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Factors associated with long-term activity after rotational acetabular osteotomy: a minimum ten-year follow-up study

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Research Article

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Abstract

Background

In this study, we aimed to evaluate patient activity more than 10 years after rotational acetabular osteotomy (RAO) and investigate the radiographic and clinical factors associated with sustained postoperative activity.

Methods

We retrospectively reviewed 59 hips of 59 patients who underwent RAO, with a minimum follow-up of 10 years. The mean age at surgery was 38 years (range, 16–57 years) and the mean follow-up period was 176 months (range, 120–240 months). Activity at the final follow-up was assessed using the University of California, Los Angeles (UCLA) activity score and the 2011 Knee Society Score. Radiographic parameters included minimal joint space (MJS), lateral center-edge (CE) angle, anterior center-edge (ACE) angle, vertical-center-anterior (VCA) angle, acetabular roof obliquity, femoral anteversion, femoral head translation distance (FTD), and the presence of a crossover sign. Labral injury was also evaluated as a clinical variable. Associations between the activity levels and clinical and radiographic variables were examined using univariate and multivariate regression analyses.

Results

At final follow-up, 33 patients (56%) engaged in low-demand activities (UCLA ≤ 4), 21 (36%) in intermediate-demand activities (UCLA 5–6), and 5 (8%) in high-demand activities (UCLA ≥ 7). Higher UCLA scores were significantly associated with greater postoperative MJS, CE angle, ACE angle, and VCA angle, as well as smaller FTD. In multivariate regression analysis, postoperative MJS, CE angle, and FTD remained independent predictors of long-term activity levels.

Conclusions

More than 10 years after RAO, most patients continued to participate in low- to intermediate-demand activities. Long-term activity was independently associated with postoperative joint space preservation, adequate acetabular coverage, and restoration of femoral head containment. Therefore, optimizing acetabular correction and minimizing residual femoral head translation may be critical not only for joint preservation but also for sustaining long-term patient activity.

Background

Developmental dysplasia of the hip (DDH) is characterized by abnormal hip morphology and represents a major cause of hip osteoarthritis (OA) [1, 2]. Smaller acetabular coverage in DDH can produce an

asymmetric concentration of force across the hip joint and increase mechanical stress on the cartilage, resulting in hip pain and dysfunction [3, 4].

Rotational acetabular osteotomy (RAO) is an established joint-preserving procedure for symptomatic DDH [5]. RAO reorients the acetabulum to improve anterolateral acetabular inclination and femoral head coverage, medially transfers the joint center, and normalizes acetabular rim loading [6]. Numerous studies have demonstrated favorable long-term survival and radiographic outcomes after RAO [7–9]. Most investigations have focused primarily on clinical endpoints such as OA progression and conversion to total hip arthroplasty; however, postoperative improvements in functional level or patient satisfaction may be more important endpoints for active younger patients [9–12]. For relatively young and active patients undergoing joint-preserving surgery, the maintenance of physical activity represents a vital metric for evaluating the therapeutic effects of discrepancies between surgeons and patients with respect to clinical evaluations (in determining the efficacy or appropriateness of a procedure) or healthcare systems (in the context of value-based healthcare). While patient-reported outcome measures, such as the Harris Hip Score, have been reported, the long-term activity level, sports participation, and factors affecting long-term activity level following RAO have not been systematically evaluated. Therefore, in this study, we sought to evaluate activity levels and sports participation more than 10 years after RAO, and identify clinical and radiographic factors associated with long-term postoperative activity.

