CLINICAL RELEVANCE OF THE LIGAMENTUM TERES: A LITERATURE REVIEW

RobRoy L. Martin^{1,2}

Christine McDonough³

Keelan Enseki²

David Kohreiser⁴

Benjamin R. Kivlan¹

ABSTRACT

Background: The ligamentum teres (LT) continues to be a structure of debate and interest. Previously thought of as a vestigial structure, an awareness of LT pathology and its potential importance has increased with the expansion of hip arthroscopy.

Purpose: To provide a comprehensive literature synthesis on the LT and provide clinicians with the most current research regarding the LT and its anatomical features, functional relevance, prevalence of injury, risk factors for injury, clinical presentation, and treatment for pathology.

Methods: A systematic literature search was conducted using Medline/PubMed, CINAHL/EBSCO, and Cochrane/Wiley databases/platforms using the following search terms: ligament, ligament teres, hip, femur, femoral head, round ligament.

Results: This search yielded 1284 articles of which 44 met the inclusion/exclusion criteria and contributed to this manuscript. Information on the LT was summarized into the following areas: anatomy, function, injury prevalence, risk factors, mechanism of injury, duration of symptoms, clinical presentation (symptoms, range of motion, functional limitations, special testing), imaging, and treatment.

Conclusions: The results of this review supported the following: 1) the LT has a function in restraining hip rotation range of motion; 2) the prevalence of LT pathology in any given population may be largely dependent on the severity of bony deformity (either femoroacetabular impingement (FAI) or dysplasia) and activity level; 3) older age and acetabular bony deformity (either FAI or dysplasia) are risk factors for generalized LT pathology; 4) unique signs and symptoms are difficult to identify because LT pathology rarely occurs in isolation and is likely the end-stage consequence of other hip pathology; 5) the presence of LT pathology may negatively affect an individual's ability to function; and 6) surgical debridement is recommended for pain relief of partial LT tears with reconstruction possible for complete LT tears when complaints of instability are noted.

Level of Evidence: 3

Keywords: Hip, hip arthroscopy, instability, pain

CORRESPONDING AUTHOR

RobRoy L. Martin, PhD, PT, CSCS
Rangos School of Health Sciences
Duquesne University
600 Forbes Avenue
Pittsburgh, PA 15282
412-396-1811
E-mail: martinr280@duq.edu

¹ John G. Rangos Sr. School of Health Sciences, Duquesne University, Pittsburgh, PA, USA

² UPMC Center for Sports Medicine, Pittsburgh, PA, USA

³ University of Pittsburgh, Pittsburgh, PA, USA

⁴ OrthopedicOne, Columbus, OH, USA

All authors have no conflicts of interest to declare.

INTRODUCTION

The ligamentum teres (LT) continues to be a structure of debate and interest. Previously thought of as a vestigial structure, an awareness of LT pathology and its potential importance has increased with the expansion of hip arthroscopy. However, an understanding of its unique anatomical features, functional relevance, prevalence of injury, risk factors for injury, clinical presentation, and appropriate treatment is still needed. The purpose of this literature review is to provide a comprehensive examination of literature related to the LT and provide clinicians with the most current information research has provided to date.

METHODS

A systematic search was conducted using the following databases/platforms as of 11/27/2017: Medline/PubMed, CINAHL/EBSCO, and Cochrane/Wiley. The following search strategy was used with adjustments specific to each database:

```
(((((ligament*[MeSH Major Topic]) OR ligament*[Title/Abstract])) AND teres)) OR (((ligament*[MeSH Major Topic]) OR ligament*[Title/Abstract])) AND (((hip) OR hips) OR head[Title/Abstract])) AND ((femor*) OR femur))) OR ((round ligament) AND ((hip) OR femur) OR femoral head))
```

Articles that did not present research or were not a systematic review or meta-analysis were excluded. The inclusion criteria and exclusion for articles are provided below:

