Preoperative gluteus medius muscle atrophy as a predictor of walking ability after total hip arthroplasty

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ABSTRACT. Purpose: To elucidate the relation between certain preoperative physical parameters and walking with a limp after total hip arthroplasty (THA) and determine whether it is possible to predict the walking ability of patients 6 months after THA. Methods: The subjects of this study comprised 74 female patients who had undergone unilateral THA. Before surgery, the hip abductor and knee extensor strengths were measured, the cross-sectional areas (CSAs) of the gluteus medius and rectus abdominis muscles were measured, and the Timed Up and Go test was conducted. The patients were then divided into two groups according to gait observation results 6 months postoperatively: walking without a limp (n=37) and walking with a limp (n=37). Results: The discriminating criteria between the two groups were age (61 years), CSA of the gluteus medius muscle (2000 mm²), and CSA of the rectus abdominis muscle (340 mm²). In the multiple logistic regression analysis, the gluteus medius muscle was the only significant predictor of limping after THA (β=1.64, R²=0.19, p<0.01). Conclusions: The results of the present study suggest that preoperative atrophy of the gluteus medius is an useful indicator for predicting walking with a limp 6 months postoperatively.

Key words: Total hip arthroplasty, Predictors, Gluteus medius muscle

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Hip osteoarthritis is the most common musculoskeletal disease that causes limping. The most common limping seen in patients with hip osteoarthritis is lateral bending of the trunk toward the affected limb during the stance phase. Leaning of the trunk toward the ipsilateral side during gait may compensate for weakened hip abductor muscles. This trunk movement is also used as a pain avoidance mechanism that reduces the contact forces at the hip joint. However, inclination of the trunk during gait may result in reduced degenerative spinal change over a period of years and leads to increased energy expenditure. Therefore, exercises to improve limping after total hip arthroplasty (THA), such as bending the trunk toward the affected side, are important. However, lateral bending of the trunk toward the affected limb during the stance phase persists for 6 months to 2 years after THA.

Accurate prediction of whether patients will be able to walk without limping after THA may allow them to set appropriate goals for their post-THA rehabilitation and is critical for the planning of effective rehabilitation interventions. Therefore, the development of standardized and valid preoperative assessment tools that can predict midterm walking ability would be useful for comprehensive rehabilitation after THA.

Abnormal gait pattern of the frontal plane is traditionally associated with impaired function of the hip abductor muscle, including muscle atrophy of the gluteus medius. Some studies reported that preoperative physical functions such as muscle strength of lower extremity and the Timed Up and Go (TUG) test predict the mid-term walking ability after THA. Perry also described that the trunk muscles including rectus abdominis muscle related the stability of trunk movement during the stance phase. However, there is
little information in the literature regarding a cutoff point for preoperative physical functions to predict post-THA limping.

The purposes of this study were to elucidate the relation between preoperative physical functions and gait disturbances following THA and identify optimal cut-off values for estimating the likelihood of limping 6 months after THA.

Methods

1. Participants

A total of 202 patients underwent THA at the Department of Orthopedic Surgery of the Kyoto University Hospital between April 2010 and March 2012. The inclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee. The exclusion criteria were primary THA due to unilateral osteoarthritis of the hip, a follow-up of 6 months, and asymptomatic knee.

The participants of the study were 74 female patients (mean age, 60.6 ± 10.3 years; age range, 35-71 years; mean body mass index [BMI], 22.6 ± 3.7 kg/m²; BMI range, 16.1-36.4 kg/m²).

All patients underwent THA using an anterolateral approach, were permitted full weight bearing on the third postoperative day and underwent a 4-week rehabilitation program. The rehabilitation program involved transfer training and progressive resistive exercises of the lower extremity, including the hip extensors and abductors, knee extensors, and ankles. The patients were encouraged and trained to move from bilateral to unilateral support, and the goal of physical therapy was to achieve ambulation with a cane-assistive device by 4 weeks from the date of surgery. The age and BMI of each patient were also recorded at the time of surgery. The limb length discrepancy was within 1 cm as measured by the difference between the right and left leg in the distance between the teardrop at the pelvis and the tip of the lesser trochanter on anteroposterior radiographs at 6 months after THA.

