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ORIGINAL ARTICLE

# The effects of modified hardinge approach on hip muscle strength in patients with primary hip arthroplasty: a patient evaluation with isokinetic strength test and gait analyses

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## Abstract

**Objective** Numerous factors affect abductor strength after Total hip arthroplasty (THA), including surgical technique, prosthesis type, postoperative rehabilitation program, and preoperative patient condition. We prospectively investigated the effects of the modified Hardinge approach on hip muscle strength, which was evaluated using the isokinetic test, functional results, and gait function of patients who underwent primary THA.

**Methods** The hip muscles strength were measured using an isokinetic dynamometer. The primary outcomes of the present study were measurement of isokinetic strength of hip abductor muscle strengths using an isokinetic evaluator and gait analyses preoperatively and at 6 months postoperatively in 27 patients.

**Results** Isokinetic muscle strength test, abductor and other hip circumference groups achieved the preoperative muscle strength at 3 months postoperatively, and the postoperative sixth month values showed a statistically significant improvement compared with the preoperative and third month values. In gait analyze, our temporospatial data showed a slight regression at postoperative 3 months but reached the same values at 6 months postoperatively. Kinematic data showed a significant regression, but the data were not compared with those in the preoperative period.

**Conclusions** Adequate muscle strength and physiological gait pattern, similar to the preoperative status, can be achieved at 6 months postoperatively.

**Level of evidence** Level III.

**Keywords** Hip arthroplasty · Isokinetic muscle strength · Gait analyses · Modified hardinge approach · Hip osteoarthrosis

## Introduction

Total hip arthroplasty (THA) is a widely used surgical intervention for end-stage hip osteoarthritis and is considered one of the most successful orthopedic surgeries [1]. Several surgical techniques are available for THA, such as the lateral approach for hip arthroplasty, also known as the Hardinge approach, which provides excellent exposure and allows easy acetabular and femoral component insertion [2, 3]. However, the major disadvantage of this approach is the release of the anterior third of the gluteus muscle tendon on the greater trochanter, which ultimately results in limping because of abduction failure.

Studies on THA typically include functional results, abductor muscle power, and gait function after surgery. Satisfactory abductor muscle strength directly relies on good physical and functional outcomes after THA [4]. Numerous

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factors affect abductor strength after THA, including surgical technique, prosthesis type, postoperative rehabilitation program, and preoperative patient condition [5, 6].

Herein, we prospectively investigated the effects of the modified Hardinge approach on hip muscle strength, which was evaluated using the isokinetic test, functional results, and gait function of patients who underwent primary THA.

## Material and methods

This prospective observational analytical study was conducted from February 2016 to May 2017 at a primary arthroplasty clinic. Patients with primary hip osteoarthritis who underwent surgery at our center were asked to voluntarily participate in this study. This study was approved by the institutional review board of the ethics committee of orthopedics and traumatology. Detailed study procedures were explained to all patients, and written informed consent was obtained from them. This prospective study assessed the recovery of abduction strength after surgery based on isokinetic muscle strength using isokinetic test and gait analyses.

The inclusion criteria were patients with primary end-stage hip osteoarthritis who were treated with primary THA. The exclusion criteria were as follows: patients who underwent hip replacement surgery for secondary hip osteoarthritis (e.g., trauma or rheumatological disease), revision hip arthroplasty, or surgery in both hips; those with severe osteoporotic bone, neurological disease, or body mass index (BMI) of > 40; those who have a history of hip surgery on the operated and contralateral sides or a history of knee prosthesis; and those who refused to participate in this study. In addition, patients with an inadequate range of motion, as determined using isokinetic tests, or those with a diagnosis of liver/coagulation dysfunction or end-stage kidney disease were excluded from this study.

All surgeries were performed at the same center and by a single surgeon with > 20 years of experience in arthroplasty. The modified Hardinge approach, which involves a flap consisting of the anterior part of the gluteus medius muscle with the underlying gluteus minimus and the anterior part of the vastus lateralis, was performed in all patients. The flap was sutured via bone-to-bone repair using nonabsorbable sutures. All acetabular and femoral components were uncemented (Smith & Nephew, Memphis, TN).