Methods

Study Population

From February 2010 to January 2015, RAO was performed for DDH in 59 patients (59 hips), including 55 women and four men, without femoral osteotomy. The indications for RAO included activity-related hip pain, center-edge angle (CEA) of Wiberg < 20°, and improved femoral head coverage and joint congruency on preoperative anteroposterior (AP) plain radiographs of the hip in abduction [13]. The mean age at surgery was 38.8 (range, 18–47) years, and all patients were diagnosed with early-stage OA (according to Japanese Orthopaedic Association [JOA] criteria) (Table 1). Postoperative activities were evaluated using the University of California at Los Angeles (UCLA) activity score before surgery and at the final follow-up [14, 15]. The postoperative activity level was also assessed using the 2011 Knee Society Scoring System (KSS) as described by Scuderi et al., specifically the advanced activities subscale within the functional activities domain [16]. Clinical evaluations, including the JOA score (0–100 points, where 0 was the worst and 100 was the best; pain, 40; range of motion, 20; walking, 20; and activities of daily living [ADL]), were evaluated preoperatively and at the final follow-up. Furthermore, patient-reported outcome measures (PROMs) were assessed using the Japanese Orthopaedic Association Hip Disease Evaluation Questionnaire (JHEQ) (0–88 points, where 0 represents the worst and 88 the best score; pain, 0–28 points; movement, 0–28 points; mental, 0–28 points) and were evaluated at the final follow-up [17]. Radiographic assessments were performed using preoperative and postoperative computed tomography (CT) to evaluate hip morphology. Labral injury was assessed based

on the intraoperative arthroscopic findings. The mean follow-up period was 148 (range, 121 to 198) months.

Surgical Procedure

RAO was performed according to the technique described by Ninomiya and Tagawa [5], with the distinction that fixation of the rotated acetabulum was performed with two poly-L-lactic acid screws (Super-FIXSORB; Depuy, Warsaw, USA) instead of Kirschner wires [13]. Intraoperative evaluation was performed using arthroscopy to assess the labral injuries in all patients. Injuries were graded using the Yoon PW scale [18] and were assigned “positive” when the arthroscopic damage was over grade 2. The grades were as follows: grade 1, partial delamination or blistering of the labrum with minimal fraying at the chondrolabral junction (CLJ); grade 2, labral tears with CLJ disruption; grade 3, unstable labral tears with capsulolabral recess (CLR) disruption without labral displacement; and grade 4, unstable labral tears with CLR and CLJ disruption with labral displacement. After surgery, no postoperative cast was used. Partial weight bearing on two crutches was allowed in the third postoperative week, and full weight bearing was allowed approximately 5 months postoperatively when the Trendelenburg’s sign had disappeared.

Activity Assessment and Stratification

Pre- and postoperative activities, sports, and recreation were assessed using a structured questionnaire administered at the final follow-up. The patients were asked to report the type, frequency, and intensity of activities performed at least twice weekly for a minimum duration of 30 min. The UCLA score (a validated measure of physical activity) was employed [14]. Patients in whom the UCLA score decreased or remained unchanged were classified into the non-improvement group, whereas those demonstrating an increase in the UCLA score at the final follow-up were classified into the improvement group. To enhance construct validity, functional outcomes were assessed using the 2011 KSS, specifically the advanced activities subscale within the domain of functional activities. We specifically analyzed advanced activity subscales, such as squatting, kneeling, and recreational activities, graded according to the degree of difficulty reported by the patient, to evaluate higher-level functional performance beyond the basic ADL. The activities were categorized into three demand levels (low, intermediate, and high) based on impact loading, torsional stress, and pivoting requirements. Low-demand activities are characterized by low-impact, predominantly linear motions with limited torsional stress, such as long-distance walking, swimming, stationary cycling, recreational cycling on level ground, gardening, stretching exercises, golf, and bowling. Moderate-demand activities involve sustained joint loading with mild increases in cumulative mechanical stress, such as biking, long-distance or uphill cycling, and low-impact aerobics. High-demand activities involve repetitive impact loading and/or pivoting movements and are associated with increased joint contact forces and torsional stress; examples include yoga, racket sports (e.g., tennis, badminton), and high-impact aerobics.

Radiographic Evaluation

Supine AP views of the pelvis and Lequesne false-profile radiographs of the hip joint were obtained from all patients preoperatively and at each follow-up visit. CT was performed before and after surgery. The radiographic parameters analyzed were the minimal joint space (MJS) width based on the preoperative AP radiographs (Fig. 1) and the vertical-center-anterior angle (VCAA) from the false-profile radiographs. The CEA, acetabular roof obliquity (ARO), femoral anteversion (FA), and acetabular center-edge angle [19] were calculated using CT. Data were analyzed for intraobserver and interobserver variability, and the coefficient of variation was < 5%.