Inclusion criteria

- functional anatomy relevant to ligamentum teres
- risk factors for ligamentum teres injury and/or dysfunction, disorders, and conditions involving ligamentum teres
- diagnostic characteristics of ligamentum teres injury and dysfunction, including but not limited to pain location, duration, and quality, and related impairments and functional limitations
- tests and measures for diagnosis and/or differential diagnosis of conditions involving the ligamentum teres

- primarily adults (≥ 16 years old)
 - studies reporting on persons < 16 years old IF the proportion in the sample is small ($< 5\%$) OR that separate data are available for adults

Exclusion criteria

- primarily infants and children (< 16 years old)
- hip pain related primarily to conditions other than ligamentum teres injury or dysfunction.
- animal studies
- case reports or case series with < 10 subjects

RESULTS

This search yielded 1284 articles. After removal of duplicates and obviously irrelevant articles based on title and abstract review, 440 articles were identified to include the following: systematic reviews, meta-analyses, experimental and quasi-experimental, cohort, case series, and cross-sectional studies. After reviewing these articles, 44 met the inclusion criteria and were included in this literature review.

Information on the LT was identified and summarized to the following: anatomy, function, injury prevalence, risk factors, mechanism of injury, duration of symptoms, clinical presentation (symptoms, range of motion, functional limitations, special testing), imaging, and treatment. It should be noted the term “pathology” refers to any injury to the LT, including both partial and complete tears. The term “complete tear” was reserved for studies that specially defined tears as such.

ANATOMY

A summary of research studies that described the anatomy and embryology of the LT was presented in a systematic review by Perumal et al.¹ The LT was described as originating from the acetabular fossa and transverse acetabular ligament to insert on the fovea capitis of the posteroinferior aspect of the femoral head.¹ A recent study by Mikula et al.² identified the LT as having six distinct attachment sites on the acetabular notch. These attachment sites were noted to be evenly dispersed at the anterior, posterior, superior, and inferior margins of the acetabular

notch.² This study concluded the anchoring points associated with these attachment sites and structural design of the LT would allow the LT to restrain end-range rotational movement.²

Perumal et al.¹ in their review reported on the LT dimensions and found average length ranged from 25.0 to 37.5 mm with average thickness at its origin and insertion to range from 8-10 mm and 14-16 mm, respectively. The microscopic anatomy of the LT was found to be composed of collagen matrix, fibrous tissue, and adipose tissue, and surrounded by a thin synovial lining.^{1,3} A study included in this review found Type II collagen and fibrocartilage cells identified at the LT attachment site supported the function of mechanical loading of the LT.⁴ Although blood vessels within the LT have been noted, their vascular function to the femoral head in adults is thought to be minimal.⁵ Nerve fibers, mechanoreceptors, and free nerve endings within the LT suggest that it is involved in proprioception and is a source of pain generation.¹

FUNCTION

Early work by Fuss and Bacher⁶ could not identify a unique function for the LT. However, recent studies have offered evidence that the LT does have a purpose in restraining hip rotation range of motion^{7,8} and used a ball and string model to describe the function of the LT.⁹⁻¹³ Femoral head rotation that occurs in the transverse and frontal planes was found to cause the LT to tighten and act as a sling as the LT wrapped around the femoral head.¹³ Also, as the LT tightened the femoral head was pulled into the acetabulum, presumably to increase stability at the end range of hip motion.¹³ This ball and string model was further supported by Mikula et al.,² who described the six acetabular notch attachment sites of the LT, with the anterior attachment site tightening during external rotation and the posterior attachment site tightening with internal rotation. Martin et al.⁹ found the LT to be a rotational stabilizer in all hip positions and the primary stabilizer in limiting external and internal rotation when the hip was in flexion greater than 90°. Research by van Arkel et al.¹⁴ also found the LT to be a rotational stabilizer in flexion even under relatively low loads. Additionally, the LT was found to support the femoral head inferiorly when the hip

joint was moved into flexion and abduction, a position that resembled squatting.¹³ The string model found maximum LT tension to occur when the hip was in: (1) 90° flexion, 0° adduction, and 60° external rotation and (2) 20° extension, 0° adduction, and 60° internal rotation.¹² This study noted these two positions of maximal tension were similar with respect to hip orientation to that obtained when an individual: (1) squats and (2) attempts to cross one leg behind the other when standing.¹²

