and secondary outcome measures: clinical outcomes, radiographic outcomes and mechanical outcomes; (6) complications reported. Authors were contacted if data were missing. Data that was only available in graphs were read off the graphs.

Quality assessment

The methodological quality assessment was independently conducted by two authors using SPSS version 23 (SPSS Inc.). The included studies were assessed by two authors (C. H. and F.N.) using interclass correlation coefficient (ICC) with 95% confidence intervals (CI). The Methodological Index for Non-Randomized Studies (MINORS) tool was used for quality assessment [25]. ICC scores were based on previously published standards [16]. Full-text peer-reviewed studies of all included studies were obtained and graded according to a 'levels of evidence' rating (Table 1) [30]. Each of the included studies was reviewed by each of the authors independently and assigned a level of evidence. If there was disagreement on the level assigned to a paper, this was discussed with the senior author (A. C.) and resolved.

TABLE 1 Pertinent data about the papers eligible for inclusion in this systematic review.

Author	Year	Type of study	Comparison type	Mean MINORS score	Level of evidence	Study quality
Can [3]	2018	Retrospective	Noncomparative	11	III	Moderate
Floerkemeier [8]	2013	Multicenter	Comparative	15	II	Moderate
Huang [13]	2022	Retrospective	Noncomparative	10	III	Moderate
Herbst [11]	2021	Prospective	Comparative	15	III	Moderate
Howells [12]	2014	Prospective	Noncomparative	10	II	Moderate
Majeed [17]	2020	Prospective observational	Noncomparative	9	II	Moderate
Siboni [24]	2018	Prospective cohort	Noncomparative	9.5	II	Moderate
Tuhanioğlu [28]	2018	Prospective	Noncomparative	9	II	Moderate
Wu [31]	2023	Retrospective cohort	Comparative	13.5	III	Poor

Abbreviation: MINORS, methodological index for non-randomized studies.

TABLE 2 Patient demographics and surgical data.

Author	Total patients	Obese patients (BMI >30)	Number of obese males (%)	Number of obese females (%)	Mean age	Mean BMI (kg/m^2)	Mean follow-up (years)
Can [3]	138	65	-	-	53.0	28.5	8.0
Floerkemeier [8]	386	79	-	-	49.0	27.2	3.6
Huang [13]	34	34	9 (26.5)	25 (73.5)	64.0	34.6	1.9
Herbst [11]	85	30	22 (73.0)	8 (27.0)	54.6	28.6	6.7
Howells [12]	95	34	-	-	50.0	-	10.0
Majeed [17]	53	-	-	-	55.2	28.1	6.0
Siboni [24]	41	17	-	-	59.0	30.3	0.5
Tuhanioğlu [28]	18	18	5 (27.8)	13 (72.2)	53.1	36.4	2.6
Wu [31]	123	36	14 (38.9)	22 (61.1)	58.6	32.7	2.0
Average	108	39	13 (41.6)	17 (58.5)	52.7	29.0	4.8

Abbreviation: BMI, body mass index.

Statistical analysis

Patient demographics were analysed using descriptive statistics. For continuous variables, the mean difference and standard deviations (SD) were calculated. The selected data from studies describing knee function scores, pain scores, conversion to TKA, osteoarthritic grading and mechanical angles were pooled. If SD was not reported or obtainable through study data, the SD was calculated based on utilizing the range rule that the SD of a sample is approximated by one-fourth of the maximum value minus the minimum value (range). To calculate the SD of the mean difference, the formula from the Cochrane Handbook (Sect. 16.1.3.2) with a correlation of 0.5 was used. For conversion to TKA, studies describing conversion to TKA were pooled.

Primary outcome measures were the determination of statistical risk factors comparing BMI among patients. Studies that measured qualitative rather than quantitative data were included for discussion purposes but were not included in the pooled means data set. For data measurement, the standardized mean difference with a 95% CI was pooled using SPSS (Statistical Package for the Social Sciences) (IBM SPSS Statistics for Mac; Version 28.0.: IBM Corp.).

