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The effect of postoperative femoral offset on outcomes after hip arthroplasty: A systematic review☆

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ABSTRACT

The purpose of this systematic review was to analyze the effect of decreased, restored, or increased femoral offset on patient reported outcomes (PROs) following hip arthroplasty. Databases were searched according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. With regard to Harris Hip Score, two studies reported superior outcomes for the increased femoral offset group, one study reported superior outcomes for a restored offset group, and the final study reported favorable outcomes for the decreased offset group. Patients with restored offset following arthroplasty may demonstrate superior PROs.

1. Introduction

Soft-tissue tension following hip arthroplasty has been shown to have an effect on patient reported outcomes.[1–8] Femoral offset (FO), defined as the distance between the center of the femoral head and the anatomical axis of the femur, affects soft-tissue tension following arthroplasty.[1,9] Multiple variables such as the design of the implant, the diameter of the head, and the positioning of the stem within the femoral canal, can influence postoperative femoral offset.[1,9] Current literature shows that restoration of optimal FO improves the abductor lever arm and results in increased survivorship, as well as reduced implant wear in total hip arthroplasty (THA).[8,10,11] Lack of restoration can lead to a host of complications including loss of abductor tension, prosthetic joint dislocations, gait disturbances, increased edge loading on the acetabular component, and polyethylene wear.[1–3,5–7] Excessive FO can increase tension on the abductor muscles, which may result in pain, reduced function, and increased polyethylene wear.[12,13] In order to help navigate offset restoration, implant components with varying degrees of offset combinations have been devised. Likewise, multiple reports have commented on outcomes of THA at varying femoral offset.[2,14] The purpose of this systematic review was to analyze the effect of decreased, restored, or increased femoral offset on patient reported outcomes (PROs) following hip arthroplasty. Our hypothesis was that patients with increased femoral offset would demonstrate superior outcomes.

2. Methods

In March 2019, we performed a comprehensive literature search using the PubMed, Embase, and Cochrane databases to identify articles that examined the relationship between femoral offset and functional outcomes following hip arthroplasty. The search followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines[15] and utilized the following key words: arthroplasty, femoral offset, patient reported outcomes. The exact search algorithm is provided in the Appendix.

After conducting an initial abstract review, two reviewers (XXX and YYY) examined the full text to select relevant studies. In any cases of disagreement, a third reviewer (ZZZ) helped the group reach consensus. Studies were included in our analysis if they reported (1) preoperative or postoperative femoral offset following arthroplasty and (2) minimum one-year patient reported outcomes. Exclusion criteria were case series, technique articles, studies with less than one-year follow-up, and studies not published in the English language.

☆ This study was performed at the American Hip Institute Research Institute.

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When available, we reported patient demographics, mean follow-up time, type of replacement, preoperative offset discrepancy, postoperative offset, physical examination findings, native abductor lever arm, patient reported outcomes (PROs), and complications in the selected studies.

2.1. Quality assessment & data analysis

Two authors independently assessed each selected article using the validated Methodological Index for Non-randomized Studies (MINORS)[16] criteria. There were no cases of disagreement in MINORS scoring.

The standardized mean difference (SMD) was calculated to compare the effect size of femoral offset on PROs. As described by Kemp et al., the SMD was calculated by dividing the difference between the postoperative and preoperative outcome scores by the standard deviation of the respective preoperative score.[17] If the standard deviation was not provided, it was estimated in the method described by Griffin et al., which includes using the range of the respective preoperative score.[18] The standard error (SE) of the SMD was calculated in a method described by Kelley et al.[19]; then, the 95% confidence interval (CI) was calculated using the formula SMD ± 1.96 x SE.[18] The magnitude of the effect size was analyzed using the threshold literature values of SMD: weak, SMD between 0.2 and 0.49; moderate, SMD between 0.5 and 0.79; large, SMD ≥ 0.8.[20]

3. Results

Our literature search generated a total of 117 unique studies. Following a preliminary abstract review, 17 articles were selected for full-text review. There was one study that examined the relationship between stem type and PROs, three studies that did not report PROs, one study that did not report minimum one-year follow-up, and two studies that were written in the Chinese language. Ten studies, with 1,738 hips in total, met the inclusion criteria.[12,14,21–28] A flowchart of our search strategy is provided in Fig. 1. MINORS and Level of Evidence are summarized in Table 1.

