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Research Article

# The Muscular Suspension of the Hip-An Anatomical Study -

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## ABSTRACT

Muscle forces are essential to provide functional stability of the hip joint. Although the mechanics of the gluteal muscles are well described in the literature, little is known about the short pelvi-trochanteric muscles. Aim of the study is to elucidate the mechanical effect of those muscles onto the hip joint by evaluating the orientation of their axes. We dissected 10 cadaveric hip joints to study the exact orientation of the muscles situated behind the hip joint within the frontal plane. The angle of the upper and lower margins of the muscles to the vertical axis of the body and their mid substance perimeter were measured.

The m. obturatorius externus, the m. obturatorius internus with both m. gemelli and the m. quadratus femoris are oriented towards cranial in a way to stabilize the hip joint in a standing position by stretching.

In contrast to the m. glutaeus medius which stabilizes the hip joint by increasing the pressure on the sourcil, the muscles listed above decrease the pressure on the sourcil and "unload" the joint by a spring-suspension mechanism. To preserve this mechanism, one should save the integrity of the muscles and their tendons at the trochanter major. Surgical techniques should be adapted to this anatomy.


**Keywords:** Hip joint; Hip suspension; Hip joint pressure; Total joint replacement; Surgical approach

## INTRODUCTION

Friedrich Pauwels postulated that osteoarthrosis could be caused by excessive static articular pressure between femoral head and acetabulum [1]. Augmentation procedures [2-4] and pericoxal reorientation osteotomies [5-7] have proven in selected cases to halt progression in the degenerative process of arthrosis [8]. Those operative corrections aim to optimize the mechanics of the joint by altering the levers of the abductor muscles and of the gravity forces. In fact, the levers of those forces can be optimized by e.g. lengthening the femoral neck (abductor forces) [9] and medialising the centre of rotation through pelvic osteotomies (gravity forces) [10]. However, the abductor muscles are not the only muscles which link the pelvis to the proximal femur. There are a series of muscles originating on the pelvic bone and inserting on the proximal femur which are not categorized as "hip abductors". Their precise anatomy has not attracted much attention in the past and their exact function remains thus to be elucidated. Precisely, their anatomical orientation in relation to the cranio-caudal axis, hence their static effect on the hip joint have not been described yet at this day in the literature. Our aim was to study the anatomy and more precisely the direction of the muscular fibres of the

- m. glutaeus medius
- m. piriformis
- m. obturatorius internus with gemelli
- m. obturatorius externus
- m. quadratus femoris to assess their function under weight bearing conditions.

## METHODS

5 fresh cadavers (10 hip joints) were dissected. The bodies were positioned horizontally prone, both legs parallel and symmetric in relation to the pelvis. Attention was drawn to the parallel position of both feet. A metallic bar was positioned in the rima ani and fixed to the underlying surface at the level of the knees to simulate the vertical axis within the sagittal plane of symmetry. This bar was used as reference to the angular measurements. Quantitative assessments were performed on 3 cadavers (6 hip joints, n = 6).

A skin incision was performed along the pelvic crest and the lateral edge of the sacrum. The m. glutaeus maximus was reflected towards lateral distal. The underlying muscles were indentified and well individualized between the distal margins of the m. glutaeus medius and the m. adductor magnus at the posterior aspect of the hip (Figures 1-3).

A hinged goniometer was used to measure the angle between the straight margins of the muscles listed above and the horizontal line (Figure 4).

We define the inclination of a muscle by considering the mean value of both angles formed by the proximal and the distal margins and the vertical axis (angle bisector). Negative inclination of a muscle means that the muscle is directed towards lateral proximal. Positive inclination of a muscle means that the muscle is directed towards lateral distal (Figure 4).

A centimeter strap was used to evaluate the perimeter of the middle part of the muscle belly.