RESULTS

Methodological quality

Included papers are denoted with the mean MINORS score, level of evidence and study quality (Table 1).

Study characteristics

The initial search yielded 336 studies, of which nine met the inclusion criteria for this review. The nine included studies were published between 2013

TABLE 3 Radiographic data from included studies.

Author	Operation	BMI/group	Pre-op mTFA	Post-op mTFA	Correction	Pre-op OA grade (I/II/III/IV)
Majeed [17]	CW-HTO and OW-HTO	Total	-	-	7.1	-
Wu [31]	OW-HTO	BMI < 25	189 ± 2.6	176 ± 2.7	-	0/0/24/12
		25–30	189.3 ± 2.9	176.9 ± 2.6	-	0/0/41/18
		30	190.2 ± 3.2	176.3 ± 3.5	-	0/0/23/5
Can [3]	CW-HTO	Obese	184.5 ± 4.6	176.5 ± 3.9	-	-
		Nonobese	185.3 ± 3.9	176.7 ± 3.6	-	-
Herbst [11]	OW-HTO	Total	184.9 ± 2.2	179.6 ± 2.6	6.9 ± 3.2	-
		Obese	184.7 ± 2.1	179.3 ± 2.7	7.3 ± 3.8	-
		25–30	184.9 ± 2.1	180.0 ± 2.6	6.3 ± 2.9	-
		<25	185.3 ± 2.6	179.0 ± 2.3	7.5 ± 0.8	-
Huang [13]	DTT-HTO	>30	181.7 ± 1.7	171.3 ± 1.5	-	0/15/11/8
Tuhanioglu [28]	OW-HTO	>30	190.4 ± 2.2	181.4	-	0/3/11/4
Siboni [24]	OW-HTO	Total	-	182.9 ± 2.5	10.7 ± 2.7	-
Howells [12]	CW-HTO	Total	186.0 ± 3.4	-	-	-

Abbreviations: BMI, body mass index; HTO, high tibial osteotomy; mTFA, mechanical tibiofemoral angle.

