

# Sex-related functional outcome after periacetabular osteotomy in mild to severe hip dysplasia

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## Aims

Periacetabular osteotomy (PAO) is well established for acetabular reorientation and has shown successful improvement in patient-reported outcome measures (PROMs). Nevertheless, studies focusing on postoperative outcomes related to patient individual factors are still underrepresented. Therefore, this study aimed to analyze the functional outcome and activity level in relation to patient sex with a minimum follow-up of two years after PAO for mild to severe hip dysplasia.

## Methods

A single-centre study was conducted, enrolling patients undergoing PAO and completing a preoperative and postoperative radiological and clinical outcome assessment. The PROMs were assessed using the modified Harris Hip Score (mHHS), the Hip disability and Osteoarthritis Outcome Score (HOOS) with the subscales for pain, sport, activities of daily living (ADL), and quality of life (QoL), and the University of California, Los Angeles (UCLA) activity score. Kendall's tau were calculated for correlation analyses.

## Results

In total, 145 patients (28 male, 117 female) were included. The PROMs improved significantly across males and females at the latest follow-up. Female patients had significantly lower preoperative PROMs: mHHS (47 vs 57.4;  $p = 0.002$ ); HOOS pain (44.9 vs 60;  $p = 0.003$ ), sport (47 vs 57.4;  $p = 0.002$ ), ADL (58.9 vs 69.3;  $p = 0.032$ ), and QoL (26.8 vs 39.3;  $p = 0.009$ ); and UCLA (5.6 vs 6.7,  $p = 0.042$ ) scores. Males showed higher postoperative UCLA scores (7.5 vs 6.7;  $p = 0.03$ ). Kendall's tau showed significant negative correlation between BMI and UCLA scores in females and males ( $-0.21$  to  $-0.29$ ;  $p = 0.002/0.048$ ), while BMI and HOOS sport ( $-0.16$ ;  $p = 0.015$ ) and ADL ( $-0.2$ ;  $p = 0.003$ ), as well as QoL ( $-0.14$ ;  $p = 0.031$ ) and preoperative acetabular inclination ( $-0.13$ ;  $p = 0.049$ ) were only significantly negatively correlated in females.

## Conclusion

Patient sex affects PROMs before and after PAO. Female patients experience higher improvement in hip function and activity level, due to poorer preoperative PROMs than males. Thus, these data are particularly interesting in providing preoperative guidance regarding postoperative outcome expectations.

## Take home message

- Females experience a higher symptom burden at the time of periacetabular osteotomy (PAO) compared to males.
- Male patients have a higher activity level before and after PAO.

- Greater BMI negatively affects postoperative outcomes in female and male patients.

## Introduction

Hip dysplasia (HD) is a common congenital malformation of the hip joint, characterized by inadequate coverage of the femoral head

by the acetabulum. This structural anomaly can lead to instability, pain, and premature joint degeneration, significantly impacting the quality of life (QoL) of affected individuals.<sup>1,2</sup> An established surgical treatment option to correct this deformity and improve the biomechanical conditions of the hip joint is periacetabular osteotomy (PAO).<sup>3,4</sup> PAO, a major hip-preserving procedure, allows 3D acetabular correction in mild to severe HD to optimize joint load distribution.<sup>5,6</sup> Mid- and long-term data on PAO report high joint survival rates and improved clinical outcomes.<sup>7-9</sup>

Various predictors for the outcome after PAO are known. It has been shown, among others, that age, body weight, presence of osteoarthritis, and patient's psychological state influence the outcome of PAO.<sup>10-13</sup> Some studies have also identified sex-specific differences, for example male sex as a negative predictor for daily activities post PAO.<sup>10</sup> However, investigations into sex-specific outcomes are still underrepresented. Sex-specific outcomes in orthopaedic studies are generally rarely investigated, despite the sex distribution among the patients included in the studies being homogeneous,<sup>14</sup> even though it is known that females and males benefit to varying degrees from orthopaedic procedures.<sup>15-17</sup> Studies on sex-specific outcomes are particularly important in PAO research given the sex-specific differences already observed in the prevalence of HD, with females being significantly more frequently affected.<sup>18,19</sup>

