Hip muscle atrophy in patients with acetabular labral joint pathology

<table>
<thead>
<tr>
<th>Journal:</th>
<th>Clinical Anatomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript ID</td>
<td>Draft</td>
</tr>
<tr>
<td>Wiley - Manuscript type:</td>
<td>Original Communications</td>
</tr>
<tr>
<td>Keywords:</td>
<td>anatomy, imaging</td>
</tr>
<tr>
<td>Additional Keywords:</td>
<td>hip injuries, muscle atrophy, magnetic resonance imaging, osteoarthritis</td>
</tr>
</tbody>
</table>
Hip muscle atrophy in patients with acetabular labral joint pathology

Introduction: Intra-articular hip joint pathology is a source of hip and groin pain in active individuals and is thought to be a precursor to hip osteoarthritis. Limited evidence exists to guide appropriate physiotherapy management for these patients. Identification of which hip muscles are affected may help clinicians to develop effective exercise programs.

Materials and Methods: A cross-sectional observational study in a hospital setting was conducted to investigate the size of individual hip abductor, hip extensor and hip external rotator muscles in patients with acetabular labral joint pathology compared with age and sex matched healthy subjects. 12 participants (8 females, 4 males), aged 20 to 53 years, with a medical diagnosis of unilateral acetabular labral tear and 12 healthy participants were recruited. Magnetic resonance imaging was used to assess cross-sectional areas of the gluteus minimus, gluteus medius, upper gluteus maximus, lower gluteus maximus, piriformis, and quadratus femoris muscles bilaterally.

Results: Gluteus medius muscle cross-sectional area was significantly different between groups (P<0.01, effect size = 0.92) with muscle size found to be smaller in the pathology group. No differences were found for the other hip muscles (P>0.05).

Conclusions: These findings suggest that hip muscles are not all affected equally by the presence of intra-articular hip joint pathology. Atrophy of specific hip muscles, which are important in hip joint and pelvic stability, may alter hip joint function during gait and
functional tasks. Clinicians treating patients with intra-articular hip joint pathology may need to prescribe exercises targeting the specific muscles with demonstrated dysfunction.

**Keywords:** hip injuries; muscle atrophy; magnetic resonance imaging; osteoarthritis
INTRODUCTION

Intra-articular hip joint pathology, such as femoroacetabular impingement (FAI) syndrome, acetabular labral pathology and chondropathology, has a significant impact on the quality of life and function of active individuals (Clohisy et al., 2009; Filbay et al., 2016). It is thought to be a precursor to degenerative disease, in particular, hip osteoarthritis (McCarthy et al., 2001; Beck et al., 2005). Of concern is the high prevalence of intra-articular hip joint pathology reported in younger populations (Kemp et al., 2014a). However, optimal management for this condition is still under debate.

Research evidence for the management of intra-articular hip joint pathology is evolving. Trials are currently underway to compare surgical with conservative management and to investigate efficacy of post-surgical physiotherapy interventions for FAI syndrome and chondropathology (Bennell et al., 2014; Palmer et al., 2014; Kemp et al., 2015; Tijssen et al., 2016; Griffin et al., 2018). Surgery to correct the bony alignment and repair or resect the damaged acetabular labrum has been advocated, with good outcomes reported post-operatively (Kemp et al., 2012; Kierkegaard et al., 2017) although recent research has indicated that function and participation in sport and physical activity is still reduced 1 year after surgery (Thorborg et al., 2018). More recently, conservative non-surgical management approaches focusing on improving neuromuscular function around the hip have been proposed as an alternative (Casartelli et al., 2016; Casartelli et al., 2017; Casartelli et al., 2018; Pennock et al., 2018).
Muscles contribute to dynamic stability of the hip joint, along with the bony and ligamentous structures. Based on their anatomy and function, the deep hip flexor, abductor and external rotator muscles are proposed to stabilize the femoral head in the acetabulum (Retchford et al., 2013). Greater reliance on the hip muscles to provide joint stability is proposed when intra-articular hip joint pathology is present (Retchford et al., 2013). An imbalance among the muscles surrounding the hip joint may also result in altered loading of joint surfaces (Lewis et al., 2007) with injury and/or degeneration as a possible consequence. As dynamic hip joint instability is thought to be related to the pathomechanism of acetabular labral injury associated with FAI, conservative non-surgical management focusing on improving hip neuromuscular function has been recently advocated (Casartelli et al., 2016; Casartelli et al., 2017). However, to design effective neuromuscular treatment protocols, it is first important to know what deficits in hip neuromuscular function are present in association with intra-articular hip joint pathology.

