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Basic Science

# Volume Increases of the Gluteus Maximus, Gluteus Medius, and Thigh Muscles After Hip Arthroplasty

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ABSTRACT

*Background:* Muscle atrophy in osteoarthritis (OA) patients is expected to recover after total hip arthroplasty (THA) because of the increase in activity levels. Although some reports have shown an increase in the thigh muscles (Th) after THA, no reports of increases in the gluteal muscles and of analyses of the factors related to muscle recovery have been published. In this study, the changes in the gluteal and Th volumes after THA were quantitatively evaluated using computed tomography (CT) images, and the factors related to muscle recovery were analyzed.

*Methods:* The subjects were 40 OA hips with CT images taken 3 weeks after THA (first postoperative [postop] CT) and more than 2 years after THA (second postop CT). The cross-sectional areas of gluteus maximus (G-max), gluteus medius (G-med), and Th were measured in both CT images. The factors related to muscle recovery that were measured and evaluated were age, gender, days from operation, surgical approach, Kellgren–Lawrence grades, and hip functional score (Japanese Orthopaedics Association hip score).

*Results:* All measured cross-sectional areas of the operated side increased significantly from the first postop CT to the second postop CT (G-max, 40%; G-med, 11%; and Th, 20%). In the analysis of the factors related to muscle recovery, the increase rate of G-max correlated significantly with patient age, and the increase rate of G-med correlated significantly with the increase in Japanese Orthopaedics Association hip score.

*Conclusions:* Hip OA can lead to atrophy of the gluteal and Th, but the muscle volume can recover more than 2 years after THA.



It has been reported that atrophy of the muscles around the hip and thigh occurs in patients with hip osteoarthritis (OA) [1–6]. Total hip arthroplasty (THA) reduces pain, with a resulting increase in the quality of life and activity levels. The muscular strengths of the hip and thigh also recover after THA. There have been a few reports [7–9] that quantitatively evaluated the changes in hip and Th volumes after THA. These reports showed a significant increase in the volumes of muscles around the hip and thigh (iliopsoas, adductors, hamstrings, and quadriceps femoris) [7–9]. However, no reports have shown a significant increase in the volumes of the gluteus maximus (G-max) and gluteus medius (G-med) after THA. Moreover, there have been no reports of the factors related to the increases in muscles volumes. The maximum follow-up of the previous studies was 2 years, which may not be enough for the G-max and G-med to recover, and we hypothesized that the period after THA is a factor related to muscle volume recovery. Therefore, if we observe the muscle volumes after THA for a longer period, we may find significant muscle volume recovery in the G-max and G-med.

In this study, hip and Th volumes were quantitatively measured using computed tomography (CT) images taken more than 2 years after THA, the recovery of muscle volumes was evaluated, and factors related to muscle volume recovery were examined.

## Methods

Forty patients (6 men and 34 women, mean age 58 years) who had undergone unilateral THA between 2002 and 2012 and then

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underwent contralateral THA with an interval of more than 2 years were retrospectively selected as the subjects of this study (Table 1). During this period, CT images for THA navigation were routinely obtained preoperatively according to a standard protocol (General Electric Spiral scan; GE Medical System, Tokyo, Japan; 120 kV, 150 mA, slice thickness; 2.0 mm, 1-second scan time). Axial images from the iliac brim to the knee were taken. At 3 weeks after THA, postoperative (postop) CT images were obtained for evaluation with the same protocol (first postop CT). The second postop CT was taken incidentally at a mean of 4 years (range, 2-8.5 years) after THA for navigation surgery for the contralateral hip. When the initial THA was performed, contralateral hip symptoms were negligible. However, at the time of the contralateral THA, the hip became symptomatic with the progression of OA. Patient data were erased from the CT images, and this research was approved by the Institutional Review Board at Osaka University Hospital.

THA was performed through a posterolateral approach (PLA) in 33 cases and a direct anterior approach (DAA) in 7 cases. Hip resurfacing arthroplasty was performed in 4 patients, and conventional THA was performed in 36 patients. The Kellgren–Lawrence (KL) classification [10] of the operated side was grade 3 or 4, and the grade of the contralateral side was 1-4 at the time of the initial THA (Table 1). Preoperative and postop hip function was evaluated by the Japanese Orthopaedic Association hip score (JOA H-S) [11]. The JOA H-S consists of 4 subcategories: pain, range of motion, ability to walk (gait), and activities of daily living (Appendix 1). It has a maximum of 100 points and has been reported to have a strong correlation with the Harris Hip Score [12, 13]. The postop JOA H-S was measured when the second postop CT was taken.

Muscle volume measurements were done on CT images with the use of 3D template software (Kyocera Medical, Osaka, Japan). Because leg length change and offset change may affect the measurements of the muscle volume, the first postop CT and second postop CT were used in this study. The cross-sectional areas (CSAs) of the G-max, G-med, and Th of both hips on the axial plane of the CT images were measured as a surrogate for total muscle volume.

