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Assessment of hip abductors by MRI after total hip arthroplasty and effect of fatty atrophy on functional outcome

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ABSTRACT

Objectives: The aim of this study was to evaluate how fatty atrophy (FA) of the hip abductors in operated and non-operated hips affected the functional outcome following arthroplasty.
Methods: Forty-four hips of 22 patients (8 males and 14 females; mean age: 60 ± 14.4 (range: 24–84)) who matched the inclusion criteria and willing to participate in the study were retrospectively evaluated. The mean follow-up was 13.8 ± 2.3 (range: 10–18) months Magnetic resonance imaging (MRI) and Harris Hip Score (HHS) were used to evaluate muscle degeneration and functional outcome after unilateral THA through a posterolateral approach. The FA grade was evaluated using Goutallier grading system. Non-operated hips of subjects were used as the control. Age, duration after the operation, gluteal muscle FA, and the relationships with HHS were evaluated.
Results: FA was more evident in the operated hip ($p < 0.05$), and was more in the gluteus minimus than in the gluteus medius in both hips ($p < 0.05$). Patients' age was not correlated with gluteal muscle FA in the operated hip ($p > 0.05$), whereas there was a positive correlation with the contra-lateral hip ($p < 0.05$). Duration after surgery did not affect gluteal muscle FA in the operated hip. Older age and FA of either the operated or healthy hip resulted in poorer HHS ($p < 0.05$). HHS had the strongest correlations with patient age ($p < 0.001$) and FA ($p = 0.026$) of the gluteus minimus of contralateral hip.
Conclusion: Following THA, there was marked FA in the operated hip compared to that in the contralateral hip. In these cases, degree of FA in the replaced hip did not correlate with patients' age. Fatty atrophy of the gluteus minimus precedes that of gluteus medius. FA of the contralateral gluteus minimus and patient age are strongly correlated with lower HHS.
Level of evidence: Level IV, diagnostic study.

Introduction

Coxarthrosis is a major health issue in the modern aging society.[1] Total hip arthroplasty (THA) is a frequently utilized treatment option and it is one of the most successful and cost-effective interventions in medicine.[2–4] Patients' expectations are high, with emphasis on pain reduction and prompt return to daily activities.[3,5] Integrity and strength of abductor musculature are crucial to achieve a successful functional outcome following surgery.[6] As fatty degeneration of gluteal muscles progresses, patients' satisfaction declines and functional outcome deteriorates, especially in the elderly.[7,8] A strong correlation exists between presence of symptoms and degeneration of the gluteus medius muscles following THA.[9]

Fatty atrophy (FA) may be observed in gluteal muscles post-hip implant surgery. In addition, degeneration associated with osteoarthritis may be progressive.[1,10,11] As coxarthrosis progresses, certain changes such as disruption of pelvic balance during walking and fatty degeneration or atrophy of hip abductors may occur, depending on the stage of the disease.[11] Of these, changes in gluteus medius muscle are of particular concern since they are shown to influence disease progression.[1,10,11] In addition, a relation between arthritic hip and contralateral gluteus medius muscle atrophy was reported, where muscle degeneration in the healthy limb was associated with arthritis in the contralateral hip.[11] Not

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surprisingly, patients with coxarthrosis have lower muscle strength compared to normal individuals in the same age group.[11]

Magnetic resonance imaging (MRI) with optimized conventional pulse sequences and metal artifact reduction sequences (MARS) is a useful modality in the diagnosis of periprosthetic fractures, bone resorption and osteolysis, postoperative hematoma, disruption of the pseudocapsule, synovitis caused by polyethylene wear and adverse local tissue reactions, periprosthetic masses and neoplasms, bursitis, tendinopathy and tendon tears, and neurovascular compromise.[12] The metal artifact reduction sequences are optimized for reduction of metal artefact by using the following three strategies; 1) the section-selection gradient and increased radio-frequency (RF) bandwidth and a relatively narrow section thickness, 2) the increased read gradient, 3) view angle tilting. Each of these three strategies contributes about equally to reduction of metal artifact.[13] Several clinical and cadaveric studies on fatty degeneration and atrophy of hip abductors revealed that magnetic resonance imaging (MRI) is a suitable imaging modality to assess changes in gluteal musculature following THA.[2,8,9,14,15] In these studies, Goutallier classification was the most frequently used grading system to assess changes in the gluteal muscles with strong inter-observer reliability.[9,10] The focus of these studies was the effect of different surgical approaches on hip abductors.[2,8,9,14]