Tramadol and nonsteroidal anti-inflammatory drugs were prescribed after discharge for postoperative pain management. Enoxaparin was administered for 6 weeks postoperatively to prevent venous thromboembolism. Patients were rehabilitated immediately on the day after surgery and were allowed to use a walker with unrestricted weight-bearing based on their tolerance. For the first 6 weeks, patients started crutch walking and eventually progressed to full weight-bearing.

Functional evaluation was performed in all patients at 3 and 6 months preoperatively using the Harris hip score [7], Western Ontario and McMaster University osteoarthritis index score [8], and Visual pain scale (VAS). The VAS evaluation was repeated at 1 month postoperatively.

*Isokinetic test* The test procedure was performed in all patients by the same investigator to ensure standardization. All measurements were obtained between 10:00 and 13:30 to minimize the effects of hormonal changes during the day. Body weight and height measurements of patients were performed using an electronic scale (TESS RP 50 × 60) and a stadiometer (Holtain Limited). The Human Norm model (Cybex-USA) device was used for isokinetic evaluation. The patients were asked to remain in the lateral decubitus position, with the side to be tested on top, and the degree of rotation was set at 0° based on a dynamometer (Fig. 1).

The rotation axis of the hip joint was adjusted so that it was aligned with the rotation axis of the computer-assisted Cybex Norm dynamometer. The fixed point of the hip adapter of the dynamometer was connected to each patient on the measurement side. The lumbar region and thigh on the nonmeasurement side were fixed with a belt to prevent muscle movement of other body parts. Both hip abductor, adductor, flexor, and extensor muscle strengths (peak torque [PT]% and body weight [BW]) on the measurement side were compared with those on the contralateral side. Isometric muscle strength and endurance were re-evaluated at 3 and 6 months postoperatively. The percentage ratio (BW%) of patients was assessed according to their BMI to obtain individualized data in triplicate (Fig. 2).

**Fig. 1** A patients were tested in the lateral decubitus position for evaluate the hip abductor and adductor strength which stabilized in the exercise chair

