

Return to Play After Periacetabular Osteotomy for Treatment of Acetabular Dysplasia in Adolescent and Young Adult Athletes

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Background: The Bernese periacetabular osteotomy (PAO) is an effective surgical treatment option for symptomatic acetabular dysplasia. Little evidence exists regarding the results of PAO and rates of return to play (RTP) in an athletic population.

Hypothesis: The majority of athletes will demonstrate improvements in functional outcome measures, such as the modified Harris Hip Score and Hip Disability and Osteoarthritis Outcome Score, and will be able to return to sports after PAO.

Study Design: Case series; Level of evidence, 4.

Methods: A comprehensive surgical hip database at an academic referral center was used to identify a subpopulation of athletes on whom PAO was performed. Data analyzed included preceding surgeries, reoperations, and RTP timing and features. Standard pre- and postoperative radiologic parameters and validated functional outcome measures were assessed, and a regression model assessed risk factors for prolonged time to RTP.

Results: Of 245 PAOs performed over the 5-year study period, 46 were performed in 41 patients who met inclusion criteria for being an athlete (mean age, 26.2 years; range, 13-41 years; 36 females; 19% of all PAOs), representing a variety of sports. Prior surgery had been performed on 9 hips (20%). Only 1 post-PAO procedure (2%), excision of heterotopic ossification, was performed during the study period. At final follow-up (median, 3.1 years; range, 1.2-4.4 years), significant mean improvements were observed in modified Harris Hip Score (from 71 to 90; $P < .001$) and Hip Disability and Osteoarthritis Outcome Score (from 64 to 89; $P < .001$). The University of California-Los Angeles Activity Scale scores were maintained at a high level (range, 8.0-8.2; $P = .28$). RTP was reported in 80% of patients (37 of 46) at a median of 9 months postoperatively, with increased postoperative pain as the only independent predictor of longer time to RTP. Of these 37 athletes, 27 (73%) returned to the same level, although this was significantly less common ($P = .06$) in competitive athletes (11 of 19; 58%) than in recreational athletes (16 of 18; 89%). Among those who did return at the same level, 23 of 27 (85%) were able to maintain this level over time, but this was not significantly different between competitive (8 of 11; 73%) and recreational (15 of 16; 94%) athletes ($P = .27$).

Conclusion: Most athletic patients undergoing PAO are female patients and show postoperative improvements in function and return to athletic play. However, although there was no decline in overall activity level at a mean of 3 years, self-assessed athletic performance was attained and maintained in approximately one-half of the study population.

Keywords: Bernese periacetabular osteotomy; acetabular dysplasia; developmental dysplasia of the hip; athletes

Acetabular dysplasia affecting adolescents or young adults can be clinically silent through childhood but can become debilitating in later years, causing symptoms of hip pain and activity limitations. When such symptoms are refractory to nonoperative measures, the Bernese periacetabular osteotomy (PAO), which reorients the acetabulum to achieve greater femoral head coverage and broader

distribution of loads through the weightbearing portion of the acetabular articular surface, is an effective surgical option and is commonly performed at select centers.⁹⁻¹² Although results of this procedure have been good to excellent in many published series, most reported outcomes have centered on radiographic and pain-based metrics. Improvement in validated joint-specific, functional hip outcome instruments has been variably documented but is becoming a more standard approach to assessing the effectiveness of the procedure, both for clinical and research purposes.^{9,11,12,16,17,30,31} However, multiple studies have demonstrated that the value and comparability of such

outcome instruments are optimized only in conjunction with assessment of patient activity,^{7,28,29,34,40,45,51} given the degree of variation between subpopulations with different activity levels, in terms of function and effects on the involved anatomic region.

Although a recent study investigated general activity levels in a broader population of all patients with acetabular dysplasia undergoing PAO,³⁷ this subpopulation of athletes—who represent a uniquely active epidemiological sector of affected patients with different indications or expectations before surgery—has been severely understudied. Bogunovic et al⁵ recently described activity scale changes in an active population after PAO, but the nature of the preoperative or postoperative athletic activity in the population was not explored. In the literature, there is also little information on the maintenance of specific athletic participation over time after PAO, despite several studies investigating athletic populations undergoing other invasive hip procedures, such as surgical dislocation of the hip or arthrotomy for femoroacetabular impingement.^{1,35,38} The current study was therefore designed to retrospectively investigate the results of PAO and rates of return to play (RTP) specifically in an athletic subpopulation of patients with acetabular dysplasia who had undergone this open reconstructive hip procedure.