Following parameters were thus measured successively:

- Angle of the inferior margin of the m. glutaeus medius
- Angle of the superior margin of the m. piriformis
- Angle of the inferior margin of the m. piriformis

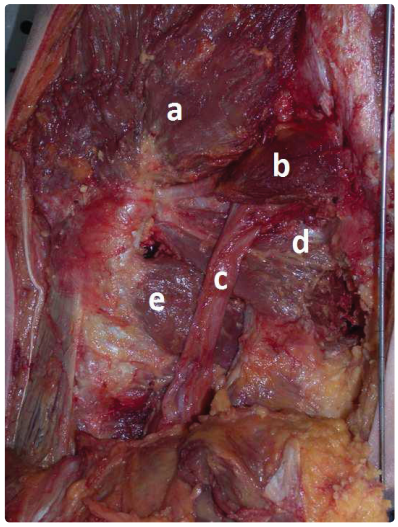


**Figure 1:** Posterior dissection of the left hip
The m. maximus is reclined towards lateral distal. Following structures are well visualized: a: m.gluteus medius, b: m. piriformis, c: nervus ischiadicus, d: m. obturatorius internus with m. gemellii, e: m. quadratus femoris. The sacro-tuberal ligament has been removed.

- Perimeter of the m. piriformis
- Angle of the superior margin of the m. gemellus superior (m. obturatorius internus)
- Angle of the inferior margin of the m. gemellus inferior (m. obturatorius internus)
- Perimeter of the m. obturatorius internus and both m. gemelli
- Angle of the superior margin of the m. quadratus femoris
- Angle of the inferior margin of the m. quadratus femoris
- Perimeter of the m. quadratus femoris
- Angle of the superior margin of the m. obturatorius externus
- Angle of the inferior margin of the m. obturatorius externus
- Perimeter of the m. obturatorius externus

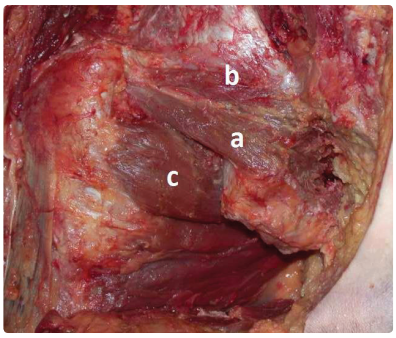


**Figure 2:** Posterior dissection of the left hip joint, detailed view
The nervus ischiadicus and the m. piriformis have been removed. The m. obturatorius internus (a) is reflected around the ischiatic bone within the incisura ischiadica minor. It originates on a wide area on the foramen obturatorius and the quadrilateral surface. The m. gemellus superior (b) originates at the spina ischiadica. The m. gemellus inferior is a quite strong muscle which originates at the inferior part of the incisura ischiadica minor. The m. quadratus femoris. (c) originates at the anterior aspect of the tuber ischiadicum.

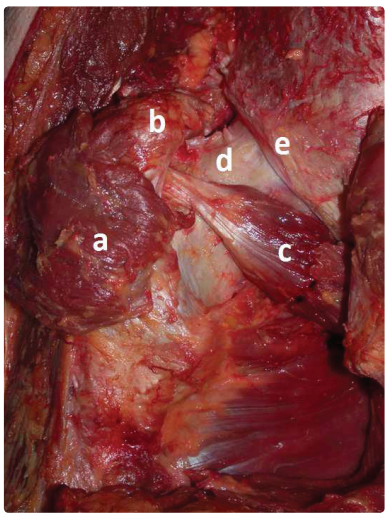


**Figure 3:** Posterior dissection of the left hip joint, detailed view.
The m. obturatorius internus with both gemelli and the m. quadratus femoris (a) have been reclined and the articular capsule removed. b: tip of Trochanter major. c: m. obturatorius externus. d: femoral neck. e: posterior acetabular rim with limbus.