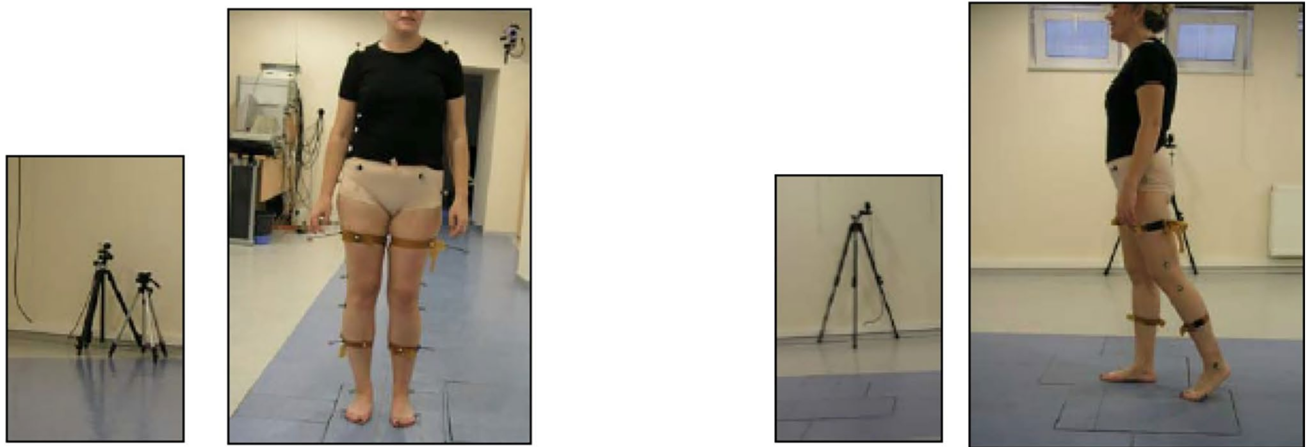

**Fig. 2** Gait analyses was performed pre and postoperatively at same laboratory

*Gait analyses* This assessment was observationally, kinetically, and kinematically analyzed at gait analysis laboratories by the same investigator**.** The gait characteristics of patients were determined using a three-dimensional motion analysis system consisting of six high-speed (100 ps) cameras and two force platforms (Elite System, BTS S.p.A, Milan, Italy). Walking parameters were determined by allowing the patients to walk at their own pace on the 15 m walkway. The patients started walking from the beginning of the 15 m walkway and were evaluated in the 4 m section corresponding to the middle of the walkway. Thus, they walked according to their speed and reached a stable walking speed. After performing at least five repetitions of each patient, the time–distance parameters of three randomly selected walks were evaluated, and the arithmetic mean of these parameters was determined. The first analysis of the patients was performed 1 week before the surgery. The same gait analyses were repeated at 3 and 6 months postoperatively.

During the analysis, the probes of kinematic assessments were constructed using bilateral acromion, C7, bilateral superior anterior iliac protrusion, sacrum, bilateral trochanter major, bilateral lateral mid-thigh, bilateral lateral epicondyle, bilateral fibular head, bilateral middle of the crus, and bilateral lateral malleolus. Walking analysis was performed to determine the patients' temporospatial values, pressing phases (%), double support times (%), double step lengths, step lengths, number of steps/min (cadence), velocities, and step widths. Kinematic data were obtained and processed according to three coronal, sagittal, and transverse planes in the spatial plane of the pelvis and hip joint.

Kinematic parameters, including pelvic obliquity and tilt, hip joint maximum abduction–adduction, maximum flexion–extension, and maximum degrees of internal and external rotations, were recorded and compared. Kinetic data were recorded by determining the maximum hip flexion moment (N/kg), maximum hip abduction–adduction moment, and maximum hip flexion–extension strength (W/kg). These analyses aimed to reveal the changes in the walking physiology; pelvic position, particularly in the frontal plane; and related kinematic parameters of the patients. We also investigated on changes in pelvic tilt and improvements in pelvic obliquity throughout the healing process of the gluteal muscles. Additionally, kinetic and kinematic parameters related to other hip circumference muscle groups and their relationships were investigated in this study.

## Results

This study included 14 women (51.8%) and 13 men (48.2%), with an average patient age of $58.22 \pm 12.06$ years. The mean BW, height, and BMI of these patients was $75.74 \pm 10.8$ kg, $162.63 \pm 9.4$ cm, and $28.6 \pm 3.8$. No complications were observed in either group during the entire follow-up period.

The VAS, WOMAC and HHS were significantly improved at 3 months postoperative compared the preoperative results ($p < 0.001$, $p < 0.001$ and $p < 0.001$). However, there were no significant difference between 3th months and sixth months results (Table 1).

### Isokinetic muscle strength

The flexion, extension, and adduction peak torque was significantly improved at 3 and 6 months postoperatively compared with the preoperative strength on the operated side ($p < 0.001$ and $< 0.001$, $p < 0.001$ and $< 0.001$, and $p < 0.001$ and $< 0.001$, respectively). No significant difference was observed between the preoperative abduction peak torque (BW%) and the third month peak torque (0.141); however, a significant difference was noted between the preoperative