Considering these findings, it is crucial to investigate sex-related outcomes in patients undergoing PAO, especially given the increasing number of hip preservation procedures and the significant physical as well as psychosocial burdens associated with PAO for patients and their families.<sup>20-22</sup>

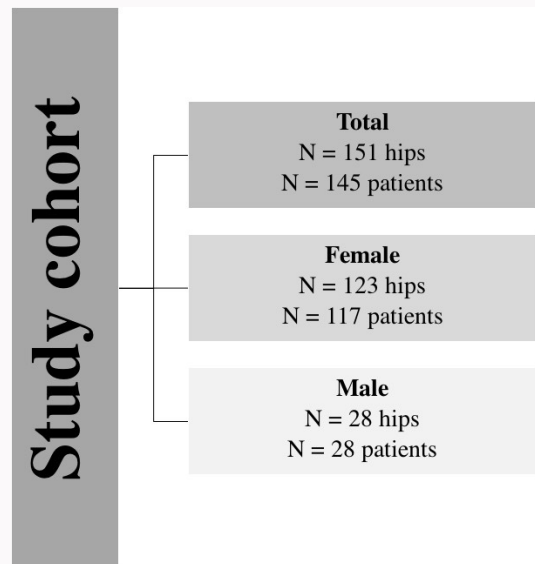
As a result, we aimed to comprehensively evaluate patient-reported outcome measures (PROMs) in a cohort of 151 hips treated with PAO for mild to severe HD, with a minimum follow-up of two years. The objectives of this study were to report PROMs between male and female patients. We hypothesize that precise bone correction through PAO uniformly leads to improved PROMs regardless of sex.

## Methods

### Study design

A total of 145 patients (151 hips) were identified from the institutional PAO registry (Center for Orthopaedics, University Medicine Greifswald, Germany) and included in this single-centre study. The cohort included 117 female and 28 male patients (Figure 1). The patients underwent PAO due to symptomatic HD (threshold lateral centre-edge angle (LCEA) < 18°) or borderline hip dysplasia (BHD; threshold LCEA 18° to 25°) between January 2019 and January 2021. Until today, 29 patients have undergone bilateral operation, with six patients undergoing bilateral PAO within the study period. All included patients completed the PROMs assessment and had a minimum follow-up of two years. The mean follow-up was 3.1 years (2 to 5).

Patients presented with refractory hip pain lasting more than six months and failure of conservative therapy. The treatment decision was made based on a combination of patient-reported symptoms, physical examination, and radiological parameters. All patients gave written informed consent prior to study enrolment.



**Fig. 1**  
Distribution of female and male patients.

### Surgical technique

A modified, minimally invasive Bernese PAO technique was performed in all hips. This involved either a rectus-sparing (RS) approach (104/151, 69%) with bony detachment of the sartorius from its origin or a rectus- and sartorius-sparing (RASS) approach (47/151, 31%), as previously described.<sup>23</sup> Using the Smith-Peterson approach, a mini-open arthrotomy was performed for femoral head-neck osteoplasty in the case of cam morphology concomitant with PAO. Cam resection was performed in 78% of female and 93% of male patients. All procedures were done by one fellowship-trained, high-volume surgeon (GIW). Physiotherapeutic training and mobilization of the operated hip joint started directly on the first postoperative day. In case of RASS approach, active hip flexion was permitted directly after surgery.

### Radiological assessment

Preoperative and postoperative radiological evaluation included anteroposterior (AP) pelvic radiographs, as well as axial and faux-profile femoral views. These were reviewed independently to analyze Tönnis osteoarthritis grade,<sup>24</sup> femoral neck-shaft angle (NSA), LCEA, acetabular inclination (AI), anterior and posterior wall index (AWI/PWI), femoroepiphyseal acetabular roof (FEAR index), and gothic arch angle (GAA).<sup>25-28</sup> Concomitant acetabular retroversion was defined with the appearance of crossing over sign, posterior wall sign, and sciatic spine sign simultaneously on AP pelvic radiographs.