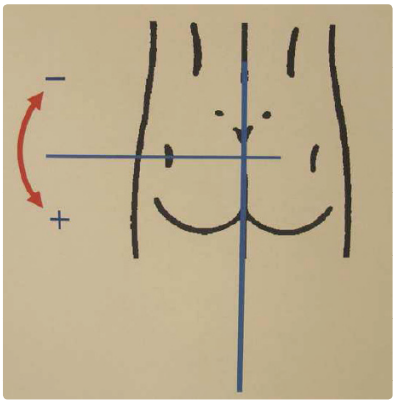


**Figure 4:** Angular measurements. Schematic representation
The body lies prone in orthogonal position. A metallic bar lies on the rima ani as reference line. Angular measurements are considered "+" if the line is inclined towards lateral and "-" if the line is inclined towards medial (see text).

## RESULTS

4 hips in two cadavers were used for further dissection and were not included in the quantitative series. 6 hips in 3 cadavers were assessed quantitatively and the results are plotted in table 1 and 2.

The inclinations are plotted in table 1 considering the confidence intervals (95%). The inclination angle of the distal margin of the m. glutaeus medius was not plotted because it does not correspond to the direction of the whole muscle. Its inclination however is clearly positive: y° +- confidence interval° = 37° +- 6°. All 3 muscles: m. obturatorius internus with m. gemelli, m. quadratus femoris and m. obturatorius externus have a negative inclination. The negativity of the inclination of the m. quadratus femoris is however not significant ($p = 0.06$). The inclination of the m. piriformis is clearly positive ($p < 0.05$).

The perimeters of the muscle bellies are plotted in table 2 considering the confidence intervals ((95%). Interestingly, all muscle bellies have about the same dimension at the level of the femoral head and their differences are not significant ($p > 0.05$).

## DISCUSSION

Pauwels calculated that considering the single abductor muscles, to maintain equilibrium of the joint, the muscular force must be about three times greater than the weight supported [1]. He asserted that the resultant force always crosses the upper part of the facies semilunaris (sourcil) of the acetabulum. Our measurements of the orientation of both m. obturatorii and gemelli together with m. quadratus femoris demonstrate a "passive spring mechanism" which stabilizes the joint. Due to the active contractility of the muscles, the spring mechanism can become an "active spring mechanism" reducing the articular pressure on the sourcil. The weight bearing pelvic bone is "suspended" on both proximal femurs. Mechanically, such spring mechanism is known in various mechanical constructions requiring shock absorption (Figure 5a and 5b).

Phylogeny of homo erectus demonstrates how the small hip abductors in flexion became hip "braces". The ancestor of homo erectus was probably a quadruped mammal with a dimension of a dog. At this stage, the hips bore the weight of the posterior part of the body having the hips flexed. In this position, the m. glutaei are rather extensors-external rotators and the shorter pelvi-trochanteric muscles

are true abductors. During evolution and by standing upright, homo erectus "sat down" within his pelvi-trochanteric muscles thus altering their function. Due to their anatomical orientation, these muscles provided homo erectus with a kind of active suspension and probably a shock absorber while running and jumping. To our knowledge, this muscle function as "suspensors" of the hip joint has not been described to this day. However, muscular function logically stems from the orientation of the described muscles. Phylogeny thus altered the function of part of the pelvi-femoral musculature.

Surgical consequences of those observations are probably multiple. Trochanter osteotomy is a widely known procedure to approach the hip joint and to improve the stabilizing action of the abductors. The "digastric postero-lateral approach" has been described to be mechanically favourable for preserving the stability of the hip [11]. The anatomy demonstrates that both m. obturatorius externus and m. obturatorius internus insert at the medial wall of the trochanter major, just below the m. piriformis [12]. The present study advocates for stability reasons to perform the osteotomy leaving those muscles attachments in place [13]. It appears favourable indeed in case of lacking stability, to move more distal of the insertion of the m. glutaeus medius but leaving both m. obturatorii at their original insertion. This might be particularly true in case of a varus intertrochanteric osteotomy together with a distal move of the trochanter major.