**Table 1** Comparison of isokinetic strength of hip muscle and functional results of patients pre and postoperatively

| Isokinetic test results | Preoperative values | | 3th month postoperative | | 6th month postoperative | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | Min–Max |
| *Flexion peak torque* | | | | | | |
| Operated Side | 42 ± 18 | 6–77 | 59 ± 20 | 6–104 | 76 ± 16 | 54–116 |
| Contralateral side | 60 ± 17 | 30–98 | 51 ± 14 | 22–76 | 75 ± 20 | 30–117 |
| *p* value | < 0.001 | | 0.260 | | 0.857 | |
| *Extension peak torque* | | | | | | |
| Operated Side | 96 ± 25 | 54–154 | 132 ± 41 | 12–221 | 157 ± 27 | 107–221 |
| Contralateral side | 128 ± 33 | 60–203 | 136 ± 33 | 75–221 | 159 ± 30 | 92–221 |
| *p* value | < 0.001 | | 0.140 | | 0.8 | |
| *Adduction peak torque* | | | | | | |
| Operated Side | 40 ± 14 | 12–72 | 45 ± 16 | 18–83 | 53 ± 14 | 27–89 |
| Contralateral side | 52 ± 17 | 24–95 | 57 ± 18 | 21–110 | 58 ± 17 | 24–107 |
| *p* value | 0.037 | | 0.312 | | 0.706 | |
| *Abduction peak torque* | | | | | | |
| Operated Side | 83 ± 28 | 15–137 | 113 ± 24 | 66–173 | 117 ± 20 | 75–149 |
| Contralateral side | 96 ± 26 | 14–143 | 119 ± 21 | 83–176 | 120 ± 20 | 63–149 |
| *p* value | 0.005 | | 0.010 | | 0.208 | |
| *Functional results* | | | | | | |
| Visual analog scale | 7,2 ± 1,3 | 6–9 | 3,1 ± 0,8 | 1–5 | 2,3 ± 0,5 | 0–4 |
| WOMAC score | 34,3 ± 4,3 | 20–50 | 72,6 ± 4,8 | 60–85 | 83,4 ± 4,6 | 70–95 |
| Harris hip score | 37,1 ± 4,3 | 20–55 | 72,1 ± 4,8 | 60–80 | 83,1 ± 6,4 | 70–100 |

**Table 2** Comparison of temporal parameters of gait analyses

| | Preoperative values | | 3th month postoperative | | 6th month postoperative | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | Min–Max |
| *Stance time* | | | | | | |
| Operated Side | 850 ± 310 | 550–1930 | 754 ± 112 | 550–1060 | 727 ± 127 | 500–1170 |
| Contralateral side | 894 ± 312 | 530–1890 | 771 ± 100 | 560–960 | 723 ± 115 | 490–1000 |
| *p* value | 0.332 | 0.529 | 0.970 | | | |
| *Swing time* | | | | | | |
| Operated Side | 458 ± 65 | 340–560 | 440 ± 61 | 300–560 | 429 ± 64 | 300–530 |
| Contralateral side | 428 ± 75 | 170–520 | 424 ± 42 | 340–500 | 433 ± 43 | 330–540 |
| *p* value | 0.246 | 0.265 | 0.781 | | | |
| *Stance time* (%) | | | | | | |
| Operated Side | 64 ± 6 | 55–84 | 63 ± 4 | 57–77 | 62 ± 5 | 58–77 |
| Contralateral side | 65 ± 7 | 57–89 | 64 ± 2 | 60–70 | 62 ± 2 | 57–66 |
| *p* value | 0.452 | 0.204 | 0.869 | | | |
| *Swing time* (%) | | | | | | |
| Operated Side | 35 ± 6 | 16–45 | 36 ± 4 | 23–43 | 37 ± 4 | 23–42 |
| Contralateral side | 34 ± 7 | 11–43 | 35 ± 2 | 30–40 | 37 ± 2 | 34–43 |
| *p* value | 0.465 | 0.266 | 0.711 | | | |
| *Stride time* | | | | | | |
| Operated Side | 1324 ± 314 | 890–2300 | 1199 ± 127 | 900–1420 | 1157 ± 135 | 890–1510 |
| Contralateral side | 1307 ± 302 | 870–2270 | 1200 ± 122 | 920–1460 | 1154 ± 150 | 880–1540 |
| *p* value | 0.858 | 0.990 | 0.957 | | | |
| Cadence | 94.9 ± 17 | 53–136 | 101.5 ± 12 | 84–140 | 104.4 ± 11 | 79–132 |