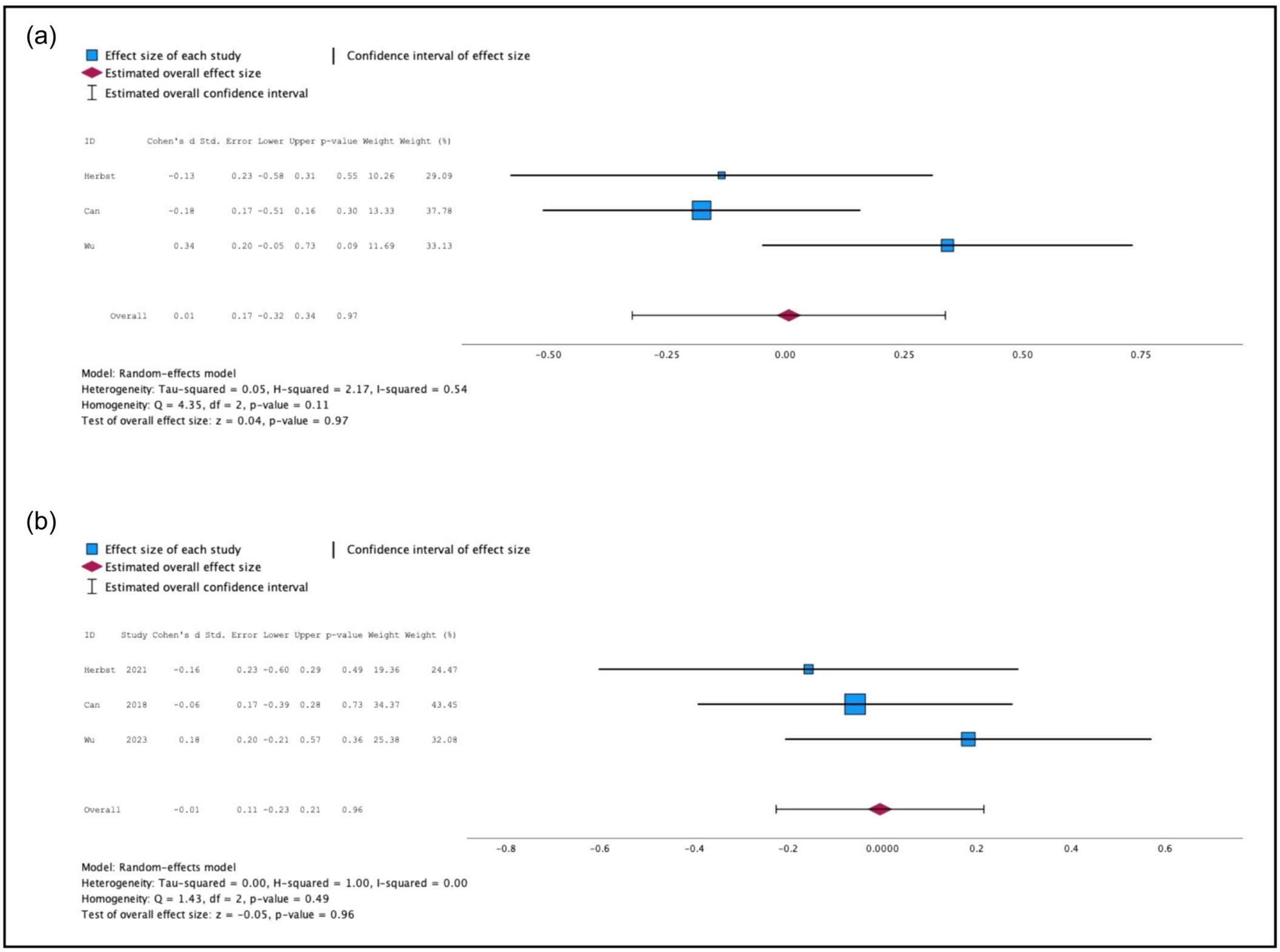

FIGURE 2 Forest plots measuring the (a) preoperative and (b) final postoperative mechanical tibiofemoral angle.

and 2023 and consisted of 973 patients who underwent HTO with a median 3.6-year follow-up (range: 0.5−10 years). The mean age was 52.7 ± 4.2 years and 38.4% were male (Table 2).

Radiographic outcomes

Three of the included studies utilized osteoarthritic grading scales (Table 3). Two of the studies only included obese patients, while the others also included nonobese patients. The presurgical angle was not significantly different (n.s.) among obese and nonobese patients (Figure 2a). The final follow-up angle (minimum of 2 years) was also not significantly different among the two groups (Figure 2b). All included studies showed significance between preoperative and final follow-up mTFA angle.

Patient reported outcomes

All but one study included at least one PROM score (Table 4). There was no significant difference between obese and nonobese patient WOMAC scores (Figure 3a) (n.s.), HSS scores (Figure 3b) (n.s.) or OKS scores (Figure 3c) (n.s.). These statistics were evaluated at various time points postoperatively (18, 24 and 72 months, respectively).

Conversion to TKA

Of the 973 patients included in this review, 30 underwent conversion to TKA within 10 years (Table 5). Notably, many studies did not have a follow-up interval where TKA conversion would be likely. There was no significant difference in revision rates at 6 years between obese and nonobese patients (Figure 4) (n.s.).

Complications

Ninety-eight total complications were noted among the nine studies, accounting for a complication rate of 11% (range: 5.9%−22%) (Table 6). When provided, it was indicated whether the compilation occurred in obese patients. No significant difference was found between the incidence of complications in obese and nonobese patients (Figure 5) (n.s.).

TABLE 4 Patient reported data from included studies.