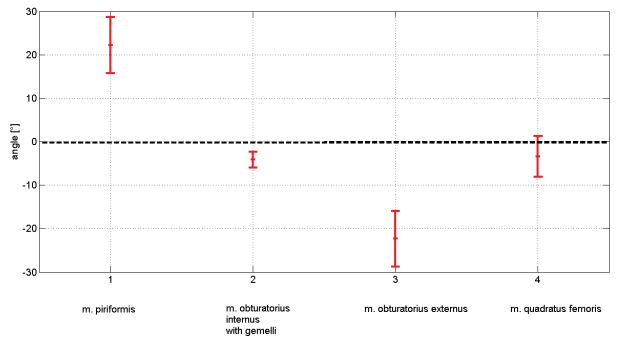


**Table 1:** Inclination of the muscles
The plots represent the inclination of four muscles following the principles of figure 4. y (°) +- confidence intervals (95%, n = 6). The measurements for both m. obturatorius internus with both gemelli and m. obturatorius externus are below 0° ($p < 0.05$). The measurements for the m. quadratus femoris are not significantly below 0° ($p = 0.06$).

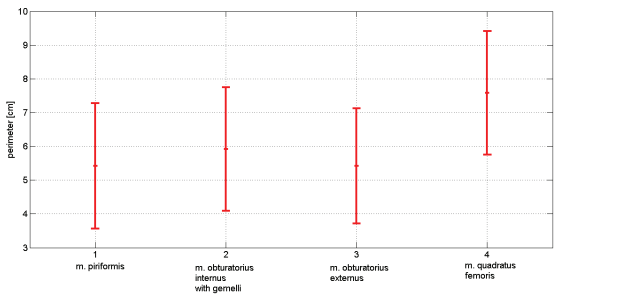


**Table 2:** Perimeters of the muscle bellies
The plots represent the perimeter measured of four muscles at the level of the femoral head. All muscles have approximately the same perimeter with a little higher value (not significant) for the m. quadratus femoris.

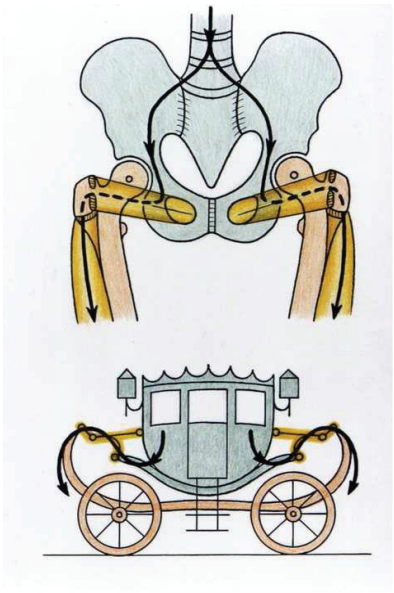

**Figure 5:** Mechanics of "hip suspension". Schematic representation
Figure 5a: Pelvis with both femorae, anterior view. Pelvi-femoral muscles with negative inclination (Figure 2) exert a hip retaining force due to the orientation of the muscle by simple weight bearing. Body weight bearing stretches those muscles thus reducing intra-articular pressure on the sourcil. The mechanics of the muscles are comparable to the suspension of an old fashioned horse-drawn coach (Figure 5b).

Reorientation osteotomies of the acetabulum should preserve the functional integrity of the short pelvi-trochanteric muscles. We described a technique in which the anterior ischial bone is cut from the anterior aspect beneath the femoral head [14]. This technique, besides jeopardizing the vascular supply of the acetabulum by eventual injury to the a.acetabularis, endangers the integrity of the m. obturatorius externus. The other part of the ischial osteotomy is performed from above the pelvic brim mobilizing the m. obturatorius internus from the quadrilateral surface. It would be safer, less invasive and less haemorrhagic to proceed for the ischial osteotomy from posterior [15]. The m. obturatorius internus turning around the gutter of the incisura ischiadica minor (lesser sciatic notch) is perfectly visualized and preserved by cutting the ischium between the incisura ischiadica major (greater sciatic notch) and the foramen obturatorius. The retroacetabular cut is then easily performed from anterior thus joining the supra-acetabular (horizontal) cut with the ischium osteotomy thus preserving mechanically the posterior column of the pelvis.

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