**Table 3** Comparison of distance parameters of gait analyses

| | Preoperative values | | 3th month postoperative | | 6th month postoperative | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | Min–Max |
| *Anterior step length R* | | | | | | |
| Operated side | 403 ± 140 | 71–697 | 441 ± 112 | 223–593 | 487 ± 100 | 275–655 |
| Contralateral side | 428 ± 128 | 148–604 | 440 ± 88 | 278–561 | 495 ± 92 | 326–639 |
| *p* value | 0.545 | 0.973 | 0.785 | | | |
| *Velocity* | | | | | | |
| Operated side | 0.697 ± 0.26 | 0.130–0.980 | 0.750 ± 0.185 | 0.41–1.010 | 0.852 ± 0.172 | 0.430–1.070 |
| Contralateral side | 0.672 ± 0.265 | 0.10–1.01 | 0.750 ± 0.189 | 0.390–1.010 | 0.865 ± 0.188 | 0.390–1.200 |
| *p* value | 0.935 | 0.993 | 0.812 | | | |
| *Swing velocity* | | | | | | |
| Operated side | 1.828 ± 0.55 | 0.490–2.500 | 2.007 ± 0.39 | 1.16–2.63 | 2.238 ± 0.29 | 1.70–2.74 |
| Contralateral side | 1.912 ± 0.58 | 0.620–3.010 | 2.080 ± 0.44 | 1.22–2.79 | 2.255 ± 0.45 | 1.12–2.99 |
| *p* value | 0.634 | 0.575 | 0.882 | | | |
| *Stride length* | | | | | | |
| Operated side | 834 ± 260 | 223–1229 | 885 ± 186 | 511–1106 | 987 ± 186 | 645–1247 |
| Contralateral side | 821 ± 277 | 235–1294 | 883 ± 189 | 500–1114 | 991 ± 184 | 603–1229 |
| *p* value | 0.877 | 0.983 | 0.952 | | | |
| Step width | 173 ± 47 | 77–312 | 165 ± 38 | 68–243 | 157 ± 37 | 89–244 |
| Mean velocity | 0.676 ± 0.261 | 0.120–1.000 | 0.744 ± 0.180 | 0.40–1.01 | 0.849 ± 0.168 | 0.41–1.10 |

**Table 4** Comparison of kinematics value of gait analyses

| | Preoperative values | | 3th month postoperative | | 6th month postoperative | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | Min–Max |
| *Maximum pelvic tilt* | | | | | | |
| Operated side | 16.6 ± 8.1 | 5.9–37 | 14.5 ± 5.4 | 0.6–21.8 | 13.9 ± 4.9 | 2.9–25.2 |
| Contralateral side | 16.7 ± 8.3 | 7–37.8 | 14.4 ± 5.3 | 2.9–21.7 | 14.5 ± 4.6 | 4.4–25 |
| *p* value | 0.968 | 0.983 | 0.655 | | | |
| *Minimum pelvic tilt* | | | | | | |
| Operated side | 9.37 ± 5.8 | −0.32–24.5 | 8.37 ± 5.8 | 0.41–1.010 | 9.60 ± 5.1 | −5.41–18.8 |
| Contralateral side | 9.32 ± 6.05 | −0.32–24.5 | 8.63 ± 5.9 | −4.4–17.8 | 9.58 ± 5.02 | −5.41–18.05 |
| *p* value | 0.978 | 0.890 | 0.991 | | | |
| *Maximum hip flexion* | | | | | | |
| Operated side | 29.9 ± 9.2 | 9.05–51.2 | 30.7 ± 7.3 | 17.4–44.3 | 32.7 ± 6.9 | 20.8–48.7 |
| Contralateral side | 32.01 ± 9.24 | 20.8–57.59 | 32.5 ± 6.4 | 22.4–47.9 | 33.2 ± 6.8 | 14.7–43.8 |
| *p* value | 0.469 | 0.421 | 0.824 | | | |
| *Maximum hip extension* | | | | | | |
| Operated side | 2.861 ± 9.64 | −13.33–21.85 | 0.44 ± 12.5 | −29.3–22.8 | −1.25 ± 10.2 | −17.8–13.7 |
| Contralateral side | 3.51 ± 10.42 | −18.56–21.20 | 0.39 ± 11.5 | −21.2–18.46 | −1.81 ± 8.7 | −13.3–17.8 |
| *p* value | 0.835 | 0.990 | 0.860 | | | |
| *Maximum hip adduction* | | | | | | |
| Operated side | 1.56 ± 5.6 | −5.2–20.4 | 3.30 ± 3.2 | −29.3–22.8 | 3.31 ± 4.5 | −8.3–12.9 |
| Contralateral side | 2.08 ± 4.7 | −8.6–9.58 | 1.01 ± 5.1 | −9.15– 11.1 | 3.3 ± 4.4 | −2.2–13.6 |
| *p* value | 0.751 | 0.113 | 0.963 | | | |
| *Maximum hip abduction* | | | | | | |
| Operated side | −6.56 ± 4.4 | −14.4–5.7 | −3.8 ± 3.7 | −13–2.8 | −4.9 ± 4.6 | −19.5–2.7 |
| Contralateral side | −5.44 ± 7.1 | −28.8–1.9 | −5.8 ± 5.2 | −18.2–5.6 | −5.5 ± 4.5 | −14.5–2.65 |
| *p* value | 0.547 | 0.187 | 0.724 | | | |
| *Maximum hip internal rotation* | | | | | | |
| Operated side | 2.61 ± 10.2 | −13.2–24 | 3.1 ± 9.7 | −11.4–21 | 8.1 ± 11.3 | −7–37 |
| Contralateral side | −1.0 2 ± 13 | −37–25 | −0.41 ± 9 | −16.2–21 | 1.43 ± 12 | −22–23 |
| *p* value | 0.323 | 0.246 | .099 | | | |
| *Maximum hip external rotation* | | | | | | |
| Operated side | −8.8 ± 9.3 | −23–13 | −8.3 ± 9 | −27–10 | −4.2 ± 12 | −20–29 |
| Contralateral side | −12.9 ± 14 | −46–15 | −11.6 ± 10 | −29–11 | −11.9 ± 9.8 | −30–1 |
| *p* value | 0.281 | 0.297 | 0.043* | | | |