Changes in neuromuscular function of the hip are associated with intra-articular hip joint pathology. Recent systematic reviews (Diamond et al., 2015; Freke et al., 2016; Mayne et al., 2017) and research studies have examined physical impairments associated with FAI syndrome, acetabular labral pathology and chondropathy, and have found impaired hip range of motion (Kemp et al., 2014b; Diamond et al., 2015), reduced hip muscle strength (Casartelli et al., 2011; Harris-Hayes et al., 2014; Kemp et al., 2014b; Mendis et al., 2014; Nepple et al., 2015; Diamond et al., 2016), impaired functional task performance (Hatton et al., 2014; Bagwell et al., 2016; Charlton et al., 2016; Kemp et
al., 2016; Samaan et al., 2016), and altered gait biomechanics (Kennedy et al., 2009; Brisson et al., 2013; Hunt et al., 2013; Ng et al., 2018). With respect to hip muscle size, previous research has investigated size of the gluteal muscles in patients with chronic hip joint pain (Mastenbrook et al., 2017) and of the individual hip flexor muscles in patients with acetabular labral pathology (Mendis et al., 2014), however, no research to date has investigated the individual hip abductor, hip extensor or hip external rotator muscles in this patient population. As intra-articular hip joint pathology could impair stability of the hip joint and the muscles surrounding the hip may be required to provide dynamic stability (Retchford et al., 2013), it is important to determine if imbalances in hip muscle size exist in the presence of joint pathology. Therefore, the aim of this study was to compare size of the hip abductor, extensor and external rotator muscles between patients with intra-articular hip joint pathology and age and sex matched healthy control subjects. It was hypothesized that there would be a significant difference in individual hip muscle size between the pathology and control groups.

MATERIALS AND METHODS

Design & Participants

A cross-sectional design was used in this study. Participant selection and procedures have been described in detail elsewhere (Mendis et al., 2014). Twelve participants, aged between 20 to 55 years and diagnosed with a unilateral acetabular labral tear, were recruited for the study prior to undergoing hip arthroscopy. Participants were recruited from an orthopaedic clinical practice where they were screened by an orthopaedic surgeon who made the diagnosis based on clinical examination and
magnetic resonance imaging (MRI). Twelve, healthy age and sex matched control participants with no history of hip pain or injury were recruited from a general university population. Exclusion criteria for all subjects included a self-reported history of: congenital or developmental hip disease, previous hip fracture or surgery, previous back surgery, painful knee/s, low back pain, acute severe sciatica, rheumatoid arthritis, epilepsy, and neuromuscular disorder (Arokoski et al., 2002); and any contraindication to undergoing MRI. All participants gave written informed consent and their rights were protected. This study was approved by the institutional ethics committee (approval no: 2007001385).

**Procedures**

All measures were collected in one session in a hospital setting and the testing sequence involved screening for contraindications to MRI, collection of demographic information and MRI examination. Height and weight were measured for all subjects. Self-report questionnaires were used to record age and the dominant leg used for kicking. Physical activity levels were measured by a Habitual Physical Activity questionnaire (Baecke et al., 1982). For the patients with labral tear pathology, presenting symptoms including pain intensity with aggravating activities, which was measured on a verbal numerical scale of 0 'no pain' to 10 'worst pain imaginable' (Murphy et al., 1988), location of symptoms (indicated on a body chart), mean duration of symptoms, Non-Arthritic Hip Score (Christensen et al., 2003) and side of injury were recorded.
For MRI assessment, subjects were positioned in supine lying on the imaging table with a pillow placed under their knees for comfort. A 1.5 Tesla Siemens Magnetom Sonata MR system (Siemens, Erlangen, Germany) was used. Transverse sections from the iliac crest to just below the lesser trochanter of the femur were acquired with a T2 weighted sequence (True FISP; TR = 6.9s, TE= 60ms, NA = 2, matrix 192 x 256, FA=150 degrees). Approximately 26 slices with a slice thickness of 8 mm and an inter-slice gap of 8.8mm were obtained over 5 minutes. The MRI operator was blinded to group allocation. Images were stored for offline measurement and were assigned an alphanumeric code to ensure blinding of the measurer to subject and group identification.