Assessment of hip instability: US

SONIMAGE HS1/HS1 PRO and SNiBLE diagnostic ultrasound (US) systems and a convex probe (3–13 MHz) (KONICA MINOLTA, Tokyo, Japan) were used [20]. This system and probe clearly showed the femoral head center and acetabulum, even in patients with thick muscles and subcutaneous fat. All patients underwent dynamic US evaluation of the hip joint by two orthopedic surgeons. The patients were instructed to press their lower back flat against the examination table to promote lumbar and pelvic stabilization and minimize variability in pelvic tilt. Subsequently, each hip was visualized in two positions: for the first position, the patient was placed in the supine position with both hips extended with 0° of abduction and internal rotation, designated as the neutral position; for the second position, the patient was placed in the supine position, and the hip was held in the ‘Patrick position’ with hip abduction and external rotation and the contralateral hip in a neutral position. In all positions, the probe was slightly angled to the sagittal plane to identify the femoral head and anterior inferior iliac spine (AIIS). The US examiner scanned the femoral head and AIIS from medial to lateral and located the femoral head and highest point of the AIIS. The distance between the anterior edge of the AIIS and the horizontal line to the sclerotic margin of the femoral head was measured to assess the femoral head position. Using this protocol, the difference between the distances, defined as the femoral head translation distance (FTD), in the neutral and Patrick positions was calculated to evaluate hip stability, as previously reported [20, 21]. This study involved two separate US examinations conducted several weeks apart to measure inter- and intra-observer reliabilities. This protocol tested the reliability among physicians at each time point (inter-observer reliability) as well as the reliability of each orthopedic surgeon individually over time (intra-observer reliability).

Statistical Analysis

All data are expressed as the mean ± standard deviation, and statistical analyses were performed using StatView-J version 5.0 software (Hulinks, Tokyo, Japan). Intergroup differences were evaluated using the Mann–Whitney U test, and correlations were evaluated using Pearson’s *chi*-squared test. Statistical significance was set at $P < 0.05$. A multivariate linear regression model was constructed to identify independent predictors of postoperative activity levels.

Results

Patient characteristics, pre- and postoperative clinical and PROM scores, radiographic parameters, and intra-articular lesions are presented in Table 1. None of the patients underwent conversion to THA during the follow-up. The mean JOA score significantly improved, and radiographic data improved after surgery.

The mean preoperative UCLA activity score was 3.4 ± 1.6, whereas the mean postoperative UCLA activity score was 5.7 ± 2.3. This difference was statistically significant, and the patients were categorized into an improved group (n = 42) and a non-improvement group (n = 17). Regarding the postoperative KSS subscale, all 59 patients engaged in low-demand activities, 21 (51%) and five (7%) engaged in intermediate- and high-demand activities (Fig. 2) The mean satisfaction score was 4.1 ± 1.1, 4.0 ± 1.3, and 4.1 ± 1.0 points for low-, intermediate-, and high-demand activities, with no statistically significant differences observed among the three groups.

Univariate comparisons between the activity groups demonstrated significant differences in radiographic parameters at the final follow-up (Table 2). Patients with higher activity levels had significantly greater final MJS, postoperative CEA, and postoperative ARO. The postoperative VCAA and FTD differed significantly between the groups, but there were no significant differences between the groups with respect to age at surgery, body mass index, duration of follow-up, labral injury, FA, or the presence of a crossover sign (all $p > 0.05$).

Correlation analysis demonstrated significant associations between the UCLA activity score and several radiographic parameters (Table 3). The UCLA score positively correlated with pre-/postoperative MJS and postoperative CEA. Significant negative correlations were also observed between the UCLA scores and postoperative ARO and FTD.