The function of the LT in restraining hip motion has been questioned by surgeons who perform open procedures and sacrifice the LT. One study noted that at a median follow-up time greater than four years, 74% and 77% of patients were found to be asymptomatic with regard to pain at rest and instability, respectively, after surgical excision of the LT during open osteochondroplasty for cam deformities.¹⁵ However, another study of those with complete LT tears found subjects with complaints of instability had osseous risk factors for instability while those subjects without complaints of instability had relatively normal bony geometry.¹² This supports the theory that the LT may be more important for stability in those with osseous risk factors of instability and less important for stability when those risk factors are not present, such as in those with the over coverage associated with femoroacetabular impingement (FAI).

PREVALENCE

The published reports on the prevalence of LT pathology have varied greatly, ranging from 4% to 93%.^{11,16-30} A summary of studies that have described the prevalence of LT pathology is provided in Table 1. More recent studies, published 2007 and later, have noted a higher prevalence than earlier reports. This increased prevalence may be attributed to more awareness and more comprehensive means of in defining LT pathology.²⁶ When looking at recent studies of consecutive hip arthroscopies published after 2007, the prevalence of LT pathology has ranged between 43%-51%.^{16-21,23-26}

Athletic activity level and the presence of FAI have been associated with LT injury. Recent studies that included athletes with FAI reported some of the highest incidence of LT pathology.^{16-19,21,22} This included one study by Philippon et al.²² that noted 93%

Table 1. Summary of Ligamentum Teres Pathology Prevalence.					
Prevalence of LT Pathology	Complete LT Tears	Publication Year and Author		Patient Demographics	Notable Patient Characteristics
4% (20/472)	1% (7/427)	1997	Gray ²⁷	None given for entire sample	Consecutive hip arthroscopies
4% (13/328)	NR	1999	Baber ²⁸	Mean age 36yr; 64% female	Consecutive hip arthroscopies
9% (237/2628)	NR	2011	Haviv ³¹	None given for entire study for the sample N=237	Excluded acute full thickness tears associated with dislocation
15% (41/271)	NR	2004	Byrd ²⁹	None given for entire study sample; *23 traumatic origin/ 18 atraumatic; 12/23 had complete tears; 8/23 had isolated LT tear	Consecutive hip arthroscopies
25% (11/44)	NR	2001	Byrd ³⁰	Mean age 29yr; 45% female; Mean duration of symptoms 16 months	Symptoms related to athletic activity
43% (684/1574)	10% (65/1574)	2013	Amenabar ²³	None given for entire study sample of N=1574	Consecutive hip arthroscopies
46% (35/75)	1% (1/75)	2014	O'Donnell ²⁴	Mean age 34yrs; 39% female	Consecutive hip arthroscopies
49% (226/463)	5% (16/463)	2013	Domb ²⁵	Mean age 36yrs; 61% female; Mean duration of symptoms 25 months	Hip arthroscopy for non-traumatic hip symptoms
51% (284/558)	5% (28/558)	2011	Boster ²⁶	Mean age 39yrs; 58% female	Consecutive hip arthroscopies
61% (47/77)	26% (20/77)	2014	Kaya ¹⁶	Mean age 48yrs; 58% female	Hip arthroscopy for FAI
63% (129/204)	2% (3/204)	2013	Ejinisman ¹⁷	Mean age 35yrs; 47% female	Hip arthroscopy for FAI and labral tear
64% (29/45)	7% (3/45)	2007	Philippon ¹⁸	Mean age 31yrs; 7% female	Professional athletes with FAI
86% (12/14)	NR	2009	Philippon ¹⁹	Mean age 31yrs; 24% female; Mean duration of symptoms 125 days	Professional athletes with traumatic dislocation
88% (15/17)	12% (2/17)	2014	Domb ²⁰	Mean age 21yrs; 75% female	Hip dysplasia who underwent arthroscopy with periacetabular osteotomy
88% (1947/2213)	1.5% (33/2213)	2016	Chahla ²¹	None given for entire study sample	Hip arthroscopy for FAI
93% (26/28)	0%	2010	Philippon ²²	Mean age 27yrs; 0% female mean duration of symptoms 19 months	Professional hockey players with FAI
(xx/xy)= ligamentum teres pathology or tear/total number of subjects					