There were eight studies that reported outcomes following a total hip arthroplasty (THA)[12,14,22,23,25–28] and two studies that reported outcomes following hemiarthroplasty.[21,24] The mean age of all hips included in our study was 69.1 years (range 25–99), and all studies included minimum one-year follow-up.[12,14,21–28] Six studies divided their respective cohorts into sub-categories using a threshold for postoperative.[12,14,22,25,26,28] To define reported offset, one study used the difference between height adjusted offset and actual offset,[14] and four studies reported global offset, which was equal to the sum of the femoral offset and cup offset.[9,23,25,27]

3.1. Functional outcomes

In total, the selected studies used twelve patient reported outcome (PROs): the Harris Hip Score (HHS), the Western Ontario McMaster Universities Index (WOMAC), the Oxford Hip Score (OHS), the EQ-5D health questionnaire (EQ-5D), the mental and physical portions of the Short Form Survey (SF-12P, SF-12M), the Hip disability and Osteoarthritis Outcome Score (HOOS), the Merle d'Aubigné-Postel Pain Score (PMA), the Instrumental Activities of Daily Living (IADL), the Modified Barthel Index, a Timed Up and Go (TUG), and a Numerical Pain Rating Scale (NPRS), as described by Downie et al.[29]

The WOMAC index was the most commonly reported PRO, with five of ten studies including it in their analysis.[14,25–28] For their entire patient population, three studies reported significant improvement ($P < 0.05$) in WOMAC scores postoperatively compared to preoperatively,[14,25,26] and the other two studies did not comment on significance.[27,28] One study showed superior WOMAC scores for the decreased offset group,[14] another study showed superior WOMAC scores for the restored and increased group,[25] and the final study did not show a significant difference in WOMAC scores between the decreased, restored, and increased FO groups.[26]

The Harris Hip Score (HHS) was reported in four studies, making it the second most utilized PRO.[12,21,24,26] With regard to HHS, two studies reported superior outcomes for the increased FO group,[12,26] one study reported superior outcomes for a restored offset group (compared to unrestored),[24] and the final study reported more favorable outcomes for the decreased FO group following hemiarthroplasty (68 ± 20).[21]

Finally, PMA was reported in two studies,[22,26] one of which reported greater range of motion and maximal swing speed in the restored and increased groups compared to the decreased group,[26] while the other reported a significant improvement in the low FO cohort.[22]

Two studies reported outcomes following hemiarthroplasty, and one study found a positive correlation between increased FO and PROs,[21] while the other study found superior PROs in the restored offset group compared to patients with increased or decreased FO.[24] Additional PROs are provided in Table 2.

Two studies reported muscle strength and range of motion for their cohorts.[25,26] The decreased cohorts exhibited less postoperative abductor strength, decreased hip adduction, reduced range of motion in the knee, and a lower swing speed compared to the restored or increased groups.[25,26] Finally, complications reported in the reviewed articles are shown in Table 3.

3.2. Sub-analysis of effect size of offset on outcomes

Four studies (1) sub-categorized their patient populations into a decreased, restored, and increased group and (2) reported preoperative and postoperative PROs for each group.[14,25,26,28] A summary of how each study divided their cohort is provided in Table 4. All four studies that reported WOMAC reported a large effect size (SMD ≥ 0.8) for the low, normal, and high offset groups.[20] Mahmood et al. showed a large effect size (1.46,1.95, respectively), for the low and normal offset groups, with respect to EQ-5D and a moderate effect size (0.53) for the high offset group.[25] Further, Sariali et al. reported a large effect size (≥ 3) for the low, normal, and high offset groups in HHS, HOOS, and PMA, with the high offset group experiencing the greatest effect.[26] One study reported SF-12P and SF-12M scores, and the effect size was weak in all groups with regard to SF-12M and large in all groups with respect to SF-12P.[28] A forest plot illustrating the effect sizes is presented in Fig. 2.