Author	Operation	BMI/group	Final HSS score	Final WOMAC score	Final LKS	Final OKS
Majeed [17]	CW-HTO and OW-HTO	Total	-	-	77.81	-
Wu [31]	OW-HTO	<25	-	83.0 ± 18.8 (2 years)	-	-
		25−30	-	85.3 ± 14.8 (2 years)	-	-
		30	-	79.9 ± 14.6 (2 years)	-	-
Can [3]	CW-HTO	<30	75.3 ± 10.8	-	84.5 ± 11.3	-
		>30	76.9 ± 10.6	-	87.3 ± 9.8	-
Herbst [11]	OW-HTO	Total	88.5 ± 11.8	-	-	39.7 ± 9.1
		<25	90.6 ± 9.2	-	-	41.5 ± 8.2
		25−30	90.0 ± 12.4	-	-	39.0 ± 9.4
		30	85.2 ± 12.2	-	-	39.5 ± 9.3
Huang [13]	DTT-HTO		86.1 ± 2.8	-	-	-
Tuhanioglu [28]	OW-HTO		-	-	-	-
Floerkemeier [8]	OW-HTO	<25	-	-	-	41.5 ± 7.2
		25−30	-	-	-	40.1 ± 8.6
		>30	-	-	-	37.5 ± 9.1
Howells [12]	CW-HTO	<30	-	86 ± 14	-	-
		>30	-	80 ± 16	-	-

Abbreviations: BMI, body mass index; HSS, hospital for special surgery; HTO, high tibial osteotomy; OKS, Oxford knee score; WOMAC, Western Ontario and McMaster Universities.

