INFLUENCE OF THE FEMORAL HEAD LIGAMENT ON HIP MECHANICAL FUNCTION

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SUMMARY

The authors investigated the femoral head ligament at hip flexion-extension and adduction-abduction ranges of motion. Seven human cadavers' hips were measured, initially with intact ligaments, and, subsequently, through arthroscopy, and then with sectioned ligaments also by means of arthroscopy. A specifically prepared device was used for measuring the range of motion which was submitted to a 2.5 N.m torque. An increased abduction-adduction range of motion was observed, which was statistically significant. We concluded that the femoral head ligament restricts hip adduction.

Keywords: *: Hip; Arthroscopy; Range of motion, joint.*

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INTRODUCTION

The hip is an enarthrosis-type joint, which means a kind of ball-socket fitting, composed by the acetabulum and by femoral head, lending a high level of stability and congruence. The acetabular concavity is developed by the presence of femoral spherical head. Inside a child's acetabulum, a three-radiated cartilage is found, which is constituted of the convergence of ileal, ischial and pubic physes(1). In an embryo, the acetabulum develops approximately on the eighth week of fetal development(2) Physis ossification is competed around 16 - 18 years old(1). The acetabulum is anteriorly, laterally, and inferiorly oriented, and femoral head is hinged with it at a medial, anterior and cranial orientation.

The acetabular lip consists of a fixed fibrocartilaginous structure to bone edge of the acetabulum, which increases joint stability by establishing an acetabular depth to reach more than half the volume of femoral head(3).

The femoral head ligament is found within hip joint and goes from acetabular pit to femoral head's fovea at the medial plane of femoral head, a little posteriorly and inferiorly to the center. Constituted of a flat band of well-organized collagen fibers, it is found harbored at the bottom of the acetabulum and its length ranges from 30 to 35 mm(4). It is inserted into the femoral fovea, which is a small depression at the medial portion of the femoral head(4). This ligament can be divided into three bundles:

- Posterior bundle - ischiatic - the longest one, going from acetabular pit and passing beneath transverse ligament.
- Anterior bundle – pubic - starts at anterior acetabular pit, behind the anterior horn of the joint crescent.
- Medial bundle - thinner, it is fixated on the upper edge of transverse ligament.

The purpose of the femoral head ligament is not well established. Some authors find that it helps on providing hip stability because, when ruptured, symptoms of instability and pain may be present(2). Other authors, such as Kapandji, find that the femoral head ligament does not have any relevant mechanical function(4), although it is very rupture-resistant (rupture load = 45kg).

With the development of arthroscopic hip surgery techniques, structures such as the femoral head ligament (FHL) can be now easily identified, both for its normal anatomy and for any pathology. We don't know the consequences for joint function when this ligament is absent, either due to a traumatic injury or arthroscopic resection. Thus, we regard as important to know its biomechanical function in order to guide therapeutic approaches to be taken. Making use of the technical potential to section femoral head ligament but not sectioning ligaments and/ or joint capsule in hip arthroscopy, we aimed, thus, to determine which changes could be caused on hip's range of motion as a result of a femoral head ligament's section.

MATERIALS AND METHODS

For conducting this study, we used nine hip joints removed from human cadavers with a post mortem time evolution ranging from 48 to 72 hours, in which period cadavers were kept under refrigeration at 4º C. Nine male cadavers with ages ranging from 21 to 60 years at the moment of death, with no traumatic death cause and without previous diagnosed hip pathology were selected. All the cadavers were taken upon approval by the committee of ethics in our service.

Joints were removes as blocks by means of hemipelvectomy (sacroiliac detachment, detachment at public symphysis, and femoral shaft osteotomy). The wide ileofemoral port was used, with 20-cm femoral bone resection. Osteotomy was made with saw and osteotomes. All soft tissues around the joint capsule and bones were removed. During this process,

Study conducted at the Laboratory of Biomechanics, Orthopaedics and Traumatology Institute, HC- FMUSP