### Ethical considerations

All patients gave written informed consent prior to inclusion. Ethical approval (BB099/20a) was obtained from the local independent ethics committee (IEC) of the University Medicine Greifswald according to the World Medical Association Declaration of Helsinki.<sup>29</sup>

**Table I.** Patient demographics and radiological parameters for male and female patients.

Variable	Total (n = 151)	Male (n = 28)	Female (n = 123)	p-value*
Mean age, yrs (SD)	32.4 (8.3)	32.3 (8.4)	32.4 (8.2)	0.239
Mean BMI, kg/m <sup>2</sup> (SD)	24.6 (4.4)	26.4 (3.5)	24.2 (4.4)	<b>0.002</b>
Median Tönnis grade (minimum to maximum)	0 (0 to 1)	0 (0 to 1)	0 (0 to 1)	0.891
Mean LCEA, ° (SD)	15.7 (5.8)	15.2 (6.9)	15.8 (5.5)	0.992
Mean acetabular inclination, ° (SD)	11.9 (6.0)	11.8 (6.6)	12.0 (5.9)	0.621
Mean NSA, ° (SD)	136 (6.7)	132.7 (8.0)	136.9 (6.0)	<b>0.002</b>
Mean AWI (SD)	0.39 (0.11)	0.38 (0.1)	0.37 (0.11)	0.621
Mean PWI (SD)	0.85 (0.17)	0.76 (0.16)	0.87 (0.16)	<b>0.003</b>
Mean FEAR, ° (SD)	-0.2 (10.4)	-3.0 (12.8)	0.5 (9.8)	0.191
Mean GAA, ° (SD)	92.5 (11.8)	90.9 (13.7)	92.8 (11.4)	0.368
Mean post LCEA, ° (SD)	28.0 (4.8)†	26.6 (4.0)†	28.3 (4.9)†	0.568
Mean post acetabular inclination, ° (SD)	2.3 (4.7)†	3.0 (3.1)†	2.1 (5.0)†	0.726

\*Mann-Whitney U test.

†Intragroup significance pre- versus postoperative; p < 0.05.

AWI/PWI, anterior/posterior wall index; FEAR, femoroepiphyseal acetabular roof; GAA, gothic arch angle; LCEA, lateral centre-edge angle; NSA, femoral neck-shaft angle.

### Data collection

PROMs were assessed during routine follow-up examination. The modified Harris Hip Score (mHHS)<sup>30</sup> and the Hip disability and Osteoarthritis Outcome Score (HOOS)<sup>31</sup> with the subscales for sport, pain, QoL, and activities of daily living (ADL) were used to quantify hip function. The University of California, Los Angeles (UCLA) activity score determined patient-reported activity level.<sup>32</sup> All PROMs had a minimum follow-up of years.

### Statistical analysis

Descriptive statistics were used to summarize the patient characteristics and outcomes. Continuous variables and PROMs are presented as mean and SD. Categorical variables including sex are reported in raw numbers. Statistical analysis was performed using SPSS v. 29 (IBM, USA). Intragroup analysis was conducted using the Wilcoxon signed-rank test, while intergroup analysis was performed using the Mann-Whitney U test. Correlation analyses were performed for the metric variables age, BMI, preoperative LCEA and AI, and postoperative mHHS, HOOS, and UCLA scores. Kendall's tau was calculated as the correlation coefficient with a CI of 95% and 99% and a Z-test was used for significance testing of the correlation. A p-value < 0.05 was considered statistically significant.

## Results

### Patient demographics and radiological parameters

The preoperative patients' demographics and the radiological measurements are presented in Table I. The mean age at the time of surgery was 32.4 years (SD 8.3), without significant differences between male and female patients. Male patients had a significantly higher BMI than female patients at the time of surgery (26.4 kg/m<sup>2</sup> vs 24.2 kg/m<sup>2</sup>; p = 0.002).

Additionally, male patients showed significantly lower preoperative NSA angle (132.7° vs 136.9°; p = 0.002) and

PWI (0.76 vs 0.87; p = 0.003) compared to female patients, while other preoperative radiological parameters did not differ significantly (Table I). Concomitant acetabular retroversion appeared in 41.9% (13/31) of male and 27.3% (33/121) of female patients.