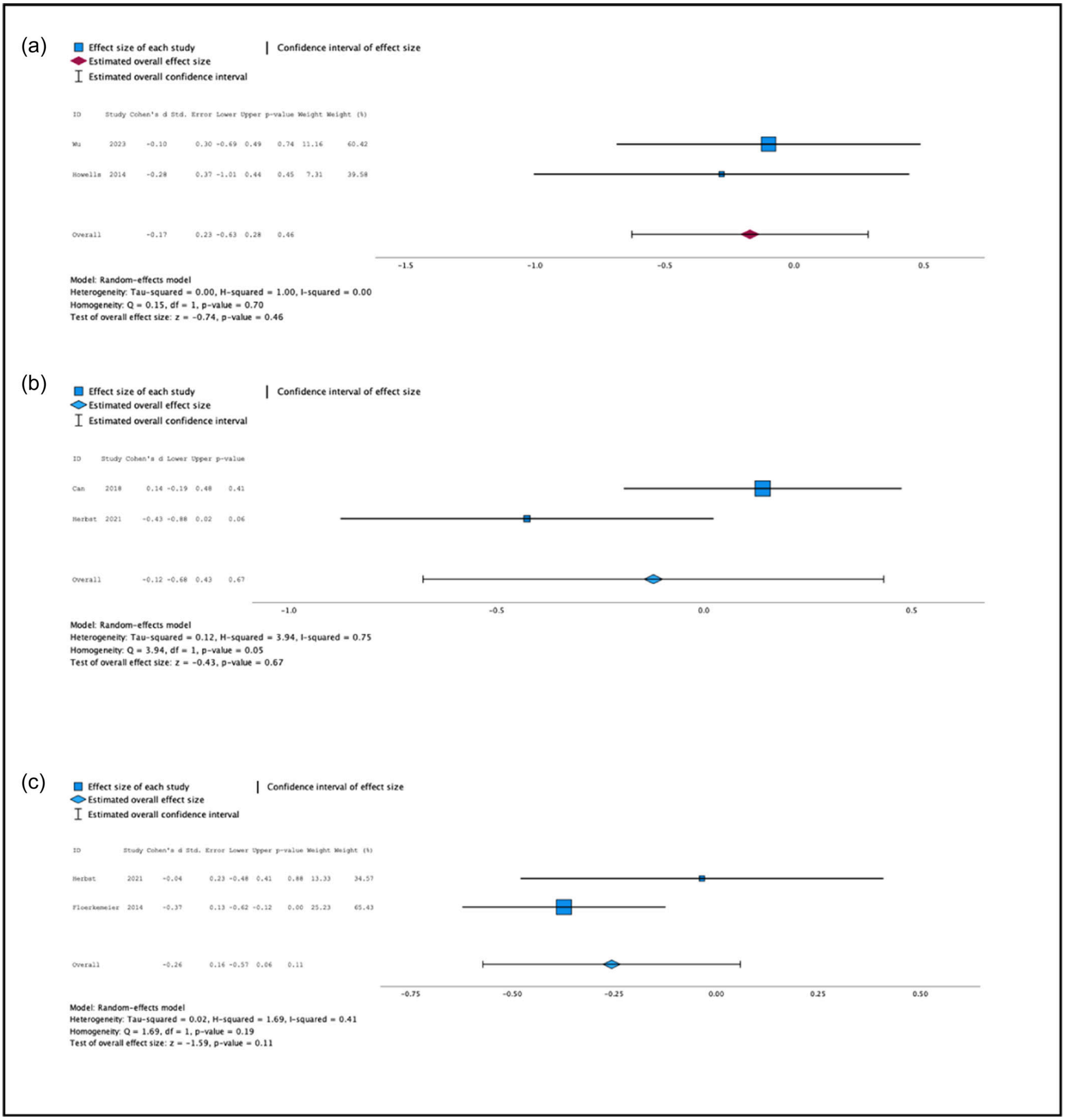

FIGURE 3 Forest plots measuring: (a) Western Ontario and McMaster Universities arthritis index (WOMAC) at 2 years follow-up, (b) hospital for special surgery knee score (HSS) at 6 years follow-up and (c) Oxford knee score (OKS) at 18 months follow-up.

DISCUSSION

The most important finding of this systematic review was that obesity did not appear to be associated with increased complications or worsened patient-reported outcomes after HTO. Furthermore, tibiofemoral mechanical angles and incidence of surgical complications were not significantly affected by patient obesity status. These findings were valid for both closing wedge and opening wedge procedures, as seen in recent studies [29]; however, the sample size for closing wedge was limited. Overall, most PROMs did not vary significantly between obese and nonobese patient groups. Furthermore, delineation of patients between an 'overweight' group with a BMI of 25–30 versus 'obese' (BMI > 30) did not significantly alter these results. All studies included in the review showed

TABLE 5 Revision outcomes.

Author	Operation	BMI/ group	# of patients	Number of revisions	Time to conversion (months)	Mean follow-up (months)
Wu [31]	OW-HTO	Total	123	0 (0%)	None	24
Herbst [11]	OW-HTO	Total	85	9 (10.6%)	50.1 ± 25.0	72
		Obese	30	4 (13.3%)	48.3	-
		25–30	37	3 (8.1%)	49.7	-
		<25	18	2 (11.1%)	57.0	-
Floerkemeier [8]	OW-HTO	<25	111	1 (1.0%)	-	43
		25–30	191	-	-	-
		>30	79	-	-	-
Howells [12]	CW-HTO	<30	61	6 (9.8%) at 5 years, 10 (16.4%) at 10 years	-	120
		>30	34	6 (17.6%) at 5 years, 10 (29.4%) at 10 years	-	-

Abbreviations: BMI, body mass index; HTO, high tibial osteotomy.