METHODS

Patient Selection

After obtaining institutional review board approval, a query was performed using a departmental hip surgery registry. We identified patients who underwent a PAO between January 2007 and May 2010, a period that was selected to allow sufficient follow-up but was also based on the time after which comprehensive preoperative and postoperative outcome measures in registry patients were prospectively collected for the registry. The indications for PAO included hip pain interpreted to be secondary to acetabular dysplasia, with radiographic evidence of femoral head uncovering and a lateral center edge angle (LCEA) of <20°. Patients were included in this study if they were aged between 10 and 45 years at the time of surgery, were considered an athlete based on a minimum University of California–Los Angeles Activity Scale (UCLA-AS) score of 8 of 10, had adequate self-reported sport participation (further described below), and completed a hip questionnaire before surgery and at least 1 year after surgery. Patients were excluded if they had an underlying neuromuscular disease, had incomplete questionnaires, or did not meet the strict criteria to be considered an athlete.

This study was a retrospective analysis of prospectively collected data, with additional patient contact made specifically regarding athletic status in a subset of patients. An athletic activity questionnaire developed for this study was used for this purpose (Figure 1). All initial clinical data were collected from the medical records and radiographs. Patients completed a standardized hip questionnaire to determine their activity level and functional information during standard preoperative and follow-up office visits and were mailed the questionnaires if they were between standard follow-up visits in the period of study enrollment. If there was a longer than 3-month difference between the office-based questionnaire completion and the period of study enrollment, then both the standard functional questionnaire and the athletic activity questionnaire were sent to ensure correlation between the 2 instruments.

Surgical Technique

The technique of the Bernese PAO utilized at our institution during the study period is that described previously in detail by Matheny et al.^{30,31} Briefly, a direct anterior abductor-sparing surgical approach was performed, with the patient lying supine on a radiolucent table. Atraumatic treatment of all tissues was emphasized. Osteotomies of ischium, superior pubic ramus, and posterior column were performed, and a partial osteotomy of the ischium below the acetabulum was performed, as described previously. The image intensifier was used during the ischial osteotomy. Arthrotomy was performed in selected cases, always with careful rectus tendon repair. Routinely, instruments including a Weber bone clamp and Schanz screw were used to rotate the acetabular fragment to achieve the desired femoral head coverage while avoiding potential impingement. Final correction was based on both impingement-free passive motion and on imaging. Flexion to at least 95° with at least 15° of internal rotation without impingement was standard. Intraoperative imaging to optimize correction was by image intensifier analysis in 2 planes, often supplemented with a plain anteroposterior (AP) radiograph of the pelvis. Imaging guidelines for optimal correction included a near-horizontal sourcil, normal acetabular version, and a normal position of the hip center. Routine osteosynthesis was performed with three or four 3.5- or 4.5-mm screws placed through the iliac crest into the subchondral bone of the acetabular fragment.

Clinical Variables

Basic clinical variables that were collected from a chart review of medical records and recorded for analysis