(26/28) of professional hockey players undergoing hip arthroscopy for FAI had LT pathology. Osseous risk factors for instability have also been linked to LT pathology. One study found the prevalence of LT pathology to be 88% (15/17) in those with hip dysplasia.²⁰ Domb et al.²⁵ found individuals with a low hip stability index were more likely to have a LT tear than those with a high stability index. The results of these studies support theories that the LT could be injured in an active population with abnormal boney

geometry, such as FAI or hip dysplasia.¹¹ Therefore the prevalence of LT pathology in any given population may be largely dependent on the severity of bony deformity, either FAI or dysplasia, combined with activity level.

While LT pathology may be common, complete tears occur less frequently. The prevalence of complete tears have reportedly ranged from 1% to 26%.^{16-18,20,21,23-27} Complete tears may be associated with trauma

as Byrd et al.²⁹ noted 93% (12/13) of traumatic LT injuries were found to be complete tears. Domb et al.²⁰ noted the prevalence of complete LT tears to be 12% in subjects with dysplasia. One study compared those with a complete LT tear to those with a normal LT.²¹ Those with a complete tear had osseous risk factors for instability, including a greater Tönnis angle (Tönnis angle 8.9 vs 6.4) and a center edge (CE) angle < 25 degrees. Among patients with FAI and labral pathology, complete tears of the LT were found in 1.5% (33/2213) with those with complete tears more likely to have intraoperative findings of capsular laxity.²¹ It may be that those with FAI who engage in activities that require motion beyond the point of impingement cause abnormal tightening of the LT and complete rupture with repeated injury over time.

Isolated LT pathology has been noted to rarely occur. Three studies specifically reported the prevalence of isolated LT tears. Haviv et al.,³¹ Amenbar and O'Donnel²³ and O'Donnel et al.²⁴ found the prevalence of isolated LT tears in consecutive patients undergoing hip arthroscopy to be 1% (29/2628), 2% (27/1574), and 4% (3/75), respectively. Young women who were involved in activities that required extreme range of motion, such as gymnastics and dancing, were at the greatest risk for isolated LT injury.³¹ The rare occurrence of isolated LT tears is consistent with a systematic review that found LT pathology to commonly occur with a labral tear, degeneration of the labrum, loose bodies, chondral damage, degeneration of articular cartilage, and FAI.¹ This may be because LT pathology is an end-stage consequence related to pathomechanics caused by other hip pathology.^{32,33}

Studies have specifically reported the prevalence of LT pathology in the presence of other associated hip pathology. Labral tears were found to occur in 95%-100%,^{21,25,26} acetabular cartilage damage in 79%-93%,^{21,25} and femoral head cartilage defects in 82%²¹ of individuals with LT pathology. The descriptive grade for the labral tear worsened as the grade of LT tear worsened and more severe acetabular cartilage defects were more likely in those with complete LT tears.²⁶ Also, those with LT pathology and FAI had cartilage damage that differed from the pattern of cartilage damage typically seen in those with only FAI.¹⁶ Individuals with a complete LT tear were 3.1

times more likely to have a chondral defect on the femoral head and 3.6 times more likely to have capsular laxity diagnosed at hip arthroscopy.²¹

RISK FACTORS

Evidence supports older age and acetabular bony deformities, either FAI or dysplasia, as risk factor for generalized LT pathology.^{7,34} Domb et al.²⁵ specifically studied the risk factors for LT pathology. They found the relative risk of having LT pathology was 1.51 higher for individuals older than 30 years of age.²⁵ Generally, those with LT pathology were older than individuals without, as average ages for those with and without LT pathology ranged between 38-41 years and 33-36 years, respectively.^{25,26} Individuals younger than 20 years of age were found to have the lowest incidence of LT pathology.²⁵ Gender and BMI were not different between those with and without generalized LT pathology in consecutive hip arthroscopies.^{25,26} However, females were three times more likely to have a complete LT tear when compared to their male counterparts.²¹ Also, those with a complete LT tear had a significantly lower BMI than those without LT pathology.²¹