4. Discussion

Current literature suggests the attained femoral offset following hip arthroplasty affects patients' postoperative PROs, muscle strength, and range of motion. This study aimed to investigate the effect of varying offset on PROs following hip arthroplasty. Ten studies were reviewed, which provided PROs and functional findings for patients with decreased, restored, and increased FO compared to their native offset. All three treatment groups demonstrated significant improvement in PROs, however, the restored offset groups showed more consistent improvement compared to the decreased or increased groups.

There is a paucity of literature regarding the optimal offset following hip arthroplasty. Judge et al. established a threshold of 44 mm for female patients, where an offset of > 44 mm was associated with better functional outcomes.[30] In their cohort of 1,431 patients, the authors found higher preoperative outcomes and greater femoral offset were strong predictors for improved five year postoperative outcomes.[30] Our selected studies did not establish a blanket threshold for femoral offset, but rather examined the effect of relative femoral offset, compared to baselines measures, on patient reported outcomes. While the effect of the femoral offset on THA outcomes varied between studies, the greatest proportion of studies found that restored postoperative femoral offset lead to superior PROs. With regard to hemi-

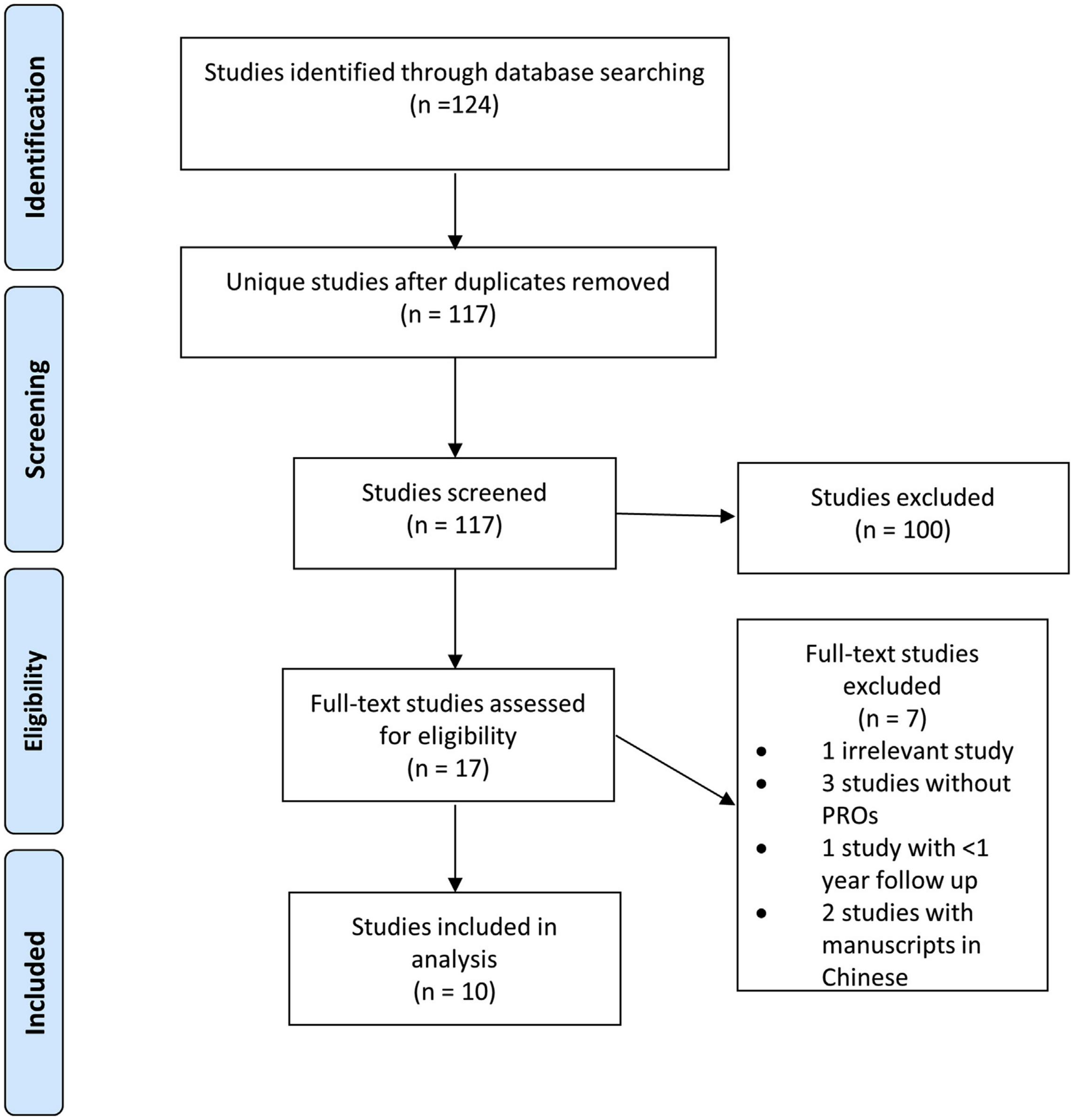

Fig. 1. Patient selection process.

Table 1
MINORS and level of evidence of selected studies.

Study	MINORS Score	Level of Evidence
Bjordal et al.,[12] 2015	22	III
Buecking et al.,[21] 2015	14	IV
Cassidy et al.,[28] 2012	18	III
Clement et al.,[23] 2016	22	III
Ebied et al.,[22] 2005	13	IV
Ji et al.,[24] 2017	21	III
Liebs et al.,[14] 2014	22	III
Mahmood et al.,[25] 2016	21	III