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Athletic Activity Questionnaire	
1. Before your hip became painful or symptomatic enough for you to seek medical help, did you participate in sport(s) or athletic activities? <input type="checkbox"/> ₁ YES <input type="checkbox"/> ₀ NO	
1a. If 'yes,' in what sport(s) or athletic activities did you participate? (check all that apply)	
<input type="checkbox"/> ₁ Baseball	<input type="checkbox"/> ₁₀ Skiing or snowboarding
<input type="checkbox"/> ₂ Basketball	<input type="checkbox"/> ₁₁ Soccer
<input type="checkbox"/> ₃ Cycling (mountain, road, track, etc.)	<input type="checkbox"/> ₁₂ Swimming
<input type="checkbox"/> ₄ Football	<input type="checkbox"/> ₁₃ Wrestling
<input type="checkbox"/> ₅ Gymnastics	<input type="checkbox"/> ₁₄ Other: 1) _____
<input type="checkbox"/> ₆ Hockey	<input type="checkbox"/> ₁₅ Other: 2) _____
<input type="checkbox"/> ₇ Racquet (tennis, racquetball, squash, badminton, etc.)	<input type="checkbox"/> ₁₆ Other: 3) _____
<input type="checkbox"/> ₈ Rugby	
<input type="checkbox"/> ₉ Running (cross country, track and field, etc.)	
1b. What was the highest level at which you were participating? (check only one)	
<input type="checkbox"/> ₁ Recreational (casual, pick-up with friends, no organized competition)	
<input type="checkbox"/> ₂ Recreational (competition or events/races)	
<input type="checkbox"/> ₃ Youth League (competition)	
<input type="checkbox"/> ₄ High School (Interscholastic competition)	
<input type="checkbox"/> ₅ College (Interscholastic competition)	
<input type="checkbox"/> ₆ Semi-pro/Amateur League	
<input type="checkbox"/> ₇ Professional League	
2. What did you do after surgery?	
<input type="checkbox"/> ₁ Returned to sport(s) or athletic activities	
<input type="checkbox"/> ₂ Could not return to sport(s) or athletic activities because of my hip	
<input type="checkbox"/> ₃ Did not to return to sport(s) or athletic activities, but not because of my hip	
COMPLETE QUESTIONS BELOW ONLY IF YOU RETURNED TO SPORT(S) OR ATHLETIC ACTIVITIES.	
3. How many months after surgery were you able to return to your sport(s) or athletic activities? ___ months	
4. Were you able to return to the level at which you had been playing/participating prior to surgery ? <input type="checkbox"/> ₁ YES <input type="checkbox"/> ₀ NO	
5. Were you able to return to the level at which you had been playing/participating prior to when your hip pain/symptoms began ? <input type="checkbox"/> ₁ YES <input type="checkbox"/> ₀ NO	
6. If YES to question 4 or 5, have you been able to maintain that level of play?	
<input type="checkbox"/> ₁ Yes, I've maintained my level of play	
<input type="checkbox"/> ₂ No, my hip caused me to decrease my level of play	
<input type="checkbox"/> ₃ No, my level of play decreased, but not because of my hip	

Figure 1. An athletic activity questionnaire developed for this study and mailed to all study patients identified as potential athletes.

included laterality of surgery, previous surgery on the same hip, and labral tear data recorded during the time of PAO (when applicable). Also, procedures performed on the same hip after PAO, including arthroplasty, were recorded, but removal of hardware procedures were excluded from this analysis, given that elective screw removal was recommended by both senior surgeons to all patients who underwent PAO throughout the study period.

Radiologic Measurements

Radiographic evaluation of preoperative and postoperative images included AP pelvic view, a frog or Dunn lateral view, and a false profile view. All postoperative radiographic values were measured based on the most recent office visit in which radiographs were obtained, which

correlated with the time of the functional outcome measure collection in the majority of cases, uniformly greater than 1 year postoperatively. The AP pelvis radiograph was used to measure LCEA and Tönnis angle. The Dunn lateral or frog-leg lateral was used for an alpha angle measurement and the false profile image was used to measure the anterior center edge angle.

In the subpopulation of patients for whom a delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) study was obtained, the glycosaminoglycan (GAG) content of the weightbearing cartilage of the hip was assessed using previously described techniques, with the dGEMRIC index (measured in milliseconds) representing the average T1 value of the acetabular and femoral head cartilages in the weightbearing zone across 4 coronal slices of the hip.^{8,13,18,19,25,26} The dGEMRIC index,

UCLA Activity Scale	
1. Please circle the ONE number that best describes your activity level over the last 6 months. Regularly = once a week or more Sometimes = once a month or less	
10	I regularly participate in <i>impact sports</i> such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking
9	I sometimes participate in <i>impact sports</i> such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking
8	I regularly participate in <i>very active</i> events such as golf or bowling
7	I regularly participate in <i>active</i> events such as bicycling
6	I regularly participate in <i>moderate activities</i> such as swimming, unlimited housework, or shopping
5	I sometimes participate in <i>moderate activities</i> such as swimming, unlimited housework, or shopping
4	I regularly participate in <i>mild activities</i> such as walking, limited housework, or limited shopping
3	I sometimes participate in <i>mild activities</i> such as walking, limited housework, or limited shopping
2	I am mostly inactive : restricted to minimal activities of daily living
1	I am wholly inactive : dependent on others; cannot leave residence

Figure 2. University of California–Los Angeles (UCLA) Activity Scale. (Adapted from Amstutz HC, Thomas BJ, Jinnah R, Kim W, Grogan T, Yale C. Treatment of primary osteoarthritis of the hip. A comparison of total joint and surface replacement arthroplasty. *J Bone Joint Surg Am.* 1984;66(2):228-241.)

which has been used as a marker of the progression of osteoarthritis in the affected hip, was also assessed for potential correlation with functional outcomes and RTP in this population.