MECHANISM OF INJURY

The systematic review by Perumal et al.¹ found LT pathology can result from either trauma or overuse. The history of a traumatic hip dislocation has been thought to be associated with LT pathology.³⁵ This was supported in a study by Philippon et al.,¹⁹ as 78% (11/14) of athletes with a hip dislocation sustained a partial or complete LT tear. Twisting injuries were reported as a common mechanism of LT injury in case series by Byrd et al.²⁹ Non-traumatic LT tears were found to occur frequently in gymnasts and ballet dancers. It was hypothesized these non-traumatic injuries occurred as a result of overuse in an effort to maintain joint stability in the supra-physiological range of motion requirements of the sport.^{36,37}

DURATION OF SYMPTOMS

In consecutive hip arthroscopies there was no difference in duration of symptoms between those with and without LT pathology.^{25,26} Chahla et al.²¹ also found duration of symptoms was not different when comparing those with complete LT tears to those without LT pathology.

CLINICAL PRESENTATION

Symptoms

A systematic review noted that LT pathology should be considered in those with reports of persistent localized groin pain and symptoms of hip instability.³⁸ In a case series of those with traumatic LT pathology, Byrd et al.²⁹ noted that 100% (23/23) of subjects reported anterior groin pain and 83% (19/23) noted mechanical symptoms (catching, popping, locking, giving way). However, unique signs and symptoms for LT pathology are difficult to identify because LT pathology rarely occurs in isolation, but is usually associated with significant labral and cartilage pathology. A sudden onset of pain and pain intensity do not seem to provide information regarding the presence or absence of generalized LT pathology or complete LT tear. A significant difference was not identified between individuals with and without LT tears with respect to an acute onset of pain, as only 29-34% reported an acute pain.^{25,26} When looking at individuals with complete tears, only 30% (9/30) reported an acute onset of pain.²⁶ Also, individuals with LT complete tears were found to have comparable pain levels to those without LT pathology.²⁶

Range of Motion

Studies of consecutive hip arthroscopies comparing those with and without LT pathology found only minimal ROM difference that were not significantly different.^{21,25,26}

Functional limitations

In consecutive hip arthroscopies individuals with a LT tear had significantly lower scores on self-reported functional outcome measures compared to those without LT tears.²⁶ Subjects undergoing arthroscopic surgery with borderline dysplastic patients and LT tears were found to have worse short-term outcomes than those without LT tears.³³

Special Tests

O'Donnel et al.²⁴ described the LT test to assess for partial LT tears. This test is performed with the patient supine and in 70° of hip flexion and 30° short of full abduction. In this position the hip is externally and internally rotated looking for reproduction of pain at end range of motion. This test was developed on previous work and the hypothesis that the

LT will be under maximal tension and painful at end range of internal and external rotation.¹² In a study of 75 consecutive patients, the LT test was found to be reproducible and accurate, with moderate to high inter-observer reliability and sensitivity and specificity values of 0.90% and 0.85, respectively.²⁴

IMAGING

Controversy exists in the usefulness of imaging for diagnosing LT pathology.³⁹⁻⁴¹ Magnetic resonance arthrogram (MRA) is thought to be more useful than conventional magnetic resonance imaging (MRI).^{1,42} Studies have noted intact and partially LT tears can have similar imaging findings on MRA, making the diagnosis of partial LT tears difficult.³⁸ Generally, there seems to be a lack of accuracy of an MRA in diagnosing of LT tears when compared to arthroscopy, highlighting the need for improved imaging.²⁶