To measure the 3 CSAs, the coordinate system of the pelvis and the femur was determined on each CT image using anatomic landmarks. The anterior pelvic plane (APP) was defined as the plane touching the most anterior points of the bilateral anterior superior iliac spines and the pubic tubercles (Fig. 1). The CSA of G-max was measured on the plane perpendicular to APP through the bilateral most proximal points of the greater trochanters (Fig. 2). The CSA of G-med was measured on the plane perpendicular to APP through the bilateral anterior superior iliac spines (Fig. 2). The table top plane (TTP) of the femur was defined as the plane touching the most posterior point of the proximal femur and bilateral femoral posterior condyles, with the vertical axis set as a line through the trochanteric fossa and the knee center (Fig. 3). The CSA of Th was measured on the plane perpendicular to the TTP at the center of the femur, which was defined as the center of the femoral head and the knee center (Fig. 4). After each slice to measure CSA was reconstructed, the border line of the muscle and the other tissue was traced manually, and the muscle volume was measured using imaging analysis software (ImageJ version 1.48; National Institutes of Health, Bethesda, MD). After identifying the border line of the muscles, the 3 CSAs were measured on the first postop CT and the second postop CT and compared.

**Table 1**
Patients' Characteristics.

| Parameter | Value |
|---|---|
| Male/female (cases) | 6/34 |
| Age (y)[a] | 58 (45-74) |
| Conventional THA/HRA (cases) | 36/4 |
| Intervals between the 2 CT images (y)[a] | 4 (2-8.5) |
| PLA/DAA (cases) | 33/7 |
| KL grade of the operated side (cases) | Grade 3: 3, grade 4: 37 |
| KL grade of the contralateral side (cases) | Grade 1: 3, grade 2: 8, grade 3: 19, grade 4: 10 |

CT, computed tomography; DAA, direct anterior approach; HRA, hip resurfacing arthroplasty; KL, Kellgren–Lawrence; PLA, posterolateral approach; THA, total hip arthroplasty.
[a] Values are expressed as means (range).

The factors related to muscle recovery that were measured and evaluated were age, gender, days from operation, surgical approach (DAA or PLA), KL grade of the operated side (grade 3 or 4), KL grade of the contralateral side (grade 1, 2, 3 or 4), and the JOA H-S. To assess the positional change of the pelvis and the femur between the first postop CT and the second postop CT, the flexion angle and the abduction angle of both hips and pelvic sagittal tilt were also measured on both CT images. The hip flexion angle was measured as the angle between the CT table and the TTP, and the hip abduction angle was measured as the angle between the craniocaudal axis of the APP and the vertical axis of the TTP. Pelvic sagittal tilt was measured as the angle between the APP and the CT table and was defined as positive for posterior inclination.

All statistical analyses were performed with SPSS statistical software, version 23 (IBM Japan, Tokyo, Japan). Bivariate analysis was carried out with the Wilcoxon signed-rank test and Mann–Whitney *U* test, and correlations between the factors and CSA increase rates were assessed by Spearman's rank correlation coefficients. The correlation coefficient (R) was also calculated. Intraobserver and interobserver reliabilities were tested using intraclass correlation coefficients (ICCs) and their 95% CIs to assess the reliability of measuring the CSA of each muscle. Since a previous analysis of a similar study by Grimaldi et al [4] studying the CSAs of the muscle around the hip by magnetic resonance imaging (MRI) found an ICC of greater than 0.9, it was determined that a sample size of 20 subjects (half of the subjects) with 2 replicates and 2 evaluators per subject would achieve more than 80% power to detect an ICC value of 0.9 with the minimum value of the 1-sided 95% CI of 0.70. Values of $P < .05$ were considered to represent significant differences and significant correlations.

## Results

All the measured CSAs of the operated side increased significantly after THA. G-max increased from 25.1 $cm^2$ (interquartile range [IQR], 21.5-29.5 $cm^2$) to 35.1 $cm^2$ (IQR, 30.6-40.2 $cm^2$); G-med increased from 20.4 $cm^2$ (IQR, 18.3-23.4 $cm^2$) to 22.6 $cm^2$ (IQR, 20.1-27.0 $cm^2$); and Th increased from 76.5 $cm^2$ (IQR, 69.2-85.4 $cm^2$) to 92.0 $cm^2$ (IQR, 84.6-102.7 $cm^2$; all $P < .01$; Table 2). JOA H-S of the operated side improved significantly from 48 (range, 25-72) to 79 (range, 63-91; $P < .01$). The average postop JOA H-S was relatively low because of OA of the contralateral hip.

In the analysis of the factors related to the increase rate of the 3 muscles, gender, surgical approach, KL grade of the operated side, and KL grade of the contralateral side were not significant factors (Appendix 2). Furthermore, no significant correlations were seen between the increase rates of the 3 muscles and days from the operation. There were also no correlations between patient age and the CSA increase rates of G-med and Th. However, a negative correlation was found between the CSA increase rate of G-max and patient age ($R = -0.359$, $P = .02$). In the analysis of hip function and muscle recovery, there was no significant correlation between the preoperative JOA H-S and the increase rate of each CSA. There was also no significant correlation between the postop JOA H-S and the increase rate of each CSA. However, there was a significant