Measuring anatomical cross-sectional areas on MRIs is a validated method of objectively documenting skeletal muscle size (Engstrom et al., 1991; Scott et al., 1993). Muscle size was measured by manually tracing the relevant muscle boundary and calculating its cross-sectional area (CSA) (Mendis et al 2009, Mendis et al 2014) using Image J software (version 1.43u, National Institutes of Health, Bethesda, USA, http://rsb.info.nih.gov/ij/). The gluteus minimus, gluteus medius, upper gluteus maximus, lower gluteus maximus, piriformis, and quadratus femoris muscles were measured bilaterally. Average muscle CSA for each muscle was calculated from slices of interest at anatomical landmarks as follows. The gluteus minimus muscle was measured on six consecutive slices superior to the femoral head. The gluteus medius muscle was measured on six consecutive slices starting from the base of the sacrum. The division between the upper and lower gluteus maximus muscles was based on the anatomical
landmark of the largest CSA of the femoral head (Grimaldi et al., 2009a). The upper
gluteus maximus muscle was measured on six consecutive slices superior to this
landmark while the lower gluteus maximus muscle was measured on six consecutive
slices inferior to this landmark. The piriformis muscle was measured on three
consecutive slices from the point where the muscle was first visible on the image
(Leung et al 2015). The quadratus femoris muscle was measured on three consecutive
slices inferior to the femoral head. These particular anatomical landmarks were chosen
for each muscle as they crossed the hip and pelvic region (Figure 1). Intra-rater
reliability of CSA measurement for each muscle was assessed in 5 randomly selected
subjects and found to be high (ICC\textsubscript{1,1} ranging from 0.95 to 0.99; 95% CI:0.90, 0.99;
SEM: 0.5 to 1.5 cm\textsuperscript{2}).

Data analysis

Data analyses were performed on SPSS statistical software (version 22, SPSS Inc,
Chicago, USA). Statistical significance was set at $P<0.05$. To compare hip muscle size
between groups, a repeated measures analysis of variance (ANOVA) was performed
with ‘Group’ (Control vs Labral Tear) and ‘Gender’ (Male vs Female) as between
subjects factors and ‘Side’ (injured/non-injured for the Labral Tear group; dominant/non-
dominant for the Control group) as a within subjects factor (Grimaldi et al., 2009b).
Covariates of age, height and weight were included and a Type 1 sums of squares
model was used (Hides et al., 2008). Separate models were run for each muscle. Main
effects for ‘Group’ and interaction effects for ‘Group’ and ‘Side’ were of interest. All
cases were assessed.
RESULTS

Table 1 lists the descriptive characteristics (age, height, weight, physical activity level) for each group. There were 8 females and 4 males in each group. All participants in the Control group were right leg dominant while 10 participants were right leg dominant and 2 were left leg dominant in the Labral Tear group. All subjects in the Labral Tear group had anterosuperior quadrant tears of the labrum and presented with symptoms of intermittent hip pain or ache and clicking in the anterior hip and groin region. Symptoms were aggravated by activities such as running, cycling, kicking, pivoting, hip flexion >90 degrees, prolonged sitting and standing (>1hr) (mean pain intensity: 6.3 ± 2, range: 3 - 9), and eased with rest (mean pain intensity: 2 ± 2, range: 0 – 7). The mean duration of symptoms was 21 ± 26 months (range: 2 – 96 mths). The mean Non-Arthritic Hip Score was 67 ± 13 (range: 44-91) with normal function indicated by a score of 100. Six participants had a labral tear on the right leg and six participants had a tear on the left leg.