All procedures in this study were approved by the ethics committee of Kyoto University Graduate School and Faculty of Medicine. The subjects were informed about the study procedures before testing and provided written informed consent before participating.

2. Assessment of preoperative physical functions

The maximum voluntary lower limb muscle strength (hip abductor and knee extensor) on the affected side were assessed preoperatively. The hip abductor strength was measured using a hand-held dynamometer (Nihon Medix Co., Ltd., Matsudo, Japan) during isometric contraction for 3 seconds with manual resistance. The subjects rested in the supine position with the hip and knee in neutral flexion/extension and the hip in neutral abduction/adduction. The force sensor was placed 5 cm above lateral condyle of the femur, while another person fixed the contralateral pelvis and distal thigh with the hands. The knee extensor strength and lower limb load force were assessed using an IsoForce GT-330 (OG Giken Co., Ltd., Okayama, Japan) during isometric contraction for 3 seconds. The patient was in a sitting position with the hips at 90° angles and the knees at 60° angles, the force sensor was placed over the anterior part of the lower leg 5 cm above the lateral malleolus. The torque was calculated by multiplying the measured force by the lever arm (distance between the position of the force sensor and the greater trochanter for the hip abductor strength; distance between the position of the force sensor and the level of the tibial plateau for the knee extensor strength) and expressed as a percentage of the body weight (Nm/kg).

The TUG test was conducted to assess the patient’s ambulatory ability before THA. The TUG test measures the time in seconds that a patient requires to stand up from an armless chair with a seat height of 45 cm, walk a distance of 3 m, turn, walk back to the chair, and sit down. The test was performed with the patients wearing shoes and walking at their maximum speed with no assistive devices.

The cross-sectional area (CSA) of the gluteus medius and rectus abdominis muscles on the affected side were assessed at the bottom end of the sacroiliac joint using transaxial computed tomography for preoperative planning. Transaxial computed tomography was performed at intervals of 5-mm slices. Using dedicated software (TeraRecon Ltd., Tokyo, Japan) for computerized planimetry, the areas of interest (individual muscles) were manually circumscribed and automatically computed. According to the previous study, CSA of the gluteus medius and rectus abdominis muscles were expressed as a raw data.

3. Classification of walking ability

All patients were observed by the same skilled therapist while walking back and forth along a 14-m walkway without any assistive device, wearing their own shoes and at their preferred walking speed. Based on the gait observation 6 months postoperatively, the patients were classified into either the non-limping group, in which patients walked without a limp, or the limping group, in which patients walked with a limp. A patient was considered to be walking with a limp after THA when the trunk leaned laterally toward the side of the supporting leg (equivalent to level 3 of Horstmann’s research). An experienced physical therapist who was blinded about the patients’ profiles identified which patients walked with a limp.

4. Statistical analysis

For the preoperative muscle strength determination
Predictors of limping after THA

Table 1. Subjects’ characteristics and preoperative physical functions

<table>
<thead>
<tr>
<th></th>
<th>Non-limping group (n=37)</th>
<th>Limping group (n=37)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>Mean 56.7 SD 9.3</td>
<td>Mean 64.5 SD 9.6</td>
<td>0.00</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>Mean 23.5 SD 4.3</td>
<td>Mean 21.7 SD 2.7</td>
<td>0.12</td>
</tr>
<tr>
<td>Hip abductor strength (Nm/kg)</td>
<td>0.58 0.23</td>
<td>Mean 0.56 SD 0.17</td>
<td>0.38</td>
</tr>
<tr>
<td>Knee extensor strength (Nm/kg)</td>
<td>1.45 0.42</td>
<td>Mean 1.32 SD 0.45</td>
<td>0.21</td>
</tr>
<tr>
<td>Cross-sectional area of the gluteus medius muscle (mm²)</td>
<td>2317.6 372.5</td>
<td>Mean 1680.0 269.5</td>
<td>0.00</td>
</tr>
<tr>
<td>Cross-sectional area of the rectus abdominis muscle (mm²)</td>
<td>392.4 63.9</td>
<td>Mean 293.1 81.5</td>
<td>0.00</td>
</tr>
<tr>
<td>Timed Up and Go test (s)</td>
<td>8.46 1.91</td>
<td>Mean 9.45 SD 2.32</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 2. Discriminatory analysis results