TREATMENT

There is no description regarding the conservative treatment of LT pathology.⁴³ As noted, LT pathology rarely occurs in isolation and therefore treatment is usually directed at the impairment associated with the accompanying pathology. Typically conservative treatment addresses range deficits associated with FAI or instability associated with hip dysplasia. With regards to surgical treatment, a systematic review concluded that debridement of the LT is indicated for short-term relief of hip pain caused by partial LT tears.³⁸ Reconstruction was felt to be indicated for complete LT tears when the tears that are deemed "repairable," cause instability, and/or have failed previous treatment.^{7,38}

DISCUSSION

This comprehensive literature review provides a current understanding of the LT including its unique anatomical features, functional relevance, injury prevalence, risk factors for injury, clinical presentation, and appropriate treatment. Anatomic studies support that the LT has a function in restraining hip rotation range of motion and can be involved in proprioception and pain generation. The LT anchoring points are positioned to restrain end-range rotational movement² and the presence of Type II collagen and fibrocartilage cells as these attachment sites reflect mechanical tendon loading.⁴ The function of the LT

has been described using a ball and model with the LT acting as a sling as it wraps around and pulls the femoral head into the acetabulum as presented in Figures 1 and 2.⁹⁻¹³ This model supports theories that

Figure 1. Ligamentum teres model of stability: as the hip joint is externally rotated, the ligamentum teres (LT) wraps around the femoral head, while simultaneously pulling it into the acetabulum.

Figure 2. Ligamentum teres model of stability: as the hip joint is abducted, the ligamentum teres (LT) wraps under the femoral head, while simultaneously pulling it into the acetabulum.

the LT adds to increase stability at the end range of hip motion in the frontal and transverse planes, especially in hip flexion.⁹ This model is also supported by studies that found the LT to support the femoral head inferiorly when hip joint was moved into a combined position of flexion and abduction.¹³

Trauma, over-use with activities that require extreme range of motion, FAI, and osseous risk factors for instability may contribute to LT injury. Prevalence of LT pathology can range between 43-51%,^{16-21,23-26} with complete tears occurring in 1-26%,^{16-18,20,21,23-27} and isolated LT pathology occurring in 1-4%^{23,24,31} of individuals undergoing hip arthroscopy. Evidence supports age as risk factor for generalized LT pathology, while female sex and lower BMI may be risk factors for complete LT tears.²¹ The prevalence of and risk factors for LT pathology in any given population may be largely dependent on activity level combined with the severity of bony deformity, either FAI or dysplasia.

LT pathology is commonly associated with other hip conditions, including labral tear, degeneration of the labrum, loose bodies, chondral damage, and degeneration of articular cartilage.¹ These findings suggest LT injury may be related to the progression of degenerative arthritis and have potential implications for LT reconstruction in preventing the progression of early-onset osteoarthritis.^{16,33} Unique signs and symptoms for LT pathology are difficult to identify because LT pathology rarely occurs in isolation, but is associated with significant labral and cartilage pathology.

Studies have found no difference in duration of symptoms or pain levels when comparing those with and without LT pathology.^{21,25,26} However, the presence of LT pathology seems to negatively affect a patient's ability to function. Physical examination may not identify range of motion differences between those with and without LT pathology but LT test with pain provocation may be used to identify partial LT tears. Generally, there seems to be a lack of accuracy in imaging for the diagnosis of LT tears. Surgical treatment debridement for pain relief of partial LT tears is an option, with reconstruction possible for complete LT tears when complaints of instability are noted.

CONCLUSIONS

The findings of this literature review supported the following: 1) LT has a function in restraining hip rotation range of motion; 2) the prevalence of LT pathology in any given population may be largely dependent on the severity of bony deformity (either FAI or dysplasia) and activity level; 3) older age and acetabular bony deformity (either FAI or dysplasia) are risk factors for generalized LT pathology; 4) unique signs and symptoms are difficult to identify because LT pathology rarely occurs in isolation and is likely the end-stage consequence of other hip pathology; 5) the presence of LT pathology may negatively affect an individual's ability to function; and 6) surgical debridement is recommended for pain relief of partial LT tears with reconstruction possible for complete LT tears when complaints of instability are noted. Further higher-level clinical studies are needed to outline the best treatment for those with LT pathology.