Functional Outcomes

The standard hip questionnaire, which was given to patients both preoperatively and a minimum of 1 year postoperatively, contained well-described, established functional outcome measures, including the modified Harris Hip Score (mHHS) and the Hip Disability and Osteoarthritis Outcome Score (HOOS).^{36,48} A subset of the HOOS, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), was used to assess pain, stiffness, and function.⁴⁸ For patients who underwent bilateral PAO, separate forms were collected for each hip.

Activity Level and Sports Participation

The UCLA-AS, a previously validated activity scale instrument,⁵¹ was included in the standard hip questionnaire and describes 10 different activity levels from which patients choose according to how active they are at the time of completing the questionnaire (Figure 2). The athletic activity questionnaire was developed at the study institution and includes a series of questions related to the degree of athletic participation and competition, as well as any changes in participation or performance before and after

the hip procedure. The questionnaire was also designed to allow for better understanding of whether the reasons for failing to return to sports were for hip or non-hip-related reasons, as may be common for high school athletes who do not continue competitive sports in college.

To be deemed an athlete, a patient had to meet each of 3 separate criteria, which included (1) a minimum preoperative or postoperative UCLA-AS score of 8 of 10, suggesting at least “regular [participation] in active activities,” as described in the instrument⁵¹; (2) reported preoperative athletic participation; and (3) completion of the athletic activity questionnaire, in which patients identified in which sports they participated and at which level they played. Although the authors of a recent study published in the sports medicine literature described a similar athletic population of PAO patients and utilized a minimum UCLA-AS score of 7,⁵ the current study was designed to have even stricter inclusion criteria to ensure an athletic population. The study population of athletes was further substratified into those who identified themselves as recreational athletes on the athletic activity questionnaire (answering 1 or 2 on question 1b) versus those who identified themselves as competitive athletes (answering between 3 and 7 on question 1b). A further subset of the competitive athletes underwent substratified analysis according to a designation as elite athletes or those who participated in either collegiate, semiprofessional, or professional competitive sports (answering between 5 and 7 on question 1b).

Statistical Analysis

Analysis of demographic, clinical, and functional outcomes data, including comparisons between competitive and recreational athletic subpopulations, was performed using the *t* test, with separate assessment of mean improvement in mHHS and HOOS using paired *t* tests. Because WOMAC scores demonstrated a non-normal, skewed distribution, preoperative to postoperative change was assessed using the Wilcoxon signed-ranks test, with values summarized as median and interquartile ranges. A Kaplan-Meier survivorship curve was constructed to estimate the median time to RTP for the entire cohort of 46 participants, with competitive and recreational athletes compared by the log-rank test. A multivariable Cox regression model was utilized to assess potential risk factors (including age, sex, follow-up time, and preoperative functional outcome measure scores) for prolonged RTP. Statistical analysis was performed using SPSS software (version 21.0; IBM Corp). Two-tailed values of *P* < .05 were considered statistically significant.

RESULTS

During the 5-year study period, 245 PAO surgeries were performed at the study institution by 1 of 2 different surgeons (Y.K., M.M.). Forty-six of these procedures had been performed in 41 patients who met the inclusion criterion of being an athlete (36 females; mean age, 26.2 years; range, 13-41 years; 19% of all PAOs). Five patients meeting selection criteria had outcomes collected for bilateral hips.

TABLE 1
Distribution of Patient Volume by Sport Played

Sport	No. of Patients (%)
Running sports (cross-country, track and field, etc)	20 (13.9)
Skiing or snowboarding	15 (10.4)
Other	14 (9.7)
Cycling (mountain, road, track, etc)	13 (9.0)
Swimming	13 (9.0)
Soccer	12 (8.3)
Basketball	11 (7.6)
Racquet sports (tennis, squash)	5 (3.5)
Softball	5 (3.5)
Miscellaneous (rugby, field hockey, diving, horseback riding, triathlon, cheerleading, hammer throwing, rock climbing, football, wrestling, weightlifting, volleyball, lacrosse, baseball, hockey, gymnastics, dance, martial arts)	36 (25.0)

TABLE 2
Comparison of All Previous Hip Procedures Performed Within the 2 Athletic Subpopulations