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a joint was lost due to technical error with joint capsule injury. Four intact pieces on the left side and for on the right side were removed. Just after removal, the anatomical pieces were stored into plastic bags, allowing for the air content inside to be emptied, identifying and maintaining the pieces refrigerated at a temperature of -18^{o}C for a period ranging from 1 to 4 months.
Previously to the experiment, the pieces were soaked into saline solution, at room temperature, for about four hours, until completely unfrozen.
A mechanical device was used, which had the following purpose: keep the hip in an orthostatic position; apply a torsion moment through hip at the motion axis related to flexion, extension, abduction and adduction, and to record the range of angle for each studied movement compared to orthostatic position.
The device is composed by a support, a wooden box, a pulley, and a camera. The femur was fixed to the box support by means of a cylindrical jaw, which allowed for axial translation (pistoning) and rotation. The hip was fixed to a pair of Ilizarov's fixator rings with three length-adjustable shafts, each one fixated by three spongy screws (4.5 mm wide), which enabled joint's flexion-extension or abduction-adduction axis alignment to the two joint axis of the ring with the wooden box (Figure 1).
A 120-mm wide pulley was attached to one of ring's axis and a torsion moment of 2.5 N.m was applied by means of a load of 4.285 kgf connected to a steel wire attached to the pulley for a period of 3 minutes. A digital camera, model Mavica CD-300 by Sony® with 3.3 Mpixels resolution was positioned at a fixed distance of 60 cm away from pulley allowing for framing the pulley and the reference point fixed to the wooden support (Figure 2). The pulley showed a marking on its axis and on its periphery. We could determine an angular dislocation by means of software that calculated, using trigonometry, pulley's angle to the reference point with 0.1^{o} accuracy.
Adduction, abduction, flexion and extension range of motion tests were performed with intact hips, and the values were recorded as degrees.
Then, inspection arthroscopies were conducted on joints to assess femoral head ligament's integrity and morphology, and hip joint integrity, as well as the absence of pathologies. At this phase, one joint (right side) was unconsidered because it presented with femoral head ligament ruptured and degenerated. The anatomical analysis of the femoral head ligament was performed with an arthroscope, using a 4.0-mm wide and 30^{o}-angled optics from anterolateral and posterolateral ports[5], as well as a medial side port (not described as a usable port in vivo) to check for integrity with probe and its subsequent use at ligament sectioning.

Figure 1 - Hip fixated to device.

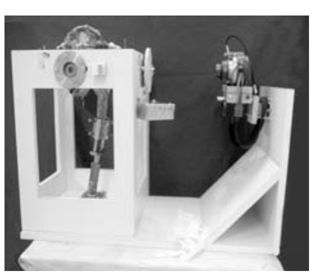

Figure 2 - Photograph of the device used in measurements. Each piece was separately assessed, one at a time.

The anterolateral port was built anteriorly and superiorly to major trochanter peak, which is found at 1cm anteriorly to it. An intravenous 30 mm x 1.3 mm catheter was used for inflating joint capsule by injecting 40 ml of saline solution. External traction of the joint was not necessary, since femur was pending and with only joint capsule of the hip.
The posterolateral port was built through the superolateral angle of the major trochanter and passing close to femoral neck towards the joint. And the medial port was built through pubofemoral ligament at 1 cm from acetabulum's lower edge.
A second set of range of motion tests after hip arthroscopy was performed through the same previously mentioned ports, by sectioning femoral head ligament with the use of an arthroscopy knife through side port (medial). After that procedure, the last range of motion measurement was then performed.
The group with intact hips was named as Group A. The group with hips assessed after arthroscopy was named as Group B. The group of hips assessed after femoral head ligament's section was named as Group C.

Statistical method

Once the results were achieved, a descriptive statistics of the values for flexion-extension and abduction-adduction ranges of motion, as well as the values for flexion, extension, abduction and adduction separately on intact hips, post-arthroscopy, and post-section of the femoral head ligament was performed. The average (AVG), standard deviation (SD), mean standard error (MSE), minimum (Min) and maximum (Max) were calculated. The values for intact hips, post-arthroscopy, and post-section of the ligament were compared between each other. For samples with parametric distribution, the Variance Analysis (ANOVA) test was used for repeated measurements with Tukey's multiple comparison test, and, for non-parametric samples, the Friedman's test with Dunn's multiple comparison test were used.
The adopted significance level was 5% ($p<0.05$) and significant differences were marked with an asterisk.

RESULTS

The results for flexion range of motion are found on Table 1.

	FLEXION (degrees)		
	Intact	Post-Arthroscopy	Post-section
	105.4	108.9	112.5
	126.9	126.1	126.4
	129.1	129.1	129.5
	111.7	112.3	112.5
	140.4	138.4	138.1
	147.5	147.2	147.6
	121.9	121.6	121.4
AVG	126.1	126.2	126.9
SD	14.9	13.6	12.9
MSE	5.6	5.1	4.9
MIN	105.4	108.9	112.5
MAX	147.5	147.2	147.6

ANOVA p=0.6286

***Table 1** - Flexion ranges of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by variance analysis test in repeated measurements.*

The results for extension range of motion are found on Table 2.