Sariali et al.,[26] 2014	20	III
Takao et al.,[27] 2016	11	IV

arthroplasty, there seems to be a slight advantage to either restoring or over-restoring offset. Of the two studies reviewed, one study found superior outcomes in the increased offset group[21] and the other for the restored group, respectively.[24]

The effect of femoral offset on physical examination findings has been reported in multiple studies.[7,31] Using 11 cadaveric hips, Matsushita et al. found that increasing the femoral offset to 4 mm and 8 mm resulted in 21.1° and 26.7° of improved flexion, and 13.7° and 21.2° of improved internal rotation, respectively.[31] The authors concluded that the improved range of motion was driven by delayed osseous impingement. Furthermore, McGrory et al. found a positive correlation between increased femoral offset, range of abduction, and abductor strength in total hip arthroplasty (THA) patients.[7] Accordingly, in our systematic review, Mahmood et al.[25] reported decreased postoperative abductor strength and greater use of walking aids in the decreased FO group relative to the restored and the increased FO groups. Additionally, Sariali et al.[26] reported significantly reduced range of motion at the knee, lower swing speed in the operative limb, and decreased hip adduction for the decreased FO group, compared to the restored and increased FO groups. Further, Takao et al. found that decreased FO was significantly associated with increased leg length discrepancy and increased abduction.[27]

Four studies reported femoral offset as the sum of the femoral offset and cup offset (global offset).[9,23,25,27] In three (75%) studies, inferior functional outcomes were found in the decreased offset group.[23,25,28] In a separate study, Bjarnason et al. found a stronger correlation between

Table 2
Findings from selected studies.