**Table 5** Comparison of kinetic parameters of gait analyses

| | Preoperative values | | 3th month postoperative | | 6th month postoperative | |
|---|---|---|---|---|---|---|
| | Mean ± SD | Min–Max | Mean ± SD | Min–Max | Mean ± SD | Min–Max |
| Maximum hip flexion moment | 0.442 ± 0.21 | 0.145–0.887 | 0.537 ± 0.22 | 0.271–1.22 | 0.696 ± 0.26 | 0.33–1.27 |
| Maximum hip adduction moment | −0.182 ± 0.137 | −0.49–0.01 | −0.165 ± 0.133 | −0.59–0.02 | 0.576 ± 0.13 | 0.33–0.77 |
| Maximum hip abduction moment | 0.464 ± 0.272 | 0.091–0.977 | 0.481 ± 0.220 | 0.17–0.88 | −0.176 ± 0.10 | −0.41–0.04 |
| Maximum hip gen power | 0.280 ± 0.213 | 0.040–0.910 | 0.372 ± 0.220 | 0.06–0.99 | 0.542 ± 0.298 | 0.09–1.33 |
| Maximum hip abs power | −0.132 ± 0.210 | −1.022–0.010 | −0.163 ± 0.09 | −0.33–0.05 | −0.216 ± 0.107 | −0.38–0.04 |

abduction peak torque (BW%) and the sixth month strength on the operated side ($p < 0.001$).

The extension and adduction peak torque (BW%) was significantly improved at 3 and 6 months postoperatively compared with the preoperative strength on the nonoperated side ($p = 0.012$ and $< 0.001$ and $p < 0.001$ and $< 0.001$, respectively). The flexion strength was significantly improved at 6 months postoperatively ($p < 0.001$). However, no significant difference was observed between the preoperative and third month flexion strength on the nonoperated side. Additionally, abduction strength did not improve at 3 and 6 months postoperatively ($p = 0.097$ and 0.222, respectively).

After comparing the operated and contralateral sides, a significant difference was noted among all strengths at the preoperative evaluation. However, no significant difference was observed among any strength at 3 or 6 months postoperatively (Table 1).