	EXTENSION (degrees)		
	Intact	Post-Arthroscopy	Post-section
	5.4	4.9	5.5
	16.0	16.4	15.9
	10.5	11.3	13.4
	14.3	15.2	15.3
	29.5	29.4	29.4
	18.4	17.5	18.1
	6.6	8.5	9.4
AVG	14.4	14.7	15.3
SD	8.2	7.9	7.5
MSE	3.1	3.0	2.9
MIN	5.4	4.9	5.5
MAX	29.5	29.4	29.4

Friedman p=0.4861

***Table 2 -** Extension ranges of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by Friedman's test.*

The results for abduction range of motion are found on Table 3.

	ABDUCTION (degrees)		
	Intact	Post-Arthroscopy	Post-section
	45.2	47.8	49.8
	48.3	49.2	52.1
	53.7	51.8	51.3
	17.0	18.2	18.8
	33.6	34.4	35.2
	41.2	42.8	44.0
	32.3	31.3	35.1
AVG	38.8	39.4	40.9
SD	12.3	12.1	12.1
MSE	4.6	4.6	4.6
MIN	17.0	18.2	18.8
MAX	53.7	51.8	52.1

Friedman p= 0.0515

***Table 3 -** Abduction ranges of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by Friedman's test.*

The results for adduction range of motion are found on Table 4.

	ADDUCTION (degrees)		
	Intact	Post-Arthroscopy	Post-section
	5.0	4.7	6.3
	9.9	11.3	12.2
	11.9	13.3	13.1
	22.5	23.3	23.4
	20.1	20.6	22.0
	19.4	18.7	19.4
	4.9	5.7	6.7
AVG	13.4	13.9	14.7
SD	7.3	7.2	7.0
MSE	2.8	2.7	2.6
MIN	4.9	4.7	6.3
MAX	22.5	23.3	23.4

Friedman p= 0.0207

Dunn's multiple comparison test: intact vs. Post-Arthroscopy $p>0.05$ – Intact vs. Post-Section $p<0.05$* Post Arthroscopy vs. Post-Section $p>0.05$

***Table 4 -** Adduction ranges of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by Friedman's test, discriminated by Dunn's multiple comparison test.*

The results for flexion-extension range of motion are found on Table 5.

The results for abduction-adduction range of motion are found on Table 6.

	Flexion-Extension Range (degrees)		
	Intact	Post-Arthroscopy	Post-section
	110.8	113.8	118.0
	142.9	142.5	142.3
	139.6	140.4	142.9
	126.0	127.5	127.8
	169.9	167.8	167.5
	165.9	164.7	165.7
	128.5	130.1	130.8
AVG	140.5	141.0	142.14
SD	21.4	19.7	18.78
MSE	8.1	7.4	7.10
MIN	110.8	113.8	118.00
MAX	169.9	167.8	167.50

ANOVA p= 0.1927

***Table 5 -** Flexion-extension ranges of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by variance analysis test in repeated measurements.*

	Abduction-Adduction Range (degrees)		
	Intact	Post-Arthroscopy	Post-section
	50.2	52.5	56.1
	58.2	60.5	64.3
	65.6	65.1	64.4
	39.5	41.5	42.2
	53.7	55.0	57.2
	60.6	61.5	63.4
	37.2	37.0	41.8
AVG	52.1	53.3	55.63
SD	10.6	10.5	9.89
MSE	4.0	4.0	3.74
MIN	37.2	37.0	41.80
MAX	65.6	65.1	64.40

ANOVA p= 0.0014 *

Intact vs. Post-Arthroscopy $p>0.05$, Intact vs. Post-Section $p<0.01$ *
Post-Arthroscopy vs. Post-Section $p<0.05$ *

***Table 6** - Abduction-adduction range of motion for intact hips, post-arthroscopy and post-section of the femoral head ligament. Comparison by variance analysis test (ANOVA) by repeated measures, differentiated by Tukey's multiple comparison test.*

We found an increased statistical significance on abduction-adduction motion in comparison to A vs. C samples (intact hip vs. post-section of the femoral head ligament) and B vs. C (post-arthroscopy hip vs. post-section of the femoral head ligament). Also, an increased statistical significance of the adduction motion compared to A vs. C was found (intact hip vs. post-section of femoral head ligament).

DISCUSSION

In this study, an increased adduction range of motion was found, which was statistically proven after femoral head ligament section.

With the limitation to obtain a higher number of cadavers (due to Resolution 196 of October 10th, 1996) and due to Death Examination Service's bylaws, we could not perform this study with a higher number of joints.

When the equipment was being built, we sought to obtain a rotation center that could be the closest possible to hip rotation center. This was considered as important to avoid range restraints by an eccentric range of motion, which could eventually cause bone blockage. In addition, the measurement equipment was calibrated to not to cause distortions to a recorded image, thus avoiding reading errors and range of motion calculation errors by the software developed to that end.