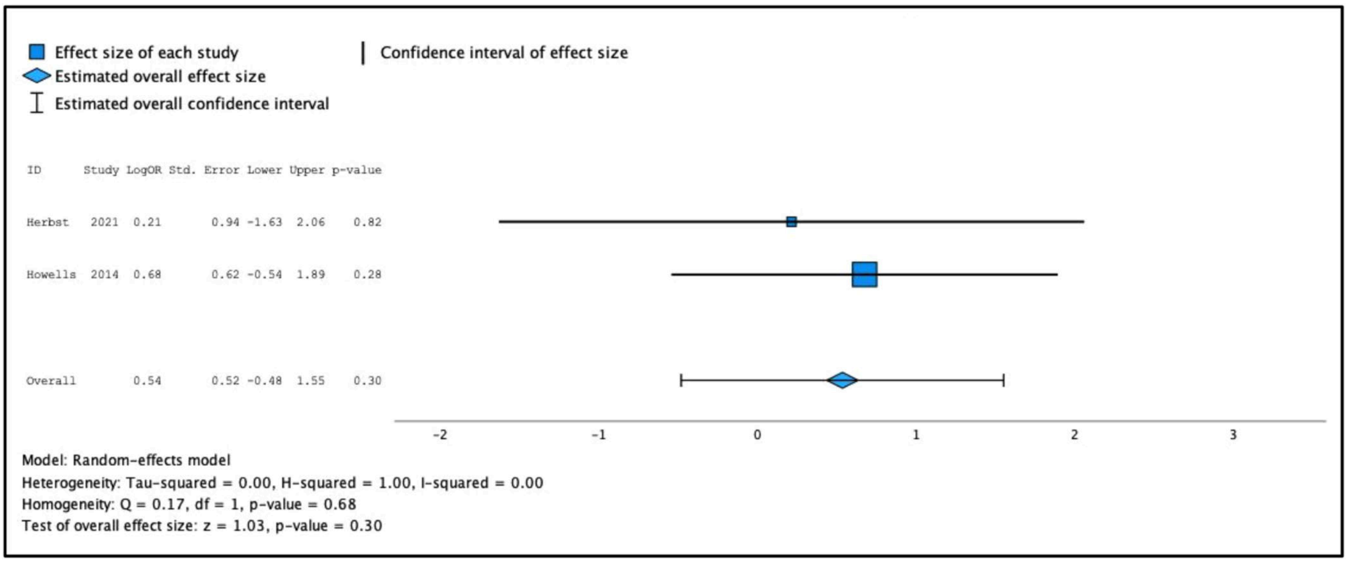

FIGURE 4 Forest plot measuring revision rate to total knee arthroplasty (TKA) at 6 years.

significant differences between preoperative and postoperative PROMs.

These improvements also appeared consistent over time, as studies show significant improvements from within 2 years [13] to up to 10 years postoperatively [12]. These findings align with previous work [18, 26], showing a significant increase in long-term PROM scores regardless of BMI status; however, these improvements may deteriorate faster for patients with risk factors such as older age at the time of surgery, female gender and higher BMI. Although BMI has been implicated as a risk factor for a faster decline in PROM scores previously [21], this study's results did not reflect this, even with a limited long-term sample size. The similarities in improvement in PROMs in obese and nonobese patients may demonstrate that obese patients can significantly benefit from these procedures.

TABLE 6 Reported complications.

Author	Operation	BMI/ group	Patients	Total	
Majeed [17]	CW-HTO and OW-HTO	Total	53	5	Implant site pain
Wu [31]	OW-HTO	<25	28	2	One donor site morbidity, one soft tissue irritation
		25–30	59	9	Three donor site morbidity, two soft tissue irritation, three wound infections, one nonunion
		>30	36	1	One soft tissue irritation
Can [3]	CW-HTO	>30	65	11	Five infection, four delayed union, two nerve palsy
		<30	73		
Herbst [11]	OW-HTO	Total	85	5	One haematoma, four surgical site infections
		>30	30	2	
		25–30	37	2	
		<25	18	1	
Huang [13]	DTT-HTO	>30	34	2	Impaired wound healing
Tuhanioglu [28]	OW-HTO	>30	18	4	One plateau fracture, one broken screw, two superficial infections
Siboni [24]	OW-HTO	Total	41	5	Five union, all obese
Howells [12]	CW-HTO	Total	95	8	One pulmonary embolus, two superficial wound infections, three delayed union, one nonunion, one nerve palsy
Floerkemeier [8]	OW-HTO	Total	533	32	One implant breakage, 8 pseudo arthrosis, 11 haematoma, 11 infection, 3 infected haematoma, 2 impaired wound healing, 3 other soft tissue, 1 thromboembolic complication

Abbreviations: BMI, body mass index; HTO, high tibial osteotomy.