Postoperatively, the LCEA increased significantly in male and female patients (p < 0.001), while the AI decreased in both groups (p < 0.001). There were no statistically significant differences between the postoperative LCEA and AI between male and female patients (Table I).

### Patient-reported outcome measures

At the latest follow-up, the PROMs had significantly improved across the study cohort compared to preoperative values. These findings included the mHHS and the HOOS subscales for pain, sport, ADL, and QoL. While the UCLA scores improved postoperatively, this difference did not reach statistical significance in intragroup analysis (Table II).

Comparing male and female patients, females undergoing PAO had significantly lower preoperative hip functional and activity scores (mHHS/HOOS/UCLA), while there was no statistically significant difference between the two groups postoperatively (Table II). The magnitude of hip functional improvement in the female group was higher compared to the male group, although it did not reach statistical significance (Table II).

Preoperatively, male patients exhibited a higher activity level than female patients. Following the surgical procedure, the UCLA score indicated a significantly higher activity level in male patients (Table II).

### Correlation analyses

Kendall's tau showed a greater negative correlation between age and postoperative PROMs in males, even when not reaching statistical significance. A significant negative

**Table II.** Female patients exhibited lower patient-reported outcome measures preoperatively while experiencing a greater improvement after surgery.

Variable	Total (n = 151)	Male (n = 28)	Female (n = 123)	p-value*
<b>Mean mHHS (SD)</b>				
Preoperative	48.9 (15.9)	57.4 (16.9)	47.0 (15.2)	<b>0.002</b>
Latest follow-up	83.9 (19.9)†	88.1 (16.5)†	83.0 (20.5)†	0.401
Δ postoperative vs preoperative	35	30.7	36	0.229
<b>Mean HOOS (SD)</b>				
<b>Pain</b>				
Preoperative	47.5 (21.1)	60.0 (24.1)	44.9 (19.6)	<b>0.003</b>
Latest follow-up	79.6 (19.9)†	83.0 (18.7)†	78.9 (20.1)†	0.304
Δ postoperative vs preoperative	32.1	23	34	0.092
<b>Sport</b>				
Preoperative	40.0 (26.5)	55.6 (28.4)	36.7 (25.0)	<b>0.002</b>
Latest follow-up	69.9 (26.0)†	76.3 (23.3)†	68.5 (26.5)†	0.183
Δ postoperative vs preoperative	29.9	20.7	31.8	0.137
<b>Activities of daily living</b>				
Preoperative	60.8 (23.8)	69.3 (24.9)	58.9 (23.2)	<b>0.032</b>
Latest follow-up	84.9 (17.7)†	89.1 (14.0)†	83.9 (18.4)†	0.215
Δ postoperative vs preoperative	24.1	19.8	25	0.200
<b>Quality of life</b>				
Preoperative	29.0 (19.6)	39.3 (21.6)	26.8 (18.5)	<b>0.009</b>
Latest follow-up	58.5 (27.2)†	60.2 (28.7)†	58.2 (27.0)†	0.815
Δ postoperative vs preoperative	29.5	20.9	31.4	0.319
<b>Mean UCLA (SD)</b>				
Preoperative	5.7 (2.6)	6.7 (2.6)	5.6 (2.6)	<b>0.042</b>
Latest follow-up	6.7 (2.1)	7.5 (2.0)	6.6 (2.0)	<b>0.030</b>
Δ postoperative vs preoperative	1.0	0.8	1.0	0.889

\*Mann-Whitney U test.

†Intragroup significance pre- versus post, p < 0.05.

HOOS, Hip disability and Osteoarthritis Outcome Score; mHHS, modified Harris Hip Score; UCLA, University of California, Los Angeles activity score.

correlation between the BMI and all HOOS subscales was observed in females, while the HOOS scores were not significantly correlated with the BMI in males (Figure 2). Additionally, the BMI correlated significantly negatively with the postoperative UCLA for both sexes.

Preoperative radiological parameters revealed only for the AI in females a significant negative correlation with the postoperative HOOS ADL (Figure 2).