## Gait analysis results

Of the 27 patients, 6 were lost to gait analysis follow-up; thus, 21 patients continued the study. In the stance and swing phases, no statistically significant differences were observed between the two groups (operated and nonoperated) in the preoperative and postoperative third and sixth months (Table2). However, a significant difference was noted between the preoperative and postoperative sixth month values on the nonoperated side in the stance phase ($p = 0.010$) as well as between the preoperative and postoperative sixth month values on the operated side in the swing phase ($p = 0.042$).

The stance and swing phase time (%) did not change during the postoperative follow-up, and no significant difference was noted between the measurements on the operated and nonoperated sides.

The stride time showed a statistically significant difference between the preoperative and postoperative sixth month values of both groups ($p = 0.020$ and 0.027, respectively). However, no statistically significant difference was observed between the two groups in the preoperative and postoperative third and sixth month evaluations.

The cadence did not show statistically significant difference between the preoperative and postoperative third month values ($p = 0.073$) or between postoperative third and sixth month values ($p = 0.332$). However, a significant difference was noted between the preoperative and sixth month values ($p = 0.023$).

## Distance findings (Table3)

Anterior step length, velocity, swing velocity, and stride length did not show statistically significant difference between the two groups. No significant difference was observed between the preoperative and postoperative third month control values on the operated or nonoperated side ($p = 0.065$ and 0.808, respectively). However, a significant difference was noted between the preoperative and postoperative sixth month control values and between postoperative third and sixth month values on the operated and nonoperated side, ($p = 0.002$; $p < 0.001$ and $p = 0.006$; $p < 0.001$, respectively). The step width was not significantly different between the pre- and postoperative values. The mean velocity did not show a significant difference between the preoperative and postoperative third month values ($p = 0.281$); however, it showed a significant difference in the preoperative and postoperative sixth month values ($p = 0.002$) as well as between the postoperative third and sixth month values ($p < 0.001$).

## Kinematics value (Table 4)

The maximum pelvic tilt, minimum pelvic tilt, maximum pelvic flexion, extension, and abduction were not significantly different between the preoperative and postoperative third and sixth month values on the operated and nonoperated sides. The maximum hip internal rotation did not show a significant difference between the preoperative and postoperative third month values. However, it showed a significant difference between the preoperative and postoperative sixth month values ($p = 0.012$) and between the postoperative third and sixth month values ($p = 0.031$) on the operated side. The nonoperated side was not significant in all parameters on the operated side. A significant difference was only found between the operated and unaffected hip external rotation ($p = 0.002$).

### Kinetic analysis

No significant difference was noted between the preoperative and third month values; however, a significant difference was observed between the preoperative and sixth month and between third and sixth month values ($p > 0.05$) (Table 5).

## Discussion

THA is a surgical procedure in which satisfactory results have been achieved in cases where the hip joint cannot perform its normal function. This condition often affects the activities of daily living in patients and causes additional pain. The lateral approach can adversely affect the function of abductor gait mechanics, including the Trendelenburg gait or compensatory contralateral pelvic tilt. According to the isokinetic muscle strength test, the abductor and other hip circumference groups achieved the preoperative muscle strength at 3 months postoperatively, and the postoperative sixth month values showed a statistically significant improvement compared with the preoperative and third month values. In general, gait data showed a slight regression at postoperative 3 months but reached the same values at 6 months postoperatively. Thus, the lateral Hardinge approach is a reliable and feasible technique for total hip prosthesis applications. After appropriate repair and effective postoperative rehabilitation, the abductor, which is separated during surgery, achieves a better muscle function.