Multivariate regression analysis demonstrated that postoperative CEA, MJS at the final follow-up, and FTD were identified as independent predictors of UCLA activity score at the final follow-up (Table 4). The overall model indicated that postoperative acetabular coverage and femoral head containment accounted for a substantial proportion of the variance in long-term activity level

Discussion

The most important finding of this study was that physical activity more than 10 years after RAO is predominantly maintained at low-to-intermediate demand levels and is independently associated with postoperative joint preservation and acetabular containment. In particular, the postoperative CE angle and anteroposterior FTD emerged as independent predictors of long-term UCLA activity. These findings suggest that the quality of structural correction influences not only radiographic survivorship but also sustained functional capacity over time.

RAO improves hip biomechanics by enhancing femoral head coverage and redistributing contact stress, thereby improving clinical outcomes and PROMs. Previous investigations have primarily focused on joint

survival, radiographic progression, and pain relief, identifying the preoperative severity of dysplasia and residual joint space as important determinants of outcome [22–24]. However, few studies have examined long-term postoperative activity as the principal endpoint. In younger and more active patients with developmental hip dysplasia, the ability to maintain meaningful physical activity may be clinically relevant in delaying arthroplasty. Our study extends the existing knowledge by demonstrating a structural association between postoperative morphology and sustained activity at long-term follow-up.

Physical activity more than 10 years after RAO is predominantly maintained at low-to-intermediate demand levels. Although the mean UCLA activity score significantly improved postoperatively, the distribution of activities based on the KSS subscale demonstrated that all patients engaged in low-demand activities, while only approximately half participated in intermediate-demand activities and a small proportion performed high-demand activities. These findings suggest that even in the long-term after RAO, patients tend to maintain their activity levels within relatively moderate functional demands. Compared with previous reports describing long-term activity levels after THA, the observed activity profile appears somewhat lower, possibly due to the gradual progression of OA after joint-preserving surgery [25–27]. Because the RAO preserves the native joint, residual structural abnormalities or slow degenerative changes may limit the capacity for higher-demand activities over time. However, patient satisfaction did not differ significantly between the three activity groups, indicating that patients were generally satisfied with their current activity levels, regardless of their intensity. Clinically, this suggests that the primary goal of joint-preserving surgery—to maintain acceptable function and quality of life while delaying the need for arthroplasty—can be achieved at a satisfactory level in the long term after RAO.

Postoperative CE angle was independently associated with activity level. Adequate lateral acetabular coverage reduces the peak contact stress and improves the load distribution across the hip joint. Insufficient correction may result in residual instability or edge loading, potentially leading to discomfort or functional limitation that restricts higher-demand activities. Similarly, FTD remained an independent predictor of activity. Persistent femoral head translation may reflect incomplete restoration of joint congruity or subtle instability, resulting in abnormal shear force during dynamic loading. Over time, this mechanical imbalance may contribute to cartilage wear or activity-related symptoms. Together, these findings emphasize the importance of achieving three-dimensional containment and concentric reduction rather than relying solely on coronal plane correction.

Interestingly, the presence of the postoperative crossover sign was not associated with long-term activity levels, which is consistent with previous reports [28]. In contrast, patients without improvement demonstrated increased ARO, suggesting that insufficient correction of acetabular inclination may adversely influence functional outcomes. Although care must be taken to avoid over-interpretation, these observations indicate that balanced correction in both the sagittal and coronal planes may contribute to sustained activity.

Regarding labral pathology, previous reports have questioned whether concomitant labral treatment influences short-term patient-reported outcomes after osteotomy [29–31]. In the present study, labral

injury was not associated with long-term activity, suggesting that correction of the underlying hip morphology reduces labral stress and mitigates its functional impact over time.

