Hip Kinematics During Racket Swinging After Total Hip Arthroplasty: Rotational Range of Motion and Prosthetic Contact

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INTRODUCTION: Returning to sports after total hip arthroplasty (THA) has become an important aspect of postoperative recovery, especially for younger and more active patients. Racket sports such as tennis, table tennis, and badminton are common recreational activities after THA. However, these activities involve dynamic hip motions, which may pose risks of prosthetic contact or dislocation. This study aimed to analyze dynamic hip kinematics during racket swinging after THA by using image-matching techniques. We hypothesized that racket swinging after THA requires a substantial rotational range of motion and may lead to liner-to-neck contact. The specific objectives were to (1) quantify three-dimensional kinematics during forehand and backhand swings after THA, and (2) determine whether prosthetic contact occurs and identify factors associated with reduced liner-to-neck clearance, as a potential risk factor for prosthetic contact and dislocation.

METHODS: This retrospective case series study was approved by our Institutional Review Board, and informed consent was obtained from all patients. A total of 21 hips in 16 patients who underwent primary THA for osteoarthritis or osteonecrosis of the femoral head at three institutions and had returned to tennis, table tennis, or badminton at least 6 months postoperatively were included. The mean age was 64 ± 8 years, with 5 male hips and 16 female hips. The operated side was the right hip in 13 hips and the left hip in 8 hips. All surgeries were performed via a posterolateral approach. The mean postoperative period was 5 ± 4 years. Sports participation included tennis in 9 hips, table tennis in 9 hips, and badminton in 3 hips. Implant positioning parameters were as follows: the mean cup inclination was 36° ± 6°, mean cup anteversion was 21° ± 7°, and mean stem anteversion 27° ± 9°. Liners were either flat (13 hips) or elevated (8 hips).

Continuous radiographic images of the forehand and backhand swings were obtained using a flat-panel x-ray detector. Three-dimensional kinematics, including flexion/extension, abduction/adduction, and internal/external rotation, were analyzed using image-matching techniques. Liner-to-neck contact was assessed, and anterior and posterior clearance were measured. Anterior clearance was defined as the internal rotation angle remaining before prosthetic contact at maximum internal rotation. Posterior clearance was assessed as the extension angle and externa rotation (ER) angle remaining before prosthetic contact at maximum ER. Multivariable regression analysis was performed to identify factors associated with reduced liner-to-neck clearance, considering factors such as hip kinematics (maximum ER angle, flexion/extension angle at maximum ER, abduction/adduction angle at maximum ER), cup inclination, cup anteversion, stem anteversion, and liner type (flat/elevated).

As a sub-analysis, we compared hip kinematics and liner-to-neck clearance between tennis (n = 9 hips) and table tennis (n = 9 hips) participants.

RESULTS SECTION: During racket swinging, hips remained in slight flexion (mean 4°) and abduction (mean 5°) throughout the motion. The mean total axial rotation from take-back to follow-through was 33° ± 16°. Liner-to-neck contact occurred in 2 of 21 hips (10%), both with elevated liners and at maximum external rotation. Hips with contact had significantly greater cup anteversion (28° vs 20°, $p = 0.03$) and smaller stem anteversion (15° vs 28°, $p = 0.01$). The mean anterior clearance was 141° ± 32°. The mean posterior clearance was 27° ± 21° in extension and 55° ± 54° in ER.

Multivariable regression analysis identified maximum ER angle ($p < 0.01$), flexion/extension angle at maximum ER ($p < 0.01$), elevated liner use ($p < 0.01$), cup anteversion ($p < 0.01$), and stem anteversion ($p = 0.04$) as significant factors for posterior clearance in extension. For posterior clearance in ER, significant factors were flexion/extension angle at maximum ER ($p < 0.01$), abduction/adduction angle at maximum ER ($p < 0.01$), elevated liner use ($p < 0.01$), and cup anteversion ($p < 0.01$).

In a sub-analysis comparing patients who played tennis and those who played table tennis, no significant differences were observed in hip kinematics (maximum ER 13° vs 18°, $p = 0.13$; flexion/extension angle at maximum ER 4° flexion vs 3° extension, $p = 0.12$; abduction/adduction angle at maximum ER 7° vs 7°, $p = 0.85$) and liner-to-neck clearance (posterior clearance in extension 23° vs 22°, $p = 0.84$; posterior clearance in ER 50° vs 43°, $p = 0.81$).

DISCUSSION: This study is the first to quantify three-dimensional hip motion during racket swinging after THA. Contrary to our hypothesis, racket swinging did not require an excessive rotational range of motion, averaging 32°, which was similar to healthy individuals (29°) and lower than values reported for golf swings (50°)[1,2]. Liner-to-neck contact was infrequent (10%) and occurred only at the elevated liner rim at maximum ER, suggesting that the overall risk of prosthetic contact during racket swinging is low. Reduced posterior clearance was associated with elevated liner use, greater cup anteversion, and increased extension/external rotation angles, highlighting the importance of optimizing cup orientation and liner selection to minimize impingement risk in active patients.

This study has several limitations. The small sample size and potential selection bias may limit generalizability. The kinematic data were obtained from swings performed in a limited space under controlled conditions, and impact forces were not considered, which may not fully reflect the actual demands of play. Nevertheless, our findings demonstrated that racket swinging did not require excessive hip rotation, supporting the safety of swing movements after THA.

In conclusion, racket swinging after THA was performed without excessive hip rotation and with a low frequency of prosthetic contact. Liner-to-neck contact at the elevated rim occurred in 10% of hips during maximum ER. Elevated liner use, greater cup anteversion, and increased extension angles were associated with reduced posterior clearance, emphasizing the importance of careful implant selection and orientation for safe return to racket sports.

SIGNIFICANCE/CLINICAL RELEVANCE: This study provides the first quantitative evaluation of hip kinematics and implant contact during racket swinging after THA, demonstrating that the motion can generally be performed with minimal impingement risk. Considerations for maintaining posterior clearance include avoiding elevated liners and preventing excessive cup anteversion, which may help enable safe participation in racket sports after THA.

REFERENCES:

1. Martin C, Sorel A, Touzard P, Bideau B, Gaborit R, DeGroot H, Kulpa R. Orthop J Sports Med. 2020 Dec 11;8(12):2325967120966297.
2. Hara D, Nakashima Y, Hamai S, Higaki H, Ikebe S, Shimoto T, Yoshimoto K, Iwamoto Y. Am J Sports Med. 2016 Jul;44(7):1801-9.