To the best of our knowledge, no study in the literature compared FA of both the operated and non-operated hip following hip arthroplasty, or evaluated their effect on functional outcomes. Only 2 prior studies reported the changes in contralateral hip following hip replacement; however, without assessing the correlation between functional outcome and gluteal atrophy of the non-operated limb.[2,15] In this study, we aimed to evaluate how FA of the hip abductors in both the operated and non-operated hips affected the functional outcome following arthroplasty.

Patients and methods

Patients who underwent primary THA through a posterolateral approach for unilateral primary coxarthrosis between 2010 and 2013 were enrolled in this retrospective study. After the approval of the Institutional Ethical Review Board (no: 525/5.9.2014), patients matching the inclusion criteria were called to participate in the study. Written informed consent was obtained from all patients. Inclusion criteria were; 1) age older than 18 years, 2) history of surgery for unilateral primary coxarthrosis, and 3) minimum follow-up of 6 months. Exclusion criteria were; 1) American Society of Anesthesiologists (ASA) physical status score of IV–VI, 2) higher grade of dysplasia (≥Crowe Type 2), 3) bilateral coxarthrosis, 4) lower extremity osteotomies, 5) history of hip surgery, 6) inflammatory arthritis, any mental or physical disabilities or lumbar disc pathology, and 7) contraindications for MRI.

All patients underwent unilateral primary THA through a posterolateral approach using collarless uncemented titanium stem and uncemented press-fit titanium cup (Biomet® Orthopedics, Inc., USA).

The same post-operative rehabilitation protocol was used for all patients. Quadriceps and gluteus maximus isometric exercises, heel slide, ankle pump, 30° active assisted or passive hip and knee flexion, and hip abduction exercises were begun immediately after surgery under the supervision of a physiotherapist. At post-operative day 1, patients were mobilized with a walker for 5–10 min. For the following 2 days, the patients were allowed to walk as much as they felt comfortable. Patients were discharged at post-operative day 5. Routine follow-ups were done at 6, 12, 24 weeks, and 1 year post-operatively. Patients used walker for 6 weeks, after which they were encouraged to use single crutch until 12 weeks postoperatively.

Patients enrolled had MRI scans of their both hips performed at the last follow-up of the current study. Harris Hip Score[16] (HHS) was used to assess the functional outcome. Two observers (E.K. and A.O.) carried out the clinical analysis.

Magnetic resonance imaging

All MRI scans were performed on a 1.5 T MR system (Signa® HDxt 1.5 T, General Electric Company) by metal artifact reduction sequences (MARS). To reduce metal artifacts maximum RF bandwidth and high matrix values were used. Pelvis protocol with axial T1-weighted turbo spin-echo sequences (repetition time-TR/echo time-TE of 640/9 ms, 3.5 mm slice thickness and, 1 mm slice spacing, 400 × 400 mm field of view (FOV)) and coronal T1-weighted turbo spin-echo sequences (TR/TE 540/3 ms, 5 mm slice thickness and, 1 mm slice spacing, 400 × 400 mm FOV) were used. FA of the gluteus medius and minimus muscles was assessed on the transverse T1-weighted images at the lower 1/3 of the distance between the iliac crest and the tip of the greater trochanter.

Image evaluation

FA of the gluteal muscles was evaluated by a radiologist at the PACS (Picture Archiving and Communication System) workstation (Neorad®, Teleradiology & 3D, Serman med. Ltd. Şti., Turkey). The grade of FA was scored separately for the gluteus medius and gluteus minimus muscles bilaterally on axial T1-weighted MR images according to the Goutallier grading system[17]; grade 0: normal muscle, grade 1: muscle contains some fatty streaks, grade 2: fatty infiltration, but still more muscle than fat, grade 3: equal amounts of fat and muscle, grade 4: more fat than muscle (Figs. 1 and 2).