Another critical factor to consider was the time to conversion to TKA. It is anticipated that the vast majority of patients undergoing HTO will eventually undergo conversion to TKA [5], so longevity and time to conversion from HTO to arthroplasty are important. There is disagreement in the existing literature as to whether survivorship of HTO in obese vs. nonobese patients differs before conversion to TKA [11, 12]. In our analysis, pooled results also did not show a significant difference, but it is notable that obese patients have been shown to have a faster onset to conversion in some studies [23]. Therefore, clinicians should consider the possibility of a shorter lifespan before TKA conversion when deciding on suitability for HTO for obese patients. A thorough consideration of the patient's age, activity level and likely timeline for TKA should be a part of operative discussions to determine if HTO is an appropriate choice.

While obesity has also been implicated in many studies as being associated with higher rates of surgical complications [22, 27], obese patients in this review did not have a higher rate of postoperative complications. These findings align with similar studies that investigated HTO complication rates, which determined the rate of postsurgical complications is not higher in obese patients [10, 14]. This suggests that patients with increased BMIs do not appear to be at greater risk of postoperative complications, and they should not be disqualified due to obesity alone. However, a lack of specific investigation into morbid obesity's (BMI > 40) effect on complications is acknowledged by the authors, and orthopaedic surgeons should exhibit caution when treating these patients.

Correction angle has previously been identified as a critical indicator of surgical outcome [15]. This study