Hip Procedure	No. of Competitive Athletes	No. of Recreational Athletes
Hip arthroscopy	1	3
Varus osteotomy	1	0
Femoral osteotomy	1	0
Dega-Pemberton osteotomy	1	0
Open reduction	1	1
Closed reduction/spica	1	0
Closed reduction	0	1
Acetabular prosthesis	1	0
Varus shortening	1	0
Intertrochanteric osteotomy	2	1
Screw removal	1	0
Pavlik harness	0	1
Abduction brace	0	1
Cast brace	0	1

Within this athletic study population, a variety of sports were represented, most commonly competitive running, skiing/snowboarding, and swimming (Table 1), although most patients reported participation in multiple sports. Overall, individual sports were more common than team sports. On the basis of the above-described categories of athletic participation, surgery was performed for recreational athletes in 20 of 46 cases (43%), compared with competitive athletes in 26 of 46 cases (57%). The distribution of patients according to their athletic level is illustrated in Figure 3, which demonstrates that there were no professional athletes in the cohort, but 21% were elite athletes (collegiate or semiprofessional).

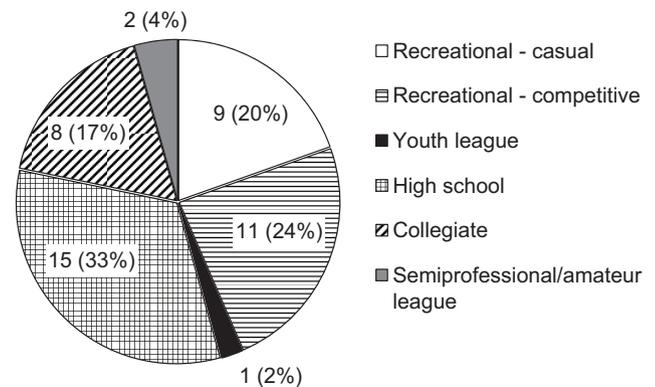


Figure 3. Distribution of athletic PAO patients based on highest level of active athletic participation just before the worsening of the hip symptoms that prompted seeking medical attention. PAO, periacetabular osteotomy.

Previous surgery had been performed on 9 hips (20%) at various ages, with a breakdown of the procedures relatively evenly distributed between patients in the recreational and competitive subsets (Table 2). Preoperative dGEMRIC indices were quantified for 33 study patients (mean, 600 ± 116 ms; range, 365-831 ms), with scores unable to be correlated in any significant way with either RTP or any of the postoperative functional outcome scores. Among 33 patients who underwent arthroscopy and intra-articular inspection at the time of PAO, labral detachment was seen in 1 patient (who underwent repair) and labral fissuring or degenerative tear with no detachment was seen in 3 patients (for whom partial debridement or no intervention was pursued).

In the follow-up period after PAO (mean 3.0 ± 0.9 years; range, 1.2-4.4 years), only 1 patient (2%) underwent an additional postsurgical procedure (open excision of heterotopic ossification at 2.9 years postoperatively) other than simple removal of iliac crest/PAO screws, which all represented outpatient procedures with no reported complications. No arthroplasty procedures had been performed on this population throughout the study period.

Preoperatively, there was no significant difference ($P = .35$) in the LCEA of the recreational athletes compared with the competitive athletes. Postoperatively, radiographic parameters for dysplasia had significantly improved in all patients, and all osteotomies were found to be healed in an expectable manner, with no delayed unions or nonunions. The mean Tönnis angle improved from 19° to 6°, the anterior center edge angle improved from 12° to 29°, and the LCEA improved from 8° to 23°. Functional outcome measures, before surgery and at the time of final follow-up, are compared for the entire cohort and within the athletic subpopulations in Tables 3 and 4, respectively. Notably, there was no significant change in UCLA-AS score in either athletic subpopulation or in the overall population.

RTP was reported in 80% of cases (37 of 46), although non-hip-related reasons were cited in one-third of the

TABLE 3
Comparison of Pre- and Postoperative Radiographic Parameters and Functional Outcome Measures^a

	Preoperative	Postoperative	P Value
Functional score, mean ± SD			
UCLA	8 ± 2	8 ± 2	.28 ^b
mHHS	70 ± 15	90 ± 12	<.001 ^b
HOOS	64 ± 18	89 ± 13	<.001 ^b
Improvement from preoperative, mean (95% CI)			
mHHS		20 (14-25)	
HOOS		25 (19-30)	
WOMAC score, median (interquartile range)			
Pain	8 (5-9)	1 (0-2)	<.001
Stiffness	3 (1-4)	1 (0-2)	<.001
Function	13 (5-23)	0 (0-3)	<.001

^aHOOS, Hip Disability and Osteoarthritis Outcome Score; mHHS, modified Harris Hip Score; UCLA, University of California–Los Angeles Activity Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

^bPaired *t* test.