There was a significant difference between groups for gluteus medius muscle size (F = 16.23, \( P = 0.001 \)), indicating that muscle size was smaller in the Labral Tear group (Table 2). There was no significant interaction effect for Group by Side for gluteus medius muscle size (F = 0.61, \( P = 0.45 \)): Control group - dominant leg 29.2 (4.0) cm\(^2\), non-dominant leg 28.4 (3.8) cm\(^2\); Labral Tear group – injured leg 25.3 (4.6) cm\(^2\), uninjured leg 24.8 (4.4) cm\(^2\). No significant differences between groups were found for the gluteus minimus, upper gluteus maximus, lower gluteus maximus, piriformis and quadratus femoris muscles (all F < 3.90, all \( P > 0.07 \)). There were no significant
interaction effects for Group by Side for all muscles (all $F < 3.50$, all $P > 0.08$). Table 2 shows mean muscle CSA of both sides for the groups.

**DISCUSSION**

This study investigated the size of individual hip abductor, extensor and external rotator muscles in patients with intra-articular hip joint pathology and healthy subjects. Despite the wide range of presenting signs and symptoms, a consistent finding of this study was decreased size of a hip abductor muscle (gluteus medius) in patients with a medical diagnosis of acetabular labral pathology compared with the healthy control group.

Joint pathology or joint injury can alter muscle size and function through mechanisms of pain inhibition, disuse, reduced neuromuscular activation or arthrogenic muscular inhibition. Evidence of gluteal muscle inhibition due to joint effusion mimicking hip joint injury has been demonstrated (Freeman et al., 2013). Previous research has found weakness of the hip abductor muscles in patients with intra-articular hip joint pathology or pain (Casartelli et al., 2011; Harris-Hayes et al., 2014; Nepple et al., 2015; Diamond et al., 2016; Mastenbrook et al., 2017). Biomechanical studies have found differences in frontal plane hip kinematics and kinetics during gait for people with FAI, specifically reduced hip range of motion in the frontal plane due to reductions in hip abduction angles (Kennedy et al., 2009; Brisson et al., 2013), smaller peak hip abduction moments post FAI surgery (Brisson et al., 2013) and reduced range of motion of hip adduction in stance phase (Hunt et al., 2013). In light of these previous findings indicating dysfunction of the hip abductor muscles, gluteus medius muscle atrophy found in the current study in patients with acetabular labral tears is consistent with
previous research. Interestingly, however, the muscle atrophy was found on both sides (injured and uninjured legs) in the group with joint pathology, indicating perhaps that the mechanism contributing to muscle atrophy may not be arthrogenic muscular inhibition alone, but that other mechanisms associated with altered biomechanics at the hip might also have a role to play. While previous studies have found evidence of gluteus medius muscle atrophy in association with severe hip osteoarthritis (Grimaldi et al., 2009b; Zacharias et al., 2018), this is the first study to find evidence of specific hip abductor muscle atrophy in the presence of intra-articular hip joint pathology in a younger, active population. In contrast, previous research found hip abductor muscle volume to be larger in young active patients with chronic hip joint pain compared with asymptomatic controls (Mastenbrook et al., 2017). However, it is important to note that this previous study did not measure size of the individual hip abductor muscles, but measured a region of interest that incorporated the gluteal group including the gluteus minimus, gluteus medius and a small portion of the gluteus maximus muscles (Mastenbrook et al., 2017).

An imbalance of hip muscle size was found in this study. While gluteus medius muscle atrophy was demonstrated, there was no difference in size for the other hip muscles in the presence of intra-articular hip joint pathology. Interestingly, a similar pattern of reduced hip abductor muscle strength with no difference in strength for other hip muscle groups was previously demonstrated in individuals with FAI (Diamond et al., 2016).