## Discussion

This case series of 151 hips undergoing hip preservation by PAO aimed to analyze the functional outcome and activity level in relation to patient sex with a minimum follow-up of two years. The data showed a significant improvement in PROMs across male and female patients. Female patients had lower preoperative scores and, therefore, experienced higher improvement ( $\delta$  value) after PAO compared to their male

counterparts. Patient age, BMI, and acetabular morphology impacted the postoperative outcomes in a distinct manner for females and males, and the BMI correlated negatively with the postoperative outcome in both.

Sex-related differences in PROMs after PAO have been rarely studied until recent years, when this research topic has been increasingly studied in various orthopaedic interventions. In 2001, the Institute of Medicine stated the importance of research on sex-related differences in medicine.<sup>33</sup> For instance, worse preoperative PROMs of females in large series of patients were reported for different orthopaedic interventions and underline our findings.<sup>17,34</sup> Reasons for the frequently reported lower preoperative PROMs in females were often connected to sex-related differences in pain perception and tolerance, as well as the decision for surgical treatment at a later state of disease in females.<sup>35–37</sup> While not reaching statistical significance, there is a trend in our results towards

## Female

	mHHS	HOOS Pain	HOOS Sport	HOOS ADL	HOOS QoL	UCLA
Age Kendall's tau p	-0.05 0.387	0.02 0.760	-0.09 0.156	-0.07 0.277	-0.05 0.424	-0.04 0.502
BMI Kendall's tau p	-0.09 0.178	-0.11 0.103	-0.16 0.015	-0.2 0.003	-0.14 0.031	-0.21 0.002
preOP LCEA Kendall's tau p	0.02 0.722	0.04 0.511	0.03 0.637	0.04 0.553	0.02 0.758	0.01 0.884
preOP AI Kendall's tau p	-0.11 0.080	0.11 0.091	0.12 0.071	-0.13 0.049	-0.01 0.150	-0.04 0.566

95% Confidence interval  
99% Confidence interval

## Male

	mHHS	HOOS Pain	HOOS Sport	HOOS ADL	HOOS QoL	UCLA
Age Kendall's tau p	-0.14 0.313	-0.22 0.131	-0.16 0.293	-0.27 0.070	-0.17 0.386	-0.21 0.149
BMI Kendall's tau p	-0.02 0.872	-0.07 0.603	-0.09 0.550	-0.16 0.272	0.03 0.851	-0.29 0.048
preOP LCEA Kendall's tau p	0.08 0.598	0.12 0.420	0.1 0.487	0.16 0.303	0.19 0.187	0.17 0.250
preOP AI Kendall's tau p	-0.02 0.871	-0.05 0.740	0.11 0.457	-0.13 0.376	-0.12 0.397	-0.15 0.296

Fig. 2

Correlation of patient individual factors with postoperative PROMs. ADL, activities of daily living; HOOS, Hip disability and Osteoarthritis Outcome Score; mHHS, modified Harris-Hip score; QoL quality of life; UCLA, University of California, Los Angeles activity score.  $p < 0.05$ , Z-test for statistical significance of correlation.

a greater postoperative improvement in females undergoing PAO. Nevertheless, reports in other orthopaedic procedures did not find any sex-related differences in PROM change comparing preoperative and postoperative scores ( $\delta$  value).<sup>34</sup> However, similar to our results, there are several studies emphasizing a higher value of PROM improvement in females undergoing arthroscopic surgery of the shoulder and hip.<sup>38,39</sup>

As mentioned before, studies on sex-related PROM differences in hip preservation have mainly focused on hip arthroscopic surgery, with a paucity of literature regarding comprehensive sex-related outcome assessments in patients undergoing PAO.<sup>15,16,40-43</sup> Recently, a matched cohort study in professional athletes demonstrated comparable outcomes between male and female patients in the setting of primary hip arthroscopic surgery. In line with our results, females had lower preoperative scores, whereas they experienced a significantly higher magnitude of improvement. In contrast to our study on PAO outcomes, patients with HD (LCEA  $< 18^\circ$ ) were excluded.<sup>44</sup> For patients undergoing PAO, there is only one large multicentre study available focusing on sex-related outcomes. The data from the ANCHOR study group of 359 hips demonstrated more improvement in female patients compared to their male counterparts.<sup>45</sup> Our study adds to this and extends the knowledge by correlating patient individual factors and radiological parameters with PROMs and illustrated sex-related differences.