Study	No. of Hips	Age (mean, range)	Follow-Up (mo, mean, range)	Arthroplasty Type & Approach	Preop Offset (mean, range)	Preop PROs	Postop Offset (mean, range)	Postop PROs	Additional Results
Bjordal et al.,[12] 2015	148 total, Group 1 (56 hips): lever arm restored to ≤ 5 mm of native Group 2 (95 hips): native lever arm was increased by ≥ 5 mm	67.7 ± 10.9	12	Anterior THA		Group 1, Group 2, p value: HHS (46.4 ± 16.7, 48.7 ± 18.6, 0.45), HOOS pain: (33.2 ± 16.0, 37.3 ± 18.0, 0.18)	Native Abductor Lever Arm: group 1: 61.6 ± 6.1 group 2: 55.8 ± 5.9	Group 1, Group 2, p-value: HHS: (94.1 ± 9.7, 94.4 ± 10.6, 0.86), HOOS: (86.0 ± 19.0, 91.3 ± 12.6, 0.16)	
Buecking et al.,[21] 2015	127	82 ± 7 (63-99)	12	Hemi-arthroplasty			Rotation-corrected femoral offset (mm): 41 ± 7.8 (17-67)	HHS: 68 ± 20, range (12-97) (IADL) 3.6 ± 3.2, range (0-8), (TUG): 39sec	Positive correlation between reconstructed offset and HHS, (r = 0.303, p = 0.025) and IADL (r = 0.325, p = 0.013)
Cassidy et al.,[28] 2012	249 Total, 31 had femoral offset < -5 mm compared to contralateral hip (decreased), 163 had between -5mm and 5 mm (normal), 55 had > 5 mm (increased)	62.3	12	THA		(Decreased, normal, increased): SF-12P: 27.82 ± 6.04, 29.71 ± 7.86, 29.86 ± 8.84 SF-12 M: 46.99 ± 11.04, 50.63 ± 11.27, 50.77 ± 10.68 WOMAC pain: 29.68 ± 17.98, 43.39 ± 24.53, 43.63 ± 20.56	femoral offset < -5 mm compared to contralateral hip (decreased), between -5mm and 5 mm (normal), > 5 mm (increased)	(Decreased, normal, increased): SF-12P: 43.3 ± 11.45, 46.99 ± 9.73, 44.39 ± 11.37 SF-12M: 52.11 ± 9.22, 54.14 ± 8.38, 54.5 ± 7.86 WOMAC pain: 86.5 ± 22.02, 91.69 ± 14.77, 92.87 ± 12.87	Decreased group exhibited inferior PROs compared to normal and increased group (P = 0.019)
Clement et al.,[23] 2016	359	67	12	THA	45.9	OHS: 20.5 ± 8.3 SF-12P: 31.8 ± 9.6 SF-12M 49.7 ± 12.3 EQ-5D: 0.388 ± 0.313	50.5	OHS: 39.7 ± 8.8 SF-12P: 45.0 ± 11.0 SF-12M 48.3 ± 8.8 EQ-5D: 0.770 ± 0.259	Increased offset correlated to greater improvement in OHS
Ebied et al.,[22] 2005	54 Total, 16 hips had preop offset < 40 mm (Group1) 38 hips had preop offset ≥40 mm (Group2)	68 (29-84)	106 (19.2-135.6)	Cemented THA	Group 1: 34 (30-39), Group 2: 46 (40-57)			Significant improvement (P < 0.05) in PMA scores in all patients following THA	
Ji et al.,[24] 2017	100	79.5 ± 7.3 (59–94)	12	Hemi-arthroplasty	37.4 ± 2.5	Modified Barthel Index: 87.5 ± 6.7 (36-100)	77% of group had femoral offset change of ± 20% (recovered) and 23% of group had femoral offset change >20% (unrecovered)	Recovered vs Unrecovered, HHS: 79.4 ± 15.6 vs 72.5 ± 23.1, Modified Barthel Index: 80.3 ± 13.5 vs 69.3 ± 20.5	
Liebs et al.,[14] 2014	362 Total, 75 < 5 mm between height adjusted offset and actual (low), 195 within 5 mm (nomal), 92 > 5 mm (high)	70 (35.2-90.5)	at 3,6,12,2-4 month intervals	THA			41.0 (25.0-58.1)	low offset group reported statistically significant less pain (WOMAC) than normal or high offset groups at 6,12,24 months (P < 0.05)	
Mahmood et al.,[25] 2016[a]	222 Total, Group 1 (71 hips): Postoperative Offset < 5 mm of contralateral hip (Decreased) Group 2 (73 hips): Offset within 5 mm of Contralateral Hip (Restored)	71	12	Posterolateral THA		WOMAC (Decreased, Restored, Increased): 61 ± 13, 60 ± 14, 61 ± 13 EQ-5D (Decreased, Restored, Increased): 0.44 ± 0.26,	Decreased Group: < 5 mm, Restored: within 5 mm, Increased > 5 mm	WOMAC (Decreased, Restored, Increased): 20 ± 19, 15 ± 15,15 ± 14 EQ-5D (Decreased, Restored, Increased): 0.82 ± 0.19, 0.86 ± 0.17, 0.86 ± 0.19	Decreased group exhibited less postoperative abductor strength and greater use of walking aids (32% vs 21% vs 15%, p = 0.04)