Selective muscle atrophy in the presence of joint injury has been demonstrated in other regions of the body, such as the lumbar spine and knee (Hides et al., 1994; Pattyn et
The differential pattern of muscle atrophy found in our study could be explained by the functional role that each muscle plays in hip joint function. The gluteus medius muscle is functionally important in providing hip joint and pelvic stability, functioning not only as a hip abductor but also to provide femoral head stability in the acetabulum and pelvic stability in single leg stance during the gait cycle (Semciw et al., 2013; Flack et al., 2014). Perhaps, as a muscle that is important in providing stability at the hip joint and pelvis in weight bearing activities, the gluteus medius muscle was more susceptible to atrophy than the other hip muscles. A limitation of the current research is the small sample size, which however, is similar to previous research involving MRI investigation of hip muscle size (Grimaldi et al., 2009a; Grimaldi et al., 2009b). Future research could investigate the relationship between size of all individual hip muscles and the presence of intra-articular hip joint pathology in a larger sample of subjects.

Identification of potentially modifiable deficits in hip neuromuscular function can guide clinicians to tailor their treatment programs for patients with intra-articular hip joint pathology. The current investigation found decreased gluteus medius muscle size in patients with acetabular labral pathology compared with a healthy control group. The results of this study taken together with previous research highlighting deficits in hip abductor muscle function, may indicate that an imbalance in hip muscle size and function is associated with intra-articular hip joint pathology. An imbalance among the muscles surrounding the hip joint may contribute to dynamic hip joint instability and further joint degeneration. Clinicians treating these patients may need to perform
specific assessment of the hip abductor muscles and prescribe exercise interventions targeted to the specific muscle dysfunction observed.

REFERENCES


Ng KCG, Mantovani G, Modenese L, Beaulé PE, Lamontagne M. 2018. Altered Walking and Muscle Patterns Reduce Hip Contact Forces in Individuals With


**FIGURE LEGENDS**

Figure 1. Measurement of muscle cross-sectional area on MRI slices for (A) Gluteus minimus muscle, (B) Gluteus medius muscle, (C) Upper gluteus maximus muscle, (D), Lower gluteus maximus muscle, (E) Piriformis muscle, (F) Quadratus femoris muscle.
TABLES

Table 1. Descriptive characteristics of subjects in the Control and Labral Tear groups.

<table>
<thead>
<tr>
<th>Subject Characteristics</th>
<th>Control Group (n = 12)</th>
<th>Labral Tear Group (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Age (years)</td>
<td>35 (12)</td>
<td>23 - 55</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.7 (0.1)</td>
<td>1.6 - 1.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66 (10)</td>
<td>53 - 86</td>
</tr>
<tr>
<td>Physical Activity Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 (1)</td>
<td>7 - 10</td>
</tr>
</tbody>
</table>

¹measured on Habitual Physical Activity Questionnaire (Baecke et al., 1982); SD – standard deviation.
Table 2. Hip muscle cross-sectional area (cm$^2$) for Control and Labral Tear groups.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Control Group</th>
<th>Labral Tear Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluteus minimus</td>
<td>11.8 (2.3)</td>
<td>11.7 (2.6)</td>
</tr>
<tr>
<td>Gluteus medius*</td>
<td>28.8 (3.7)</td>
<td>25.1 (4.3)</td>
</tr>
<tr>
<td>Upper gluteus maximus</td>
<td>37.0 (7.0)</td>
<td>39.4 (8.0)</td>
</tr>
<tr>
<td>Lower gluteus maximus</td>
<td>46.1 (8.2)</td>
<td>41.7 (9.4)</td>
</tr>
<tr>
<td>Piriformis</td>
<td>10.8 (2.7)</td>
<td>9.7 (3.2)</td>
</tr>
<tr>
<td>Quadratus femoris</td>
<td>4.6 (1.4)</td>
<td>5.5 (1.7)</td>
</tr>
</tbody>
</table>

1Values are marginal means (standard deviation) adjusted for age, height, and weight. *significant group difference $P < 0.05.$
Figure 1. Measurement of muscle cross-sectional area on MRI slices for (A) Gluteus minimus muscle, (B) Gluteus medius muscle, (C) Upper gluteus maximus muscle, (D) Lower gluteus maximus muscle, (E) Piriformis muscle, (F) Quadratus femoris muscle.

152x131mm (300 x 300 DPI)