For obtaining measurements, a 3-minute interval was employed to each position in order to allow for its sitting. Initially, the test was performed within longer intervals, of 5 minutes, with ranges of motion being recorded at shorter intervals, but, from the third minute on, variation was not checked for anymore.

Regarding torque applied, we determined a value of 2.5 N.m because this is superior to the one used in Cybex-type equipment[6], thus being superior to the physiological one, once if this was too little it wouldn't show the maximum range of motion. We avoided higher values due to the risk of secondary plastic deformation caused by overload which would lead, as a result, to false augmented results.

For positioning the piece, we tried to obtain the closest position as possible of the orthostatism using as reference the points and bone protuberances of the hip bone. The variation of hip positioning did not cause bias to the analysis of results, since each hip is assessed at the same position in every phase. Positioning variations led to variations on adduction, abduction, flexion and extension values taken alone, but values for abduction-adduction and flexion-extension remained proportional in each piece. We know that a normal hip range of motion is 120° flexion, 30° extension, 45° – 50° abduction, and 20°- 30° adduction.

The capsule, extracapsular ligaments, the acetabular lip, hip muscles, negative joint pressure and the femoral head ligament contribute to hip stability.

Joint capsule and extracapsular ligaments are very important, and play well-defined roles[4,7]. The capsule is inserted proximally to acetabular bone edge, from six to eight millimeters proximally to acetabular lip. The anterior portion of its femoral insertion is found on the intertrochanteric line, while its posterior portion is found proximally to the intertrochanteric crest, that is, posteriorly to femoral neck.

The three extracapsular ligaments are the following: the iliofemoral, ischiofemoral and pubofemoral[4,8]. The iliofemoral ligament is the strongest one, extending from anteroinferior iliac spine to the intertrochanteric line, in two separated bands, in an inverted Y format. The key role of the iliofemoral ligament is to limit hip abduction. The pubofemoral ligament is proximally inserted to upper pubic bundle and distally to the lower portion of the femoral neck, paying a similar biomechanical role. The ischiofemoral ligament is the smallest, extending from ischial posterior edge to the femoral neck, being a stabilizer of the hip ion extension.

Ligaments' action varies according to hip position. In hip extension, all these ligaments are tensioned because they twist around femoral neck. In flexion, the contrary is seen, with all ligaments relaxed. Regarding external rotation, the anterior hip ligaments are tensioned while the ischiofemoral ligament is loose. But, with internal rotation, we see the opposite, with loose anterior ligaments and tense ischiofemoral ligament. During adduction movements, the ileofemoral bundle is tensioned and the pubofemoral and ischiofemoral ligaments are relaxed. In abduction, the opposite is seen, with pubofemoral and ischiofemoral ligaments tensioned while the ileofemoral ligament gets loose[4,7] .

Another factor influencing on stability is hip joint coaptation, with joint negative pressure being an important factor for stability. In our experiment, the range of motion did not show significant change when compared to intact hips and post-arthroscopy, that is, after the negative pressure factor was removed.

In addition, the acetabular lip and muscles affect hip stability. In our study, muscles were removed by means of careful dissection, eliminating it as a restrictive factor to the range of motion.

Kapandji postulates that femoral head ligament is tensioned in hip adduction and only partially stretched in rotational movements, but he does not detail how he reached to that conclusion. He also considers, as well as other authors do[9], that the femoral head ligament does not play any relevant mechanical role.

Some patients with idiopathic chronic hip pain, when submitted to hip diagnostic arthroscopy, present with a ruptured femoral head ligament[10]. Arthroscopy may lead to a diagnosis in 40 - 68% of the cases with normal X-ray, CT and/ or magnetic resonance images[11].

The increased hip range of adduction with FHL failure, as found in our study, could hypothetically lead to progressive hip instability if other stabilizing structures of the hip were loose in adduction.

We can imagine important consequences related to an unstable hip such as acetabular lip injuries and hip arthrosis. Philippon advocates that acetabular lip injuries may be a result of hip instability[12]. He shows a test performed under X-ray visualization to provide a diagnosis to that condition and proposes thermal capsulorraphy as a treatment approach.

Usually, the acetabular labrum is not found submitted to axial loads; however, in the presence of pathological adduction movements, it may be submitted to load, which could be a cause for injury[12,13]. It is important to remember that the adduction and flexion position is the most instable one in the hip. Recent studies demonstrate a correlation of labral injuries with chondral injuries and joint surface degeneration [13,14]. In our literature review, we didn't find an expressive number of studies addressing hip instability.

We know that this matter is still little studied both in national and international literature, and that all theories probed here are theoretical, although possible. We hope that the results of this study may be an inspiration for further studies that will certainly be required to better understand hip biomechanics.

CONCLUSION

Femoral head ligament injuries increase hip range of adduction-abduction, particularly the range of adduction.

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