(*continued on next page*)

Table 2 (*continued*)

Study	No. of Hips	Age (mean, range)	Follow-Up (mo, mean, range)	Arthroplasty Type & Approach	Preop Offset (mean, range)	Preop PROs	Postop Offset (mean, range)	Postop PROs	Additional Results
	Group 3 (78 hips): Offset > 5 mm of Contralateral Hip					0.43 ± 0.22, 0.51 ± 0.66			
Sariali et al.,[26] 2014	28 Total hips: 9 had postop femoral offset decrease < 15% (decreased), 14 had postoperative femoral offset within 15% (restored), and 5 had postoperative femoral offset increase > 15% (increased)	65.6 in decreased group 67.3 in restored group 72.4 in increased group	12	Primary THA		HHS (decreased, restored, increased): 36.6 (29-53), 34.4 (27-47) PMA (decreased, restored, increased): 10.7 (8-15), 10.6 (9-13), 9.4 (8-10) WOMAC (decreased, restored, increased): 53 (14-18), 54 (34-65), 54.4 (35-73) HOOS (decreased, restored, increased): 36.5 (23-52), 33.1 (18-45), 29.0 (20-45)	Decreased Group: < 15%, Restored: within 15%, Increased: > 15%	HHS (decreased, restored, increased): 87.9 (69-100), 92.4 (79-100), 92.7 (88-100) PMA (decreased, restored, increased): 16.3 (14-18), 16.8 (15-18), 16.8 (15-18) WOMAC (decreased, restored, increased): 7.4 (0-18), 8.2 (0-37), 4.0 (0-6) HOOS (decreased, restored, increased): 86.2 (64-100),90.9 (70-99), 94.2 (85-99)	Reduced range of motion at the knee ($p = 0.004$) and lower swing speed in operated limb ($p = 0.01$); decrease in hip adduction in decreased group ($P < 0.001$)
Takao et al.,[27] 2016	89	62 ± 12 (25-83)	12	mini-incision THA (32 anterolateral, 57 posterior)	4 ± 6 (-19-24)		34 ± 5 (22-47)	WOMAC pain: 0.9 ± 2.1 (0-14), WOMAC stiffness 0.7 ± 1.5 (0-10_, WOMAC physical function: 5.2 ± 7.4 (0-33) (NPRS): 0.6 ± 1.1 (0-7)	Postop leg length discrepancy, abduction range of motion were correlated with cup-head separation postop leg length discrepancy was negatively correlated to cup-head separation

(HHS): Harris Hip Score, (WOMAC): Western Ontario McMaster Universities Index, (OHS): Oxford Hip Score, (EQ-5D), the EQ-5D health questionnaire, (SF-12M, SF-12P): the mental and physical portions of the Short Form Survey, (HOOS): Hip disability and Osteoarthritis Outcome Score (HOOS), (PMA): Merle d'Aubigné-Postel Pain Score, (IADL): the Instrumental Activities of Daily Living, (TUG): Timed Up and Go, (NPRS): Numerical Pain Rating Scale (NPRS).