TABLE 4
Comparison of Outcomes Related to Function and Return to Play Between Recreational and Competitive Athletes^a

	Competitive Athlete (n = 26)	Recreational Athlete (n = 20)	P Value
Preoperative			
Hip scores, mean ± SD			
UCLA-AS	7.9 ± 2.2	7.9 ± 1.8	.95
Marx	8.5 ± 6.0	5.0 ± 3.8	.02 ^b
mHHS	71 ± 17	70 ± 13	.92
HOOS	63 ± 20	65 ± 14	.70
WOMAC, median (IQR)			
Pain	8 (4-9)	6 (5-9)	.96
Stiffness	2 (1-4)	3 (2-5)	.12
Function	15 (3-29)	12 (5-19)	.76
Postoperative			
Hip scores, mean ± SD			
UCLA-AS	8.4 ± 1.6	8.3 ± 1.7	.85
mHHS	86 ± 13	95 ± 7	<.01 ^b
HOOS	87 ± 15	93 ± 8	.07
WOMAC, median (IQR)			
Pain	1 (0-3)	1 (0-2)	.49
Stiffness	1 (1-2)	0 (0-1)	.33
Function	2 (0-5)	0 (0-1)	.05 ^b
RTP			
No. of patients (%)	19 (73)	18 (90)	.26 ^c
Time to RTP, mo, median (95% CI)	10 (7-13)	9 (7-11)	.31 ^d

^aHOOS, Hip Disability and Osteoarthritis Outcome Score; IQR, interquartile range; mHHS, modified Harris Hip Score; RTP, return to play; UCLA, University of California–Los Angeles Activity Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

^bSignificant values.

^cFisher exact test.

^dLog-rank test.

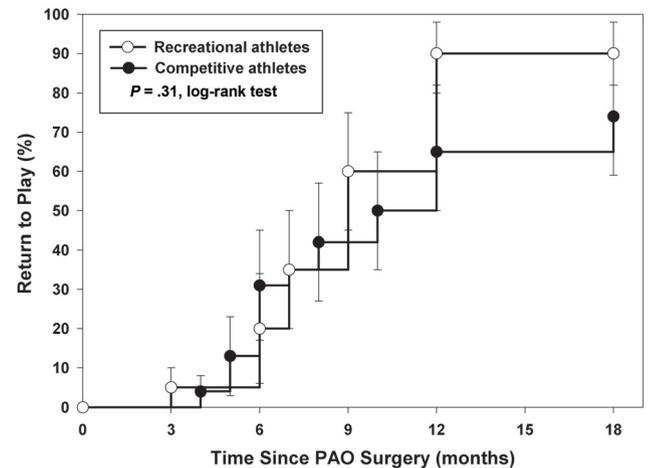


Figure 4. Kaplan-Meier survivorship curve demonstrating time between surgery and return to play in the subpopulations of recreational and competitive athletes. PAO, periace-tabular osteotomy.

cases in which there was not RTP (3 of 9). The mean duration between surgery and RTP was approximately 9 months (95% CI, 7-11 months). The log-rank test indicated no significant difference in the median time to return between competitive and recreational athletes (10 vs 9 months; *P* = .31) (Figure 4). When considering age, sex, type of athlete (competitive vs recreational), preoperative pain score, and postoperative pain score by Cox multivariable analysis, only postoperative pain was a significant factor associated with time to RTP (*P* = .01). Approximately 73% of patients who returned to play (27 of 37) reported achieving a postoperative level of athletic performance the same or higher than their previous level of performance, with maintenance of this level through the entire follow-up period in 85% of these cases (23 of 27). Notably, the ability of the recreational athletes to maintain play at the previous level was significantly greater than that of the competitive athletes (Table 4).

When specifically analyzing the subset of elite athletes in the cohort (those in competitive collegiate and semiprofessional/amateur leagues) who completed the relevant sections of the questionnaire (*n* = 7), 4 patients (57%) were able to return to their prior level of play, 2 of whom were able to maintain this level throughout the entire follow-up period. All 5 elite athletes (71%) who were not able to maintain their level of play cited their hip as the reason for this decline.