Univariate and correlation analyses demonstrated associations between the activity level and final MJS, postoperative VCAA, and postoperative ARO. Maintenance of joint space likely reflects preserved cartilage integrity, enabling repetitive loading and continued participation in physical activity. Although these variables did not remain independent predictors in multivariate modeling, they appear to collectively contribute to the biomechanical environment that supports long-term function. From a clinical perspective, these findings indicate that the objectives of RAO may extend beyond radiographic correction to prevent arthroplasty. Optimizing acetabular coverage and restoring femoral head containment may be important not only for joint preservation, but also for maintaining activity for more than a decade following surgery. Therefore, careful intraoperative assessment of coverage, inclination, and translation may influence both structural durability and long-term functional performance [31, 32].

This study has some limitations. First, its retrospective design introduced the potential for selection and information bias. Second, the cohort was relatively small and predominantly female, reflecting the epidemiology of DDH, but limiting its generalizability. Third, we did not evaluate psychosocial or occupational factors that may influence the activity level. Despite these limitations, the study benefits from a minimum follow-up exceeding 10 years and comprehensive radiographic assessment, including three-dimensional parameters. To the best of our knowledge, this is the first study to evaluate the long-term activity after RAO and identify the structural predictors of sustained activity.

Conclusions

Long-term physical activity for more than 10 years after RAO is predominantly maintained at low-to-intermediate demand levels, which have been shown to be associated with postoperative joint preservation and femoral head containment. Achieving adequate acetabular coverage and minimizing residual femoral head translation may contribute not only to structural survival, but also to sustained functional capacity following joint-preserving surgery for DDH.

Abbreviations

ADL
activities of daily living
AIIS
anterior inferior iliac spine
AP
anteroposterior
ARO
acetabular roof obliquity
CEA

center-edge angle
CLJ
chondrolabral junction
CLR
capsulolabral recess
CT
computed tomography
DDH
developmental dysplasia of the hip
FA
femoral anteversion
FTD
femoral head translation distance
JHEQ
Japanese Orthopaedic Association Hip Disease Evaluation Questionnaire
JOA
Japanese Orthopaedic Association
KSS
Knee Society Scoring System
MJS
minimal joint space
OA
osteoarthritis
PROMs
patient-reported outcome measures
RAO
rotational acetabular osteotomy
THA
total hip arthroplasty
UCLA
University of California at Los Angeles activity score
US
ultrasound
VCAA
vertical center-anterior angle.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee for Epidemiology of Hiroshima University, Hiroshima University (Approval No. E2020-2187). All procedures involving human participants were performed in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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Authors' contributions

TS conceived and designed the study. YK, HM, NN and HK collected the data. TS and SU performed the statistical analysis and drafted the manuscript. UY and NA critically revised the manuscript. All authors read and approved the final manuscript.

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Authors' information (optional)

Not applicable.

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Tables

Tables are available in the Supplementary Files section.

Figures

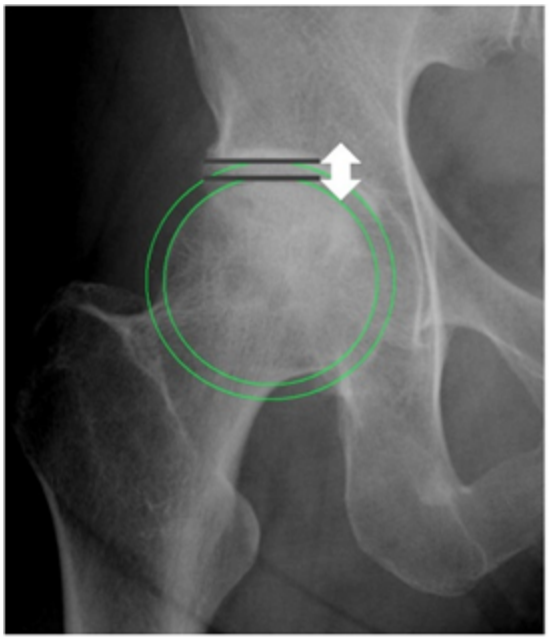


Figure 1

Measurement of minimal joint space (MJS) width. Best fit circles were fitted to the femoral head and acetabular articular surface on anteroposterior hip radiographs. The shortest distance between the two circles (black line) was defined as the minimal joint space (MSJ) width.