The operated hips were assigned to group A whereas the contralateral hips were used as control and were assigned to group B. Age, duration after the operation, FA of the gluteus medius and minimus muscles, and the relationship of these findings with HHS were evaluated.

Statistical analysis

Data were statistically analyzed using SPSS software (v. 15.0; SPSS Inc. Chicago, IL, USA). Mean and standard deviation were determined for continuous variables. Independent variables were compared with Mann–Whitney's U test and dependent variables were compared with Wilcoxon's test. Parametric nominal variables were compared with Pearson's correlation analysis and non-

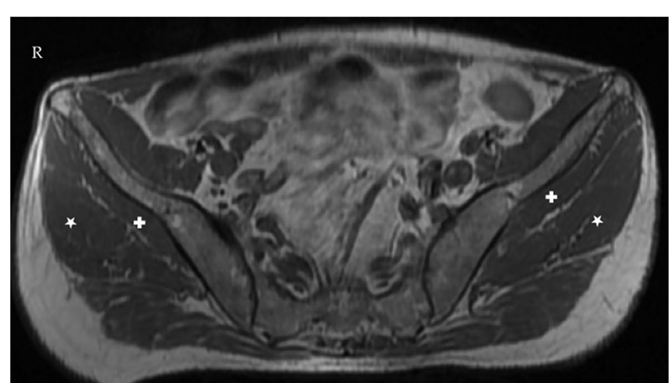

Fig. 1. In the axial T1 weighted images, the prosthesis is seen at the right hip. At the left hip in gluteus medius muscle (star) and in gluteus minimus muscle (cross) grade 1 fatty atrophy and at the right hip in both gluteus medius (star) and minimus (cross) muscles grade 2 fatty atrophies are seen.

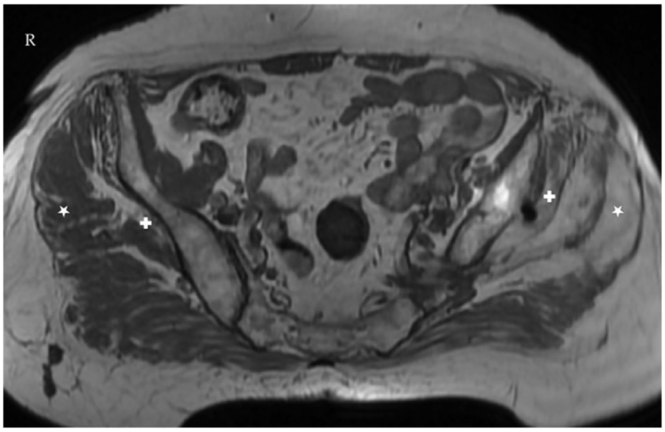

Fig. 2. In the axial T1 weighted images, the prosthesis is seen at the left hip. At the left hip in gluteus medius (star) and minimus muscles (cross) grade 4 fatty atrophy and at the right hip in gluteus medius muscle (star) grade 3 and in gluteus minimus muscle (cross) grade 4 fatty atrophies are seen.

Table 3
The correlation of HHS with FA of gluteus medius and minimus muscles, age and post-operative duration.

HSS		
	rho	p
Gluteus medius[a]		
Group A	−0.461	0.031[c]
Group B	−0.584	0.004[c]
Gluteus minimus[a]		
Group A	−0.505	0.016[c]
Group B	−0.697	<0.001[c]
Age[b](years)	−0.816	<0.001[c]
Post-operative duration[b] (months)	0.241	0.280

[a] Spearman correlation test was used to evaluate the correlation between HHS and FA.
[b] Pearson correlation test was used to evaluate correlation between HHS and age.
[c] $p < 0.05$ is statistically significant HHS: Harris Hip Score rho: Correlation coefficient.

parametric nominal variables were compared with Spearman's correlation analysis. The level of significance was set at $p < 0.05$.