[a] Used global offset = femoral offset + cup offset.

Table 3
Complications in selected studies.

Study	Complications
Buecking et al.,[21] 2015	16 complications (12.7%): 5 hematoma, 4 seroma, 2 deep infection, 1 peri-prosthetic fracture (fall), 1 wound dehiscence
Ebied et al.,[22] 2005	18 complications (33.3%) 7 cases of GT nonunion, 9 cases of HO, 1 deep infection, 1 deep vein thrombosis
Liebs et al.,[14] 2014	13 complications (3.6%): 4 dislocations in low offset group, 7 dislocations in normal offset group, and 2 dislocations in high offset group

Table 4
Summary of low, normal, and high offset classifications in select studies.

Study	Decreased	Restored	Increased
Cassidy et al.,[28] 2012	femoral offset > 5 mm less than that of contralateral hip	femoral offset ± 5 compared to contralateral hip	femoral offset > 5 mm greater than that of contralateral hip
Liebs et al.,[14] 2014	actual offset > 5 mm less than height adjusted offset[a]	actual offset within 5 mm of height adjusted offset[a]	actual offset > 5 mm greater than height adjusted offset[a]
Mahmood et al.,[25] 2016[b]	Postoperative offset > 5 mm less than that of contralateral hip	Postoperative offset within 5 mm of that of Contralateral Hip	Postoperative offset > 5 mm greater than that of contralateral hip
Sariali et al.,[26] 2014	minimum decrease of 15% in femoral offset postoperatively	femoral offset within 15% of preoperative offset	minimum increase of 15% in femoral offset postoperatively

[a] Height adjusted offset = 6.96 + 0.28 × height.
[b] Used global offset = femoral offset + cup offset.

