



# Ligamentum Capitis Femoris A Pilot an Experimental Study

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## Abstract

Ligamentum capitis femoris (syn. ligamentum teres, ligament of head of femur), connecting the acetabulum and the head of femur. This is one of the least studied anatomical elements of the human body. In order to clarify the functions of the ligamentum capitis femoris, external ligaments and abductor muscle group, we constructed a dynamic model of the hip joint. It was established that this anatomical element is involved in constraining the hip joint adduction and may locking the hip joint in the frontal plane, turning it into an analogue of a third-class lever. When the ligamentum capitis femoris is stretched and the abductor muscle group is tension, a load equal to twice the body weight is evenly distributed between the upper and lower hemispheres of the head of femur. The ligamentum capitis femoris function increases the steadiness of the orthostatic postures and unloads the muscle apparatus of the hip joint.

**Keywords:** Ligamentum capitis femoris; Ligamentum teres; Ligament of head of femur; Abductor muscle group; Hip joint; Model; Biomechanics

## Introduction

Ligamentum capitis femoris (syn. ligamentum teres, ligament of head of femur) is known for about 2500 years. The first description of the ligamentum capitis femoris in the medical text is given by Hippocrates of Kos in the treatise «Instruments of Reductions» (V-IV century BCE) [1]. In the Greek edition of the manuscript, ligamentum capitis femoris is called  $\nu\epsilon\upsilon\rho\nu\sigma$  [2], while in the Latin version it is referred to as *neruus* [3]. According to our hypothesis, the first in the history of mankind to mention a ligamentum capitis femoris, is contained in the ancient literary monument of Torah (XII-II century BCE) [4]. One of the early mentions is contained in the works by Heraclides of Tarentum (III-II century BCE) [5], Hegetor (II century BCE)[6], Apollonios of Kition (I century BCE) [7] and Galen of Pergamon (II-III century ACE) [5]. However, it remains one of the least studied anatomical structures of the human body, indeed, a ligamentum incognitum.

The ligamentum capitis femoris is in the hip joint, in a special osteochondrous cavity composed of the acetabular notch and cotyloid fossa on one side and the articular surface of the head of femur on the other side [8]. The normal ligamentum capitis femoris length is about 25 mm [9], a mean ultimate failure load of 204N [10], and maybe more about 882N [11]. Histologically, the basis of the ligamentum capitis femoris is composed of collagen fiber bundles and is surrounded by a layer of investing synovium composed of a

single layer of cuboidal cells [12,13]. The ligamentum capitis femoris had six anchoring points on the acetabulum and one anchoring point on the femur [14]. The biomechanical function of the ligamentum capitis femoris has not been unambiguously determined [15] and is subject to controversy. Tonkov wrote that the ligamentum capitis femoris function "... is not perfectly clear; in any case, its mechanical significance is not so great" [9]. However, according to Neverov and Shil'nikov, it plays an important role in the hip joint biomechanics [16], while Vorob'ev claimed that its "biomechanical function" is of importance only under certain conditions [17]. On the other hand, Pirogov compared the ligamentum capitis femoris to "a steel spring on which the pelvis is suspended from the caput" [18]. Gerdy & Savory [19] advanced a similar opinion, the former author noting that the ligamentum capitis femoris is exerted in the erect posture. Ivanitskii, when touching on the role of the ligamentum capitis femoris in maintaining an erect posture, wrote [20], "... in an asymmetrical posture, with the pelvis tilted, the ligamentum capitis femoris on the side of the supporting, usually straightened, leg is stretched to reinforce the hip joint" [20]. In hip joint biomechanics, it is commonly accepted that maintaining a one-support orthostatic posture in the frontal plane depends only on muscles [21-25]. The ligamentum capitis femoris is not mentioned as a functional component of the hip joint, and its mechanical reaction is not considered in calculating the head of femur loading.



The purpose of this study was to clarify the function of the ligamentum capitis femoris and its role in maintaining one-support orthostatic posture.

## Materials and Methods

In order to clarify the functions of the ligamentum capitis femoris and abductor muscle group, we constructed a dynamic model of the hip joint [26]. We used a Thompson unipolar endoprosthesis fixed on a base, named as a femoral basal element. In accordance with the diameter of the head of endoprosthesis (head of femur analogue), a metal model of the acetabulum was made in the form of a thick-walled spherical shell having a shaped recess that simulated the acetabular fossa and notch. A profiled plane simulated pelvis and a plate for suspending a load, a 1- to 3-kg dumbbell, were attached from the outside. The model contained a ligamentum capitis femoris analogue made from a metal cord 2 mm in diameter and external ligaments analogues (iliofemoral, ischiofemoral, and pubofemorale ligaments) made from a metal cord 1.5mm in diameter. One end of ligamentum capitis femoris analogue was tightly fixed to an opening made in the shaped recess of the acetabulum model, and the other, to the head of endoprosthesis. Both parts of the model were also linked to a dynamometer, whose spring simulated the function of the abductor muscle group; oil lubricated the friction node. The properties of the model were studied both in the absence of the ligamentum capitis femoris analogue, external ligaments analogues, and abductor muscle group analogues and in their presence in different combinations. In some experiments, we changed the length of the abductor muscle group analogue, thereby modeling different degrees of its tension. We determined the possible rotational and translational movements in the hinge of the model, their range, and constraints. We modeled equilibrium conditions for the pelvis moving in the frontal plane in the unstrained and strained types of one-support orthostatic posture.