<table>
<thead>
<tr>
<th>Variables</th>
<th>Linear discriminant function</th>
<th>Discriminating criteria (cut-off point)</th>
<th>Error rate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>Z=0.1041X-6.3086</td>
<td>61</td>
<td>32.4%</td>
<td>0.00</td>
</tr>
<tr>
<td>Cross-sectional area in gluteus medius muscle (mm²)</td>
<td>Z=0.0030X-6.0639</td>
<td>2000</td>
<td>14.9%</td>
<td>0.00</td>
</tr>
<tr>
<td>Cross-sectional area in rectus abdominis muscle (mm²)</td>
<td>Z=0.0135X-4.6179</td>
<td>340</td>
<td>27.0%</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 3. Univariate logistic regression with walking ability 6 months post-total hip arthroplasty as the dependent variable

<table>
<thead>
<tr>
<th>Variables (cut-off point)</th>
<th>Odds ratio</th>
<th>95% confidence interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (&lt;61 years)</td>
<td>2.0</td>
<td>1.03-3.89</td>
<td>0.04</td>
</tr>
<tr>
<td>Cross-sectional area of the gluteus medius muscle (&lt;2000 mm²)</td>
<td>4.7</td>
<td>2.09-10.66</td>
<td>0.00</td>
</tr>
<tr>
<td>Cross-sectional area of the rectus abdominis muscle (&lt;340 mm²)</td>
<td>3.1</td>
<td>1.41-6.93</td>
<td>0.01</td>
</tr>
</tbody>
</table>

and TUG test, the best score of two trials was used for analysis. The differences in physical measurements before surgery between the two groups were examined using Student t-test. When this test indicated a significant difference, discriminatory analysis was performed to identify discriminating criteria between the two groups. Moreover, stepwise multiple logistic regression was employed to investigate the effect of the physical variables before surgery using grouping based on limping at 6 months as a dependent variable. Furthermore, odds ratios were calculated for each explanatory variable using cut-off points identified by discriminatory analysis. Analyses were performed using SPSS for Windows (version 17.0; SPSS Inc., Chicago, IL, USA). A p-value <0.05 was considered statistically significant.

Results

Table 1 shows the age, BMI, lower extremity muscle strength, CSAs of the gluteus medius and rectus abdominis muscles, and the TUG test results of the two groups.

The difference in age between the two groups was significant, although the difference in mean BMI was not. Neither the hip abductor and knee extensor strength nor the TUG test results were significantly different between the two groups. However, the CSAs of the gluteus medius and rectus abdominis muscles were significantly greater in the non-limping group than in the limping group.

Discriminatory analysis was performed using the three most significantly different variables between the two groups: age (61 years), CSA of the gluteus medius muscle (2000 mm²), and for CSA of the rectus abdominis muscle (340 mm²) (Table 2).

These significant variables were entered into the univariate logistic regression model, and the odds ratio was calculated using the discriminating criteria. Three variables (age, CSA of the gluteus medius muscle, and CSA of the rectus abdominis muscle) were significantly associated with future walking ability 6 months after THA (β=1.64, R²=0.19, p<0.01).

Discussion

Some studies have reported that most patients who underwent THA showed a reduction in hip pain and improve-
ments in physical functions compared with their preoperative condition\textsuperscript{12,13}. Many patients expect that their limp will resolve after THA\textsuperscript{13} and strive for an improved walking ability by strengthening the hip muscles during the postoperative rehabilitation period. In this study, we investigated screening methods that may be used to predict whether patients will be able to ambulate without a limp 6 months postoperatively.