Results

Forty-four hips of 22 patients who matched the inclusion criteria and willing to participate in the study were retrospectively evaluated. Eight patients were males and 14 were females. Mean age was 60 ± 14.4 (range: 24–84) years and mean follow-up was 13.8 ± 2.3 (range: 10–18) months. The mean HHS was 84.6 ± 6.8 (range: 71.3–95.2).

FA of the gluteus medius and minimus muscles in group A was more than in group B ($p < 0.05$) [Table 1]. There was more FA in the gluteus minimus muscle than in the gluteus medius muscle in both groups ($p < 0.05$) [Table 1].

In group A, patients' age was not correlated to FA of the gluteal muscles ($p > 0.05$), whereas there was a positive correlation in group B ($p < 0.05$) [Table 2]. The relationship between follow-up time and FA of the gluteus medius and minimus muscles was not statistically significant in group A ($p = 0.767$ and $p = 0.0775$, respectively).

Older age and FA on either the operated or healthy hip resulted in poorer HHS ($p < 0.05$) [Table 3]. However, there was no relationship between HHS and follow-up time ($p = 0.280$) [Table 3]. When evaluated with backward methods of linear regression analysis (R square = 0.745), HHS had the strongest correlations with patients' age ($r = -0.816$, $p < 0.01$) and FA ($r = -0.697$, $p < 0.01$) of the gluteus minimus muscle in contralateral hip (group B).

Table 1
Fatty atrophy of the gluteus medius and minimus muscles according to Goutallier Classification.

Goutallier Classification	Group A	Group B	p
Gluteus medius	2.36 ± 0.95	1.73 ± 0.98	<0.001*
Gluteus minimus	3.09 ± 0.87	2.05 ± 0.77	<0.001*
p	<0.001*	0.020*	

Wilcoxon–Rank test was used to evaluate the significance of fatty atrophy between the groups and muscles in each group.
*$p < 0.05$ is statistically significant.

Table 2
The correlation between age and fatty atrophy of gluteus medius and minimus muscles.

Goutallier Classification	Age (years)	
	rho	p
Gluteus medius		
Group A	0.396	0.068
Group B	0.543	0.009*
Gluteus minimus		
Group A	0.372	0.088
Group B	0.537	0.010*

Spearman correlation test was used to evaluate the correlation between age and fatty atrophy.
*$p < 0.05$ is statistically significant.
rho: Correlation coefficient.

Discussion

The results of this study demonstrate the unfavorable effect of osteoarthritis and THA on gluteal muscles leading to degeneration and FA. The impact of both FA and age on functional outcome regardless of the post-operative duration after THA was noted, with more pronounced effect of the gluteus minimus muscle.

THA is a successful surgery in relieving pain and reducing disability in patients with end-stage coxarthrosis.[3] Gluteal muscles in the elderly with coxarthrosis are prone to degeneration and FA, resulting in relatively poorer functional outcomes after THA.[8,9] The number of satellite cells declines in the elderly with severe reduction in the regenerative capacity, particularly over 70 years of age.[8,18,19] This causes diminished metabolic response and impaired recovery of hip musculature to surgical trauma, resulting in more profound degeneration and reduction in muscle mass of the hip abductors at the operated than the non-operated contralateral hip.[2,8,20,21] This was evident in the present study, where FA was higher in the operated hips. Even though this result is in line with the literature, the degree of FA on the operated side was not correlated to older age. This result is somewhat controversial, with several studies reporting the influence of age on FA.[8,20] Also, the fact that FA is thought to result from diminished number of satellite cells in the elderly makes us expect less atrophy in operated hips of the younger patients. The reason for this discordance may be the relatively younger age of patients in our study. Patients in this study had a mean age of 60 years; whereas the mean age of patients in Muller's study was over 70 years.[8] Seventy years of age is a crucial threshold where satellite cells begin to decline rapidly.[8] Also, patients in the study by Muller et al[8] underwent surgery through modified direct lateral and minimally invasive anterolateral approaches, whereas patients in our study underwent surgery using a posterior approach. Different approaches may elicit different magnitudes of soft tissue damage, and we did not find studies addressing the relationship of age and FA with posterior approach. It is possible that because patients in our study were younger, the change in regenerative capacity was subtle and hence its effect on muscle degeneration was masked by the effect of surgical trauma on the operated side. When such considerable physical stress was not present, as it was in non-operated hips, the effect of decline in regeneration potential was not masked and the normal relation between older age and FA was revealed.[11]