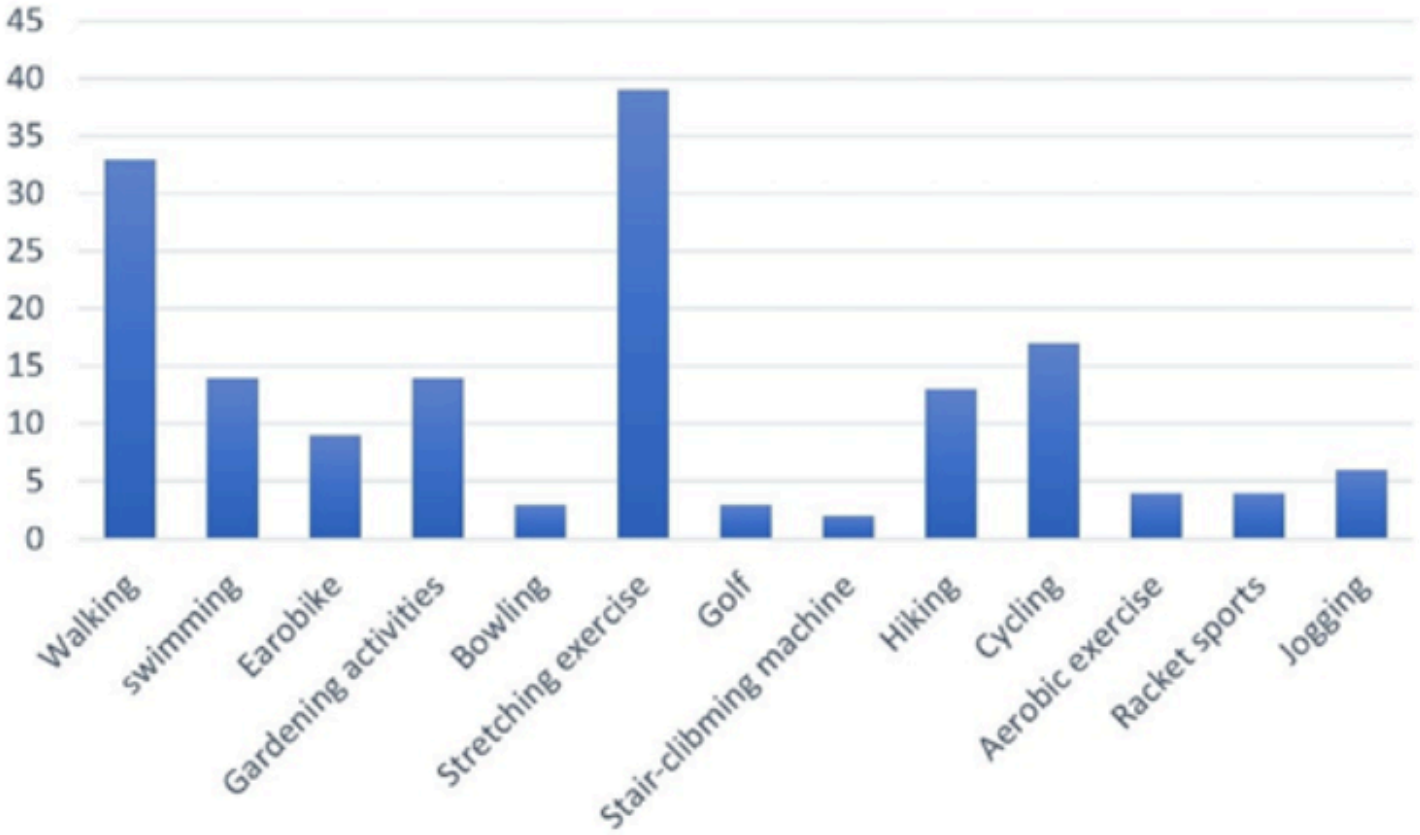


Figure 2

Sports participation at the final follow-up. Distribution of sports and recreational activities among patients more than 10 years after rotational acetabular osteotomy. Bar height represents the number of participants for each activity.

Supplementary Files

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