DISCUSSION

As our understanding of the spectrum of hip disorders in adolescents and young adults continues to expand, surgical techniques focused on hip preservation are being utilized not only with greater frequency but also in an increasingly broader patient population. One such technique is the Bernese PAO, which was popularized by the work of Ganz

et al^{16,17} over the past 2 decades for the treatment of symptomatic hip dysplasia.^{21,27,33,41,43} Designed to reorient a shallow or deficient acetabular roof into a more mechanically stable position of coverage for the femoral head, the PAO has been demonstrated to decrease pain and improve function in a variety of patient groups with dysplasia.^{39,46} Most studies reporting on outcomes after PAO have centered around validated instruments of quality of life and hip function, such as the WOMAC,^{2,3} the Merle d'Aubigné-Postel hip score,¹⁴ and the Harris Hip Score.²⁰

However, little evidence to date has focused specifically on the athletic function of typical patients undergoing PAO⁵⁰ or on the outcomes of an athletic subpopulation. One study by van Bergayk and Garbuz⁵⁰ utilized what they deemed "sports-specific outcomes" in the form of the Tegner activity scale in a series of 26 consecutive patients undergoing PAO, 22 of whom returned mailed questionnaires. Although improvement in the activity scale was seen after surgery, both mean preoperative and postoperative values were lower than 5, with only 2 patients reporting postoperative values being higher than 6, suggesting a markedly nonathletic cohort. Moreover, the preoperative measures were collected in the postoperative period, an approach that is subject to significant methodological limitations such as recall bias. Studies have examined the results of other open reconstructive hip techniques in athletes,^{4,35} some of which have aptly provided comparisons with arthroscopic alternatives.^{1,6} However, these analyses have been limited largely to the treatment of femoroacetabular impingement, which is a very different pathological entity from dysplasia in the realm of hip preservation. Novais et al³⁷ previously demonstrated that activity level can improve after PAO, and that younger age and lower preoperative pain are predictive factors for greater improvement. However, this investigation was performed on a general PAO population, at least over two-thirds of which would not have been eligible for inclusion in the current study based on the methodology. Bogunovic et al⁵ evaluated 36 active patients (defined as a UCLA-AS ≥ 7) and showed that 71% of their patients returned to the same or higher activity level, compared with preoperative status, as assessed by postoperative UCLA-AS score. However, the authors did not provide any details regarding specific type or level of athletic participation, and they did not investigate patients' ability to maintain any particular level of activity or athletic performance over time.

The goal of the current study was therefore to explore the radiographic, clinical, and functional outcomes in an athletic subpopulation undergoing PAO and better understand the potential for return to athletics in these patients, including competitive sports in elite athletes. The anecdotal impetus for the study was 2-fold: (1) the observation by the senior authors (Y.K., M.M.) that, over time, the patient population presenting to our regional hip center with symptomatic dysplasia was reporting greater baseline athletic activity level before the onset or worsening of their symptoms, with limitations in athletic performance being an increasingly common primary presenting complaint; and (2) that patients who had previously seen orthopaedic surgeons specializing in sports medicine frequently

reported being discouraged from pursuing open hip procedures if a return to athletics was desired. In other words, there appeared to be concern among both patients and colleagues in our field that undergoing an open reconstructive hip surgery as extensive or invasive as a PAO might not allow for a return to sports.

Perhaps PAO was traditionally viewed as a debilitating operation with significant morbidity,^{15,32,49} but perception of the results or rehabilitation associated with PAO may be lagging behind the current reality. As more widespread understanding and surgical expertise with the Bernese technique has been developed, newer, multicenter evidence suggests that the complications and recovery times may be more limited than previously thought, provided that the appropriate patient selection is performed by those with adequate training and technical expertise.^{42,44,47}

In the current series spanning a 5-year period, approximately 19% of all patients undergoing PAO at our institution were athletes, based on criteria that combined a baseline level of athletic activity in a validated activity scale and self-assigned athletic status. In an effort to optimize our capture of the athletic subpopulations, patients received the original sports questionnaire if they reported the minimum activity score in either the preoperative or postoperative period, based on the assumption that some patients' activity levels may have dropped to artificially low levels in the 6 to 12 months before their surgery as a result of symptoms of their hip dysplasia.