Following initial trauma, muscle regeneration begins as early as 15 days, and by the 3rd to 4th week, the healing process is mostly complete either with regeneration of mature muscle cells or formation of scar tissue.[8,20,22] After 4 weeks, the regeneration process is almost completed.[8,22] This impediment of the regeneration process after 4 weeks may explain our finding of no correlation between the follow-up time and FA, since hip muscles were assessed at a time point well beyond this period. Müller et al stated the same findings and found no difference in the degree of FA between 3 and 12 months.[23] It seems that normalization of the hip abductors after chronic diseases like osteoarthritis is not possible in spite of hip arthroplasty.[2] Further experimental cellular studies are needed to understand this issue.

Even without surgical intervention, coxarthrosis itself induces FA at the late stages of the disease with a trend of downsizing in gluteus medius and minimus muscles.[1,10] Functional and structural alterations of the gluteal muscles, especially the gluteus medius contribute to the development of osteoarthritis of the contralateral hip.[11] Fatty degeneration of gluteus minimus precedes that of gluteus medius, and it is common even in asymptomatic patients following THA.[9,10,24] FA of gluteus minimus initiates subsequent atrophy and insufficiency of gluteus medius.[24] These reports explicate our findings on gluteus minimus muscle degeneration in healthy hips.

Fatty degeneration of the hip abductors is inversely correlated with patients' satisfaction.[7] With aging, overall functional status deteriorates and HHS worsens.[6] In the present study, older age and FA on either the operated or healthy hip resulted in poorer HHS. These results are consistent with previous findings in the literature. A rather interesting finding in our study was that FA of the contralateral gluteus minimus muscle and patients' age were the most predictive factors of HHS. Even though there are some studies explaining the effects of age on functional recovery after hip arthroplasty,[25,26] to the best of our knowledge no studies reported the effect of gluteus minimus muscle FA on functional evaluation.

Patients with coxarthrosis develop severe atrophy and weakness of the hip musculature compared to ipsilateral limb.[3,27,28] This is more evident in the abductor group, with fatty degeneration of gluteus minimus being proposed as a major contributor to joint instability, and as a predictor of falls in the elderly.[1,23,28] Both preoperative and postoperative exercise programs focusing on abductor strengthening have been shown to improve functional outcome following hip arthroplasty.[1,11,27] Bilateral strengthening of abductor musculature cannot be overemphasized, since functional and structural alterations of the gluteal muscles in the operated hip will have contributions to the development of osteoarthritis in the contralateral hip, and the change in gluteus minimus of the healthy hip is the strongest predictor of postoperative HHS.[11]

Further studies with larger sample size are needed to evaluate the importance of hip abductors in the development of hip osteoarthritis and in functional recovery after hip arthroplasty. The limitation of this study is the absence of pre-operative MRI of the gluteal muscles of both hips and pre-operative HHS.

Conclusion

Degeneration and FA of hip abductors is a part of the aging process. Following hip arthroplasty, these degenerative changes progress regardless of age having a negative influence on functional outcome. Impairment of gluteal muscles contributes to the development of osteoarthritis, and may cause structural alterations in the contralateral muscles, especially gluteus medius. Previous reports in the literature and results of this study point to the importance of changes in the gluteus minimus as a predictor of degeneration of the gluteus medius and subsequent hip osteoarthritis. We think that strengthening of contralateral gluteal muscles with the arthritic or the operated hips will help to alleviate symptoms, slow down osteoarthritis progression, and facilitate functional recovery after hip arthroplasty.

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