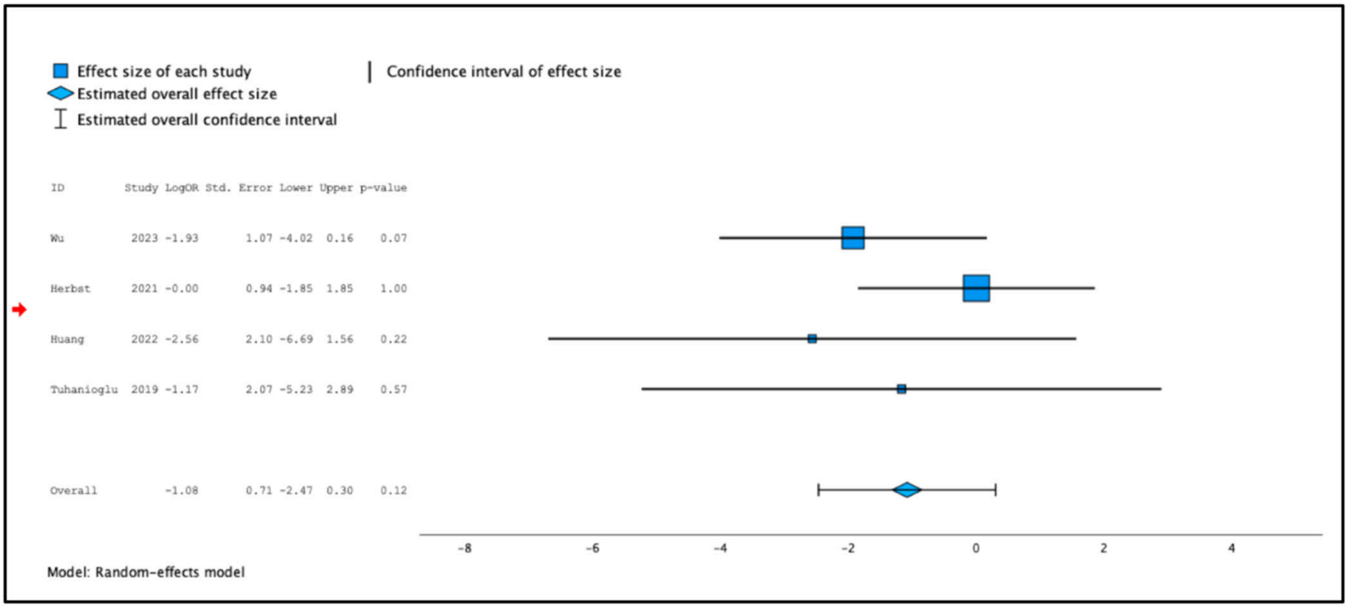

FIGURE 5 Forest plot measuring complication rates between obese and nonobese patients.

included OW-HTOs and CW-HTOs, which have shown mixed results regarding long-term survival and correction [4, 6], but did not differ in the studies included in this review. Compared to nonobese patients, obese patients' preoperative, operative correction and final follow-up angles did not differ significantly. While the potential loss of postoperative correction in obese patients has been previously investigated, this phenomenon was not seen in this review [11, 12, 17].

The effect of obesity on other procedures to address medial knee OA, such as unicompartmental knee arthroplasty and TKA, have been investigated with mixed results [1, 20]. Regarding the studies included in this systematic review, the lack of significant difference in outcomes for obese patients undergoing HTO may be due to patient selection. Patients who are considered good candidates for an HTO are generally younger and more active [9], which may positively influence outcomes. While some recent studies have shown worse outcomes for obese patients in unicompartmental knee arthroplasty [32], obesity should be considered as one of multiple factors in determining operative suitability rather than an absolute contraindication.

A strength of this study is that multiple studies and a large number of patients were pooled to directly investigate the role obesity plays in outcomes after HTO. Given the more comprehensive evidence on HTO outcomes in obese patients, this provides data for surgical decision-making and enables surgeons to serve patients more effectively. Another strength is the ability to consider multiple factors, including PROMs, operative complications and survival rates.

This investigation is not without limitations. The primary limitation of this article was the lack of randomized controlled trials or comparative studies. While this would have decreased additional bias, no such studies were available for inclusion. Despite other studies including obese patients, few could be used due to the inaccessibility of data or lack of comparable outcomes. However, the strict inclusion criteria for direct comparison of outcomes only strengthens the conclusions. Other limitations are inherent to systematic reviews, in that they are limited by the quality of the available literature; studies had inconsistent follow-up time points, and few articles had adequate length of follow-up to truly determine implant survivorship and long-term PROMs. Obesity is also only one patient characteristic that can potentially affect outcomes and is often correlated with other health conditions. Despite the limitations, this study provides a valuable resource for clinicians managing obese patients with symptomatic joint degeneration and coronal malalignment and helps to inform the surgical discussion regarding postoperative expectations. Overall, there is a need for additional long-term studies directly comparing outcomes between obese and nonobese populations due to the varying conclusions presented among the included studies.

CONCLUSIONS

Obesity does not appear to carry a greater complication risk or worse outcomes following high tibial osteotomies, and surgeons should consider HTO a viable option for young obese patients with symptomatic unicompartmental chondral wear with coronal limb malalignment.

AUTHOR CONTRIBUTIONS

All authors involved contributed to the design, implementation of the research and to the analysis of the results as well as the writing of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS STATEMENT

This study does not involve human subject research.

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APPENDIX 1

The search strategy was as follows:

1. Osteotomy[tiab] or 'high tibial osteotomy' or 'HTO' or 'MWHTO' or 'OWHTO'
2. Osteotomy[mesh]
3. #1 or #2
4. Obesity [mesh]
5. Obesity [tiab]
6. #4 or #5
7. BMI [mesh]
8. BMI [tiab]
9. #7 or #8
10. Body mass index [mesh]
11. Body mass index [tiab]
12. #10 or #11
13. Weight
14. Weight
15. #13 or #14
16. #6 OR #9 OR #12 OR #15
17. #3 AND #16