REFERENCES

1. Perumal V, Woodley SJ, Nicholson HD. Ligament of the head of femur: A comprehensive review of its anatomy, embryology, and potential function. *Clin Anat*. 2016;29:247-55.
2. Mikula JD, Slette EL, Chahla J, et al. Quantitative Anatomic Analysis of the Native Ligamentum Teres. *Orthop J Sports Med*. 2017;5:2325967117691480.
3. Dehao BW, Bing TK, Young JL. Understanding the ligamentum teres of the hip: a histological study. *Acta Orthop Bras*. 2015;23:29-33.
4. Shinohara Y, Kumai T, Higashiyama I, et al. Histological and molecular characterization of the femoral attachment of the human ligamentum capitis femoris. *Scand J Med Sci Sports*. 2014;24:e245-53.
5. Perumal V, Woodley SJ, Nicholson HD. The morphology and morphometry of the fovea capitis femoris. *Surg Radio Anat*. 2017;39:791-98.
6. Fuss FK, Bacher A. New aspects of the morphology and function of the human hip joint ligaments. *Am J Anat*. 1991;192:1-13.
7. Kraeutler MJ, Garabekyan T, Pascual-Garrido C, Mei-Dan O. Ligamentum teres tendinopathy and tears. *Muscles Ligaments Tendons J*. 2016;6:337-42.
8. Philippon MJ, Rasmussen MT, Turnbull TL, et al. Structural properties of the native ligamentum teres. *Orthop J Sports Med*. 2014;2:2325967114561962.
9. Martin HD, Hatem MA, Kivlan BR, Martin RL. Function of the ligamentum teres in limiting hip rotation: a cadaveric study. *Arthroscopy*. 2014;30:1085-91.
10. Martin RL, Kivlan BR, Clemente FR. A cadaveric model for ligamentum teres function: a pilot study. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:1689-1693.
11. Martin RL, Martin HD. Function and clinical relevance of the ligamentum teres: A current concept. *Curr Orthop Pract*. 2015;26:1-3.
12. Martin RL, Palmer I, Martin HD. Ligamentum teres: a functional description and potential clinical relevance. *Knee Surg Sports Traumatol Arthrosc*. 2012;20:1209-14.
13. Kivlan BR, Richard Clemente F, Martin RL, Martin HD. Function of the ligamentum teres during multi-planar movement of the hip joint. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:1664-68.
14. van Arkel RJ, Amis AA, Cobb JP, Jeffers JR. The capsular ligaments provide more hip rotational restraint than the acetabular labrum and the ligamentum teres: an experimental study. *Bone Joint J*. 2015;97-B:484-91.
15. Phillips AR, Bartlett G, Norton M, Fern D. Hip stability after ligamentum teres resection during surgical dislocation for cam impingement. *Hip Int*. 2012;22:329-34.
16. Kaya M, Suziki T, Minowa T, Yamashita T. Ligamentum teres injury is associated with the articular damage pattern in patients with femoroacetabular impingement. *Arthroscopy*. 2014;30:1582-87.
17. Ejnisman L, Philippon MJ, Lertwanich P, et al. Relationship between femoral anteversion and findings in hips with femoroacetabular impingement. *Orthopedics*. 2013;36:e293-300.
18. Philippon M, Schenker M, Briggs K, Kuppersmith D. Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc*. 2007;15:908-14.
19. Philippon MJ, Kuppersmith DA, Wolff AB, Briggs KK. Arthroscopic findings following traumatic hip dislocation in 14 professional athletes. *Arthroscopy*. 2009;25:169-74.
20. Domb BG, Lareau JM, Baydoun H, Botser I, Millis MB, Yen YM. Is intraarticular pathology common in patients with hip dysplasia undergoing periacetabular osteotomy? *Clin Orthop Relat Res*. 2014;472:674-80.
21. Chahla J, Soares EA, Devitt BM, et al. Ligamentum teres tears and femoroacetabular impingement: prevalence and preoperative findings. *Arthroscopy*. 2016;32:1293-97.