## Results and Discussion

Experiments with a dynamic model of the hip joint showed that the ligamentum capitis femoris imposes constraints on the hip joint adduction by limiting abduction, pronation and supination, and translational outward and upward head of femur movements, and prevents dislocation. Stretching of the ligamentum capitis femoris is brought about by adducting the hip and inclining the pelvis to the nonsupporting side, the hip joint locking in the frontal plane, becoming an analogue of a third-class lever. In the absence of abductor muscle group tension, the resultant force acting on the hip joint is directed upwards, loading only the inner lower part of the head of femur. Our data confirm that straining of the abductor muscle group increases abduction of the hip joint. In cooperation with antagonists, it can lock the hip joint in the frontal plane in an arbitrary position. If the abductor muscle group is exerted without stretching of the ligamentum capitis femoris, the resultant force acting on the head of femur is directed upwards, loading only the inner upper part of the head of femur. The abductor muscle group cooperates with the ligamentum capitis femoris in constraining adduction. Its tightening can decrease the ligamentum capitis femoris stretching, and, vice versa, stretched ligamentum capitis

femoris decreases the load on the abductor muscle group. It was established experimentally that the ligamentum capitis femoris is not subjected to stretching in a strained one-support orthostatic posture, while the abductor muscle group and its antagonists locking the hip joint movements in the frontal plane. Here, the hip joint is an analogue of a first-class lever, which means loading of the upper hemisphere of the head of femur. If we assume that the lever of the body weight exceeds threefold the lever of the abductor muscle group effort [25], then the force produced by the abductor muscle group will be three times greater than the body weight. Then, the resultant downward force acting on the head of femur is four times greater than the body weight.

Analysis of the experimental data and results of clinical examinations indicates that, in the unstrained one-support orthostatic posture, hip adduction and tilting of the pelvis toward nonsupporting side are constrained including by stretching ligamentum capitis femoris, which agrees with the opinions of other authors [20,27]. The pelvis, as stated by Pirogov, is "suspended" from the ligamentum capitis femoris [18]. The combination of stretching of the ligamentum capitis femoris and tension of the abductor muscle group is optimal in terms of loading all elements of hip joint and maintaining the steadiness of the erect posture in the frontal plane. Given this type of a one-support orthostatic posture, both the stretched ligamentum capitis femoris and the tension abductor muscle group deviate from the vertical. The horizontal components of the reaction forces of the ligamentum capitis femoris and the abductor muscle group are summed, resulting in a horizontal force that uniformly presses the acetabulum to the head of femur. The mean angular deviation from the vertical of the force produced by the abductor muscle group is 21° [22]; the angular deviation of the ligamentum capitis femoris is, according to our data, about 50°. The calculations show that the amount of pressing the pelvis to the head of femur is approximately equal to twice the weight of the body (1.96P), with the horizontal component of the ligamentum capitis femoris reaction force equal to 1.6P and the horizontal component of the abductor muscle group reaction force equal to 0.36P. The loads on the upper and lower head of femur hemispheres are approximately equivalent to the body weight without considering the mass of the supporting leg. In an unstrained one-support orthostatic posture (pose of an antique statue) with little or no participation of the abductor muscle, the movement of the hip joint in the frontal plane is that of a third-class lever analogue. If we assume that the lever of the body weight exceeds threefold the lever of the ligamentum capitis femoris reaction force, the ligamentum capitis femoris reaction force is equal to three times the weight of the body. The resultant upward force acting on the lower head of femur is equal to two times the weight of the body.

## Conclusion

- a. We established experimentally that the ligamentum capitis femoris constrains adduction and lateral and cranial displacement of the head of femur and can locking the hip joint in the frontal plane, which is equivalent to the transformation of this structure into an analogue of a third-class lever.

b. In the unstrained type of the one-support orthostatic posture, when the frontal locking of the hip joint is carried out, including through the ligamentum capitis femoris, the group of abductor muscle can be unloaded. In this case, the resultant load on the head of femur, being approximately equal to twice the body weight. This load is evenly distributed between the upper and lower hemispheres the head of femur, if a commensurate tension of the abductor muscle group and stretching of the ligamentum capitis femoris is combined.

c. Ligamentum capitis femoris stretching does not occur in a strained type of the one-support orthostatic position. The hip joint is fix in the frontal plane by tension of the abductor muscle group and its antagonists, the resultant load on the head of femur having a downward direction, acts on the upper hemisphere and being approximately equal to four times the body weight.

### Conflict of Interest

None declared.

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