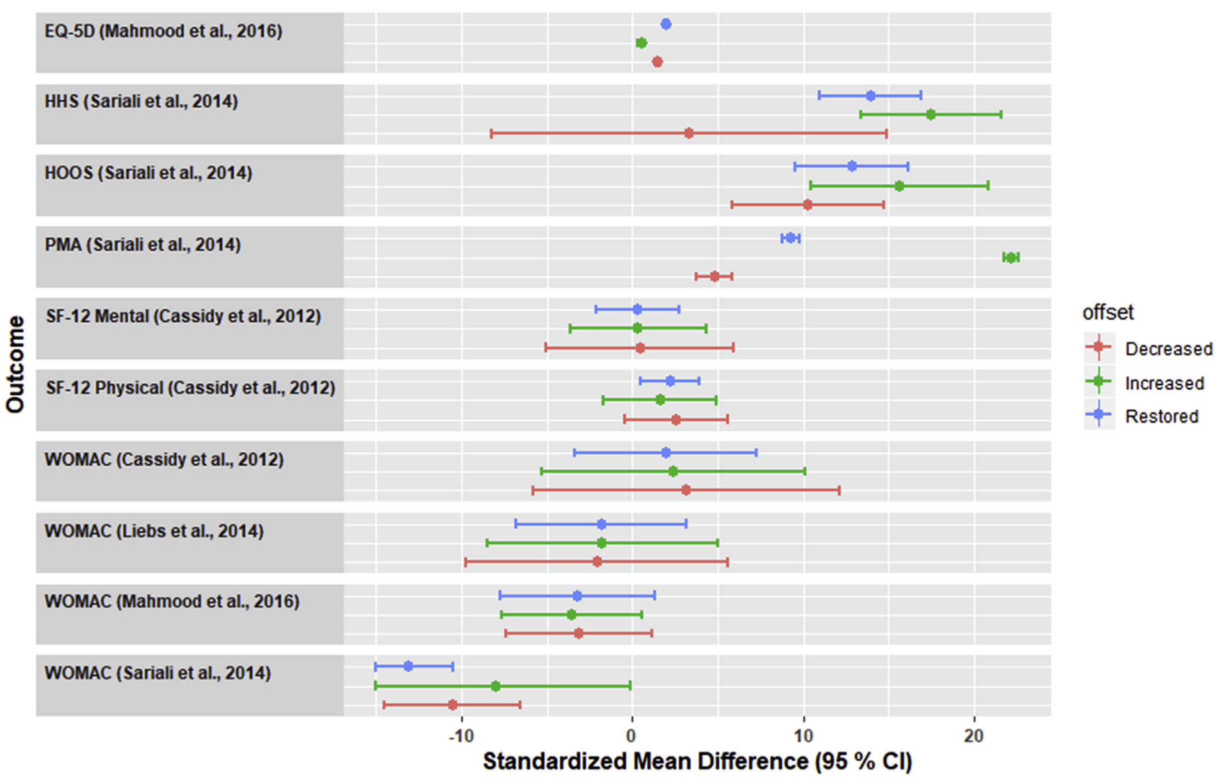

Fig. 2. Standardized mean difference of outcomes between studies.

femoral and global offset when compared to acetabular and global offset, suggesting that femoral offset alone may be a fair approximation of global offset.[32] In addition, Clement et al. showed that femoral offset was more predictive of greater postoperative outcomes than global offset, independently.[23] Both Bjarnason et al. and Clement et al. show that the acetabular component of the global offset does not play a significant role in the assessment of the abductor lever arm. Hence, although global offset seems to add more information compared to the FO, it may not add substantial value.

In summary, it is evident that FO has an effect on both functional and clinical patient reported outcomes. Setting a target FO during preoperative planning should help facilitate reconstruction of the optimal FO. In addition, accurate assessment of FO intraoperatively should be done in order to help confirm that the desirable FO was achieved. In cases were the reconstructed FO cannot be achieved, the surgeon should be aware how lack of restoration may affect overall function of the hip arthrosplasty.

4.1. Strengths

The standardized mean difference for three different offset groups was calculated for select studies to illustrate the varying effect of offset on PROs and address the notion that statistical significance does not equate clinical significance.

4.2. Limitations

We acknowledge the heterogeneity in our studies, as evidenced by the MINORS scoring system. There were varying definitions of decreased, restored, and increased OS in our analysis (Table 3). In addition, two included studies with 227 hips, examined the effect of offset on hemiarthroplasty.[21,24] The effect size was dependent on the standard deviation of each respective PROs, which differed greatly between study populations. Further, some studies did not show a significant difference in PROs between the decreased, restored and increased groups, which could be attributed to the “ceiling effect” of select patient reported outcomes.[33,34]

5. Conclusion

Patients with restored femoral offset following arthroplasty may demonstrate superior patient reported outcomes compared to patients with increased or decreased femoral offset. Furthermore, patients with decreased femoral offset tend to exhibit inferior PROs and functional outcomes.

Acknowledgements

None.

Appendix

PubMed.

(((((“Hip"[Mesh]) OR “Hip Joint"[Mesh])) AND (((“Arthroplasty"[Mesh]) OR “Arthroplasty, Replacement, Hip"[Mesh]) OR “Arthroplasty, Replacement"[Mesh])) AND (((((“Outcome Assessment (Health Care)"[Mesh]) OR “Outcome and Process Assessment (Health Care)"[Mesh]) OR “Patient Outcome Assessment"[Mesh]) OR “Treatment Outcome"[Mesh]) OR “Patient Reported Outcome Measures"[Mesh])) AND offset.

Embase & Cochrane.

Offset Total Hip Arthroplasty Patient Reported Outcomes.

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