We found not only that the patients' sex influenced PROMs after PAO, but also that an elevated BMI had a negative impact on postoperative results in both females and males. Obesity has already been described as a risk factor for severe complications after PAO, and poorer postoperative results were reported in this context.<sup>46,47</sup> Nevertheless, there is conflicting evidence, and a multicentre study in 391 cases must be noted where obesity was a positive predictor of various improved PROMs.<sup>10</sup>

Besides patient sex and BMI, several other patient factors have already been described affecting PAO outcomes. For instance, even psychological factors were revealed to be a PROMs modulator. A case series on 202 patients by Wagener et al<sup>11</sup> identified psychological distress as a negative contributor to poor postoperative results for several PROMs. Thus, several individual factors must be recognized when planning PAO.

Besides sex-related differences in PROMs, the preoperative radiological assessment revealed distinct sex-related differences with lower PWI and higher frequency of concomitant acetabular retroversion in male patients. This is in line with previous reports on higher rates of acetabular retroversion in male patients.<sup>48,49</sup> Nevertheless, PAO has shown to be an excellent choice in HD as well as acetabular retroversion, with comparable PROMs for both.<sup>50</sup>

Comparing the most frequent hip-preserving interventions, PAO is a demanding surgical procedure.<sup>51</sup> Even when muscle-sparing, minimally invasive approaches allow early patient mobilization, there is still a risk of intraoperative complications.<sup>52,53</sup> A systematic review of 4,070 hips undergoing PAO reported an overall complication rate of 7%, with severe complications including extended blood loss and nerve injuries.<sup>5,54</sup> Thus, a meticulous preoperative guidance and a critical evaluation of the expected outcome based on patient individual factors is necessary. Studies on patient individual factors affecting PROMs must be extended to improve the care of PAO patients. Our study contributes to this knowledge on postoperative outcome expectations and reported sex-related differences before and after surgical intervention.

Nevertheless, several limitations of this study must be considered and discussed. First, the current study was not balanced for male and female patients. It is worth noting that HD is more frequent in female patients, and this could be an explanation for the higher rate of female patients in our study

cohort.<sup>18,55</sup> Even if the data were prospectively collected, the study design lacks a power analysis. This could bias our results and there is a risk of underpower, especially in the small group of male patients included. Thus, the trend seen in age-related influences on PROMs in male patients may become statistically significant in a larger study cohort. Furthermore, the study included only patients receiving PAO to treat HD and BHD, and there could be an increased risk for selection and treatment bias caused by a single surgeon performing all treatments in this study. Patients with other indications for PAO, for instance acetabular retroversion, were not included in this study. Thus, the results of our cohort study are not generalizable to all PAO indications. Multicentre studies could be beneficial to improve the generalizability of the results.

Additionally, the data were limited by a minimum follow-up of two years. Future studies should report mid- and long-term outcomes to verify these results. Although a comprehensive radiological assessment was performed to describe the femoral and acetabular morphology, most radiological parameters were measured on plain pelvic radiographs. However, MRI and femoral torsion measurements were not available in all patients of the study cohort. Therefore, results on accompanying soft-tissue pathologies of the hip joint and femoral torsion affecting the outcome after PAO must be stated preliminarily and have to be further evaluated.

However, this study aimed to increase the knowledge in the rarely studied field of sex-related outcomes in PAO, and should be the starting point for advanced studies to further improve the personalized care of PAO patients.

Overall, this cohort study indicates sex-related PROM differences in patients undergoing PAO. Female patients experienced a higher overall improvement in hip function and activity level due to poorer preoperative scores at the time of surgery, and males had a higher activity level pre- and postoperatively. These data could be particularly interesting in preoperative guidance on the postoperative outcome expectations, and future research is warranted to improve the current treatment recommendations.

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## Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission

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