Several studies have investigated the effects of the lateral Hardinge approach following THA on the gait of patients [5, 9–13]. Ewen et al. conducted a meta-analysis in which postoperative gait data of patients who underwent total hip replacement were compared with those of the healthy control group; this study revealed the data on speed, stride length, sagittal hip range of motion, hip flexion, and extension peak strength [14]. Results were obtained on speed ($d = -0.79$; confidence interval $[CI] = -1.54$ to $-0.04$), stride length ($d = -1.06$; $CI = -1.62$ to $-0.49$), and sagittal hip range ($d = -1.58$; $CI = -2.12$ to $-1.04$), with increased peak hip flexion ($d = 0.52$; $CI = -0.01$ to 1.09) and extension ($d = 0.54$; $CI = -0.10$ to 1.09) moment exhibiting lower significance than the first three data [14]. A study by Rosenlund et al. compared the lateral and posterior approaches in terms of gait function and hip muscle strength of patients after THA up to 12 months postoperatively [5]. They randomized 47 patients to posterior or lateral approach, evaluated them at 3 and 12 months preoperatively. In that syduy, they found no difference between the groups, but hip abductor and flexor muscle strength improved more in the posterior approach group. Another study by Petis et al. investigated the gait analyses of patients using different surgical approaches, including the anterior, posterior, and lateral approaches [12]. In that study, 30 patients (10 each evaluated using anterior, posterior, or lateral approach) were evaluated using three-dimensional gait analyses. They found that similar temporal gait parameters were obtained following THA for all approaches. Differences in gait kinematics and kinetics exist, but with small absolute differences. Lastly, Moyer et al. investigated the effects of different surgical approaches, including posterior, anterior, direct lateral, and anterolateral approaches, on postoperative gait analyses of patients who underwent THA [11]. They included the data of 757 participants from 19 studies and revealed a slightly early or late postoperative difference in gait biomechanics among the surgical approaches. In our study, we compared the operated and nonoperated sides, and our temporospatial data showed a slight regression at postoperative 3 months but reached the same values at 6 months postoperatively. Kinematic data showed a significant regression, but the data were not compared with those in the preoperative period.

Direct incision or separation can cause damage to the abductor muscle. Reduced muscle strength after THA is most associated with poor functional scores and health-related quality of life in patients. A study by Winther et al. compared the muscular strength of patients who underwent one of the three surgical approaches, i.e., direct lateral (DLA), posterior, or anterior approaches (AA) [15]. They revealed that patients who underwent the lateral approach had reduced muscular strength than those who underwent other approaches. The nonoperated leg was significantly stronger than the operated leg in all groups at 6 months postoperatively, and this persisted until 12 months postoperatively for the DLA and AA groups. Klausmeier et al. compared the effects of the anterior and anterolateral approach [16] and revealed no significant differences in terms of functional hip scores and hip circumference muscular strength in patients who underwent total hip replacement. Another study by Dana et al. evaluated the postoperative muscular strength, function, and quality of life in patients at 1 year after THA using the posterior approach [17]. They included 26 patients who underwent THA and assessed them at 1, 3, 6, and 12 months postoperatively. This study revealed a 15% loss in flexor muscle strength, 15% loss in extensor muscle strength, and 26% loss in abductor muscle strength at postoperative 1 month, thereby emphasizing that strength deficits may persist after recovery. The study by Rossi et al. evaluated the flexor and extensor isokinetic muscle strength after THAv [18]. At postoperative day 60, the isokinetic muscle strength was evaluated using the Cybex device in 11 patients. Before surgery, the strength of hip extensors and flexors on the affected side was 39% and 29% lower, respectively, in comparison with the unaffected side. Sixty days post-surgery, there was a notable improvement, with hip extensor strength increasing by 50% and flexor strength by 27% compared to preoperative levels. Our study used the isokinetic test to evaluate the muscle strength recovery after THA via the modified Hardinge procedure and

revealed significantly improved flexion–extension and abduction–adduction peak torque on the operated side, with significant differences in strengths at preoperative evaluation between the operated and contralateral sides. However, no significant difference was found in any strength at third and sixth month evaluation between the operated and contralateral sides.

Our study has some limitations. First, it had a small sample size and short follow-up time. Second, although patients were compared with their healthy controls, different techniques were not available for comparing the results. Finally, the abductor muscle strength was evaluated using the isokinetic test; however, the imaging method for evaluating the volume of the abductor muscle was not available.

## Conclusion

According to our results, adequate muscle strength and physiological gait pattern, similar to the preoperative status, can be achieved at 6 months postoperatively. This is achieved through the appropriate repair of the abductor mechanism, which is partially removed during surgery, and effective postoperative rehabilitation.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** Approval was given by the institutional review board.

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