During the postoperative study period, approximately three-quarters of all athletes who had undergone PAO were able to return to athletics, although 59% returned to the prior level of play they had achieved before their hip symptoms limited their activities. Somewhat intuitively, the amount of postoperative pain was found to be associated with the timing of return to athletic activity. Interestingly, there was no association between sex, age, or preoperative pain, based on the regression analysis. Using the UCLA-AS score, there was no decline in the cohort's mean activity levels at a mean of almost 3 years after surgery. Nevertheless, 9% of the patients who, at some point, achieved a RTP at their previous level of performance ultimately saw a decline in that performance during the study period. Although some of these patients reported issues not related to their hip as the cause of this decline, more than one-half of the elite athletes did cite their hip as the reason for the decline, and only 42% of the competitive athletes maintained the same level of play, which was significantly lower than the 83% of recreational athletes. Moreover, the competitive cohort was significantly younger than the recreational cohort, suggesting that small differences in activity levels at the most extreme, active end of the spectrum may play a larger role than has been reported before and may have a stronger link to symptoms than age. The overall findings regarding activity level were slightly different than those described by Bogunovic et al,⁵ in that a substantial portion of their population saw increases in activity level postoperatively. This most likely relates to their inclusion of 1 additional segment of patients with a lower level of activity on the preoperative UCLA-AS (ie, those who scored 7 of 10), who had more room to improve

than the current population, from which was also filtered any patient who did not specifically identify themselves as an athlete, an exclusion criterion absent from the methodology in prior studies.^{5,37}

The majority of athletic patients were female, which is consistent with the known epidemiology of hip dysplasia.^{22-24,52} The sports played by this population included a very broad range of sports, but individual and endurance sports were more common within the cohort than team sports. However, basketball and soccer were notably among the 6 most commonly played sports. Interestingly, both swimming and biking were also among this group, suggesting that symptoms of hip dysplasia can significantly affect and limit highly active patients, even when pursuing relatively low-impact, nonweightbearing activities. Although the majority of patients were involved in competitive sports, relatively few elite athletes (4% of all PAO patients, 22% of athletic patients), which we defined by involvement in either collegiate, semiprofessional, or professional leagues, were identified in this population. However, no patients in this study proved to be professional athletes, which could suggest that the symptoms of significant dysplasia may be limiting enough to select patients who are out of the extreme level of activity needed to reach the professional ranks. Although many young adults are treated at the institutional hip center at which the study was conducted, the fact that it is a children's hospital may introduce a component of selection bias against such a subpopulation.

By radiographic parameters and functional outcome measures specific to the hip joint, most athletic patients showed adequate reorientation of their acetabular deformity and significant improvements in function, respectively. However, although radiographic reorientation of acetabular alignment toward normal values was achieved, longer term studies are needed to investigate progression toward osteoarthritis and other chronic changes in the hip. The mean dGEMRIC index scores for this population suggested minimal degeneration in the majority of the population, and the scores were not found to correlate with functional outcomes or return to athletic participation. This finding was not surprising, given that previous work on this subject demonstrated significantly lower mean values being predictive of poorer outcomes after PAO. Despite only moderate success with RTP at a sustainable athletic performance level, from the perspective of functional outcomes, general activity level, and dGEMRIC, this appears to be an appropriately selected population for this procedure.

Limitations of the current study include a relatively small sample size and those inherent in a retrospective analysis, such as recall bias and selection bias. The small sample size may have limited the number of elite athletes in the current cohort, which was notably devoid of professional-level athletes. Further prospective research, which pools patient populations from multiple geographic regions treated at multiple institutions, is needed to further elucidate the medium- and long-term results of PAO in athletes at different ages and at different levels of participation and competition. Moreover, the questionnaire investigating athletic activity has not been comprehensively validated.

Finally, the study lacked a control group of athletes with comparable ages, sports, and levels of participation, which may have demonstrated important population-based differences or similarities in the inability to maintain athletic levels over time, a well-perceived phenomenon that has not been systematically quantified to date.

In summary, PAO is generally an effective treatment for acetabular dysplasia in adolescent and young adults hoping to return to athletics. Most treated athletes demonstrated improved function and high activity levels and returned to sports at a level comparable with their prior performance. The ability to maintain prior levels of performance over time remains good overall but is somewhat variable, with results in elite and competitive athletes not as favorable as those involved in recreational athletics. These data may be helpful in counseling athletes with symptomatic dysplasia significant enough to warrant reconstructive hip surgery and adjusting expectations appropriately.

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