Studies have also reported that muscle atrophy due to chronic inactivity in patients with hip osteoarthritis was a factor associated with postoperative functional recovery after THA\textsuperscript{12,20}. The present study revealed that signs of physical functions such as gluteus medius and rectus abdominis muscle atrophy are significant predictors of the 6-month postoperative walking ability. Furthermore, the most important finding of this study is that the discriminating criterion of 2000 mm\textsuperscript{2} for preoperative atrophy of the gluteus medius muscle may be the best marker of residual deficits in the limp 6 months after THA. This finding may help patients set appropriate goals for their rehabilitation after THA.

Weakness of the hip muscles generally results in abnormal gait patterns and functional disability. Lateral bending of the trunk toward the stance limb with a stabilized pelvis compensates for hip abductor weakness while walking\textsuperscript{22}. The preoperative lower extremity muscle strength can predict patients’ functional ability following arthroplasty\textsuperscript{22,23}. Therefore, we hypothesized that the preoperative hip abductor strength is the best predictor of limping in the frontal plane after THA. However, the results of this study indicate that this is not the case. The preoperative hip abductor strength may not reflect the potential function because pain during muscle strength measurement is related to muscle weakness\textsuperscript{22,23}. Hence, preoperative gluteus medius muscle atrophy, rather than preoperative hip abductor strength, may be more strongly associated with limping after THA.

In the multiple logistic regression analysis, the rectus abdominis muscle was not the significant predictor of limping after THA. The trunk muscles including rectus abdominis muscle may lead to the stability of trunk movement during the stance phase\textsuperscript{31}. Our data appear to be in line with this hypothesis on patients with THA. However, there is little information regarding the relationship between the trunk muscles and postoperative limping. Further research is required to investigate the effect of trunk muscles on the walking ability after THA more comprehensively.

Singh et al.\textsuperscript{24} reported that age was associated with walking ability after THA. Similarly, the analysis in the present study identified age at surgery as a factor for discriminating limping after THA. However, the predictive value of age appears to be uncertain because the odds ratio for age was less than that for CSA of the gluteus medius muscle.

The present study revealed that the preoperative knee extensor strength on the affected side is not a factor related to limping after THA. Studies have shown that the knee extensor strength correlates with walking speed and stair climbing performance in patients after total knee arthroplasty\textsuperscript{22,23}. In particular, our earlier study suggested that the preoperative knee extensor strength on the affected side might be a good predictive factor of the future ambulatory status, such as the use of an assistive device in daily living\textsuperscript{10}. Therefore, physical therapists should consider including quadriceps-strengthening exercises when developing rehabilitation programs for patients with hip osteoarthritis.

The statistical procedure used in this study, namely discriminatory analysis combined with multiple logistic regression, was also used in an earlier study to identify factors and discriminating criteria for predicting the fall risk in the elderly\textsuperscript{27}. This statistical procedure efficiently identifies important variables and appropriate cut-off values for predicting postoperative limping.

The present study has several limitations. First, it does not offer strategies for patients with a gluteus medius CSA <2000 mm\textsuperscript{2}. Preoperative training thus becomes a fundamental component of rehabilitation. Further research is required to determine whether improvements in gluteus medius muscle atrophy by preoperative training will improve the waking ability after THA. Second, the categorization in the present study was based solely on gait observation by a physical therapist; walking ability was not assessed using any objective gait measures, such as three-dimensional motion analysis. Third, although this study revealed that gluteus medius muscle atrophy is a predictor of limping after THA, other possible factors remain to be evaluated, such as atrophy in other hip muscles (e.g., gluteus maximus, iliopsoas), postural stability, and the comorbidity profile. Despite the limitations mentioned above, the present study yields valuable findings that will help to predict walking ability 6 months after THA.

**Conclusion**

The present study suggests that patients with a preoperative gluteus medius muscle CSA <2000 mm\textsuperscript{2} are likely to walk without a limp 6 months after THA.

**Conflict of Interest:** There are no conflict of interest

**References**