-
22. Philippon MJ, Weiss DR, Kuppersmith DA, Briggs KK, Hay CJ. Arthroscopic labral repair and treatment of femoroacetabular impingement in professional hockey players. *Am J Sports Med.* 2010;38:99-104.
 23. Amenabar T, O'Donnell J. Successful treatment of isolated, partial thickness ligamentum teres (LT) tears with debridement and capsulorrhaphy. *Hip Int.* 2013;23:576-82.
 24. O'Donnell J, Economopoulos K, Singh P, Bates D, Pritchard M. The ligamentum teres test: a novel and effective test in diagnosing tears of the ligamentum teres. *Am J Sports Med.* 2014;42:138-43.
 25. Domb BG, Martin DE, Botser IB. Risk factors for ligamentum teres tears. *Arthroscopy.* 2013;29:64-73.
 26. Botser IB, Martin DE, Stout CE, Domb BG. Tears of the ligamentum teres: prevalence in hip arthroscopy using 2 classification systems. *Am J Sports Med.* 2011;39 Suppl:117S-125S.
 27. Gray AJ, Villar RN. The ligamentum teres of the hip: an arthroscopic classification of its pathology. *Arthroscopy.* 1997;13:575-78.
 28. Baber YF, Robinson AH, Villar RN. Is diagnostic arthroscopy of the hip worthwhile? A prospective review of 328 adults investigated for hip pain. *J Bone Joint Surg Br.* 1999;81:600-3.
 29. Byrd JW, Jones KS. Traumatic rupture of the ligamentum teres as a source of hip pain. *Arthroscopy.* 2004;20:385-91.
 30. Byrd JW, Jones KS. Hip arthroscopy in athletes. *Clin Sports Med.* 2001;20:749-61.
 31. Haviv B, O'Donnell J. Arthroscopic debridement of the isolated ligamentum teres rupture. *Knee Surg Sports Traumatol Arthrosc.* 2011;19:1510-13.
 32. Devitt BM, Smith BN, Stapf R, Tacey M, O'Donnell JM. Generalized joint hypermobility is predictive of hip capsular thickness. *Orthop J Sports Med.* 2017;5:2325967117701882.
 33. Chaharbakhshi EO, Perets I, Ashberg L, Mu B, Lenkeit C, Domb BG. Do ligamentum teres tears portend inferior outcomes in patients with borderline dysplasia undergoing hip arthroscopic surgery? A match-controlled study with a minimum 2-year follow-up. *Am J Sports Med.* 2017;45:2507-16.
 34. Lodhia P, Gui C, Martin TJ, Chandrasekaran S, Suarez-Ahedo C, Domb BG. Central acetabular impingement is associated with femoral head and ligamentum teres damage: a cross-sectional matched-pair analysis of patients undergoing hip arthroscopy for acetabular labral tears. *Arthroscopy.* 2018;34:135-43.
 35. Mandell JC, Marshall RA, Banffy MB, Khurana B, Weaver MJ. Arthroscopy after traumatic hip dislocation: a systematic review of intra-articular findings, correlation with magnetic resonance imaging and computed tomography, treatments, and outcomes. *Arthroscopy.* 2018; 34:917-27.
 36. Mayes S, Ferris AR, Smith P, Garnham A, Cook J. Atraumatic tears of the ligamentum teres are more frequent in professional ballet dancers than a sporting population. *Skeletal Radiol.* 2016;45:959-67.
 37. Papavasiliou A, Siatras T, Bintoudi A, et al. The gymnasts' hip and groin: a magnetic resonance imaging study in asymptomatic elite athletes. *Skeletal Radiol.* 2014;43:1071-77.
 38. de SA D, Phillips M, Philippon MJ, Letkemann S, Simunovic N, Ayeni OR. Ligamentum teres injuries of the hip: a systematic review examining surgical indications, treatment options, and outcomes. *Arthroscopy.* 2014;30:1634-41.
 39. Cerezal L, Carro LP, Llorca J, et al. Usefulness of MR arthrography of the hip with leg traction in the evaluation of ligamentum teres injuries. *Skeletal Radiol.* 2015;44:1585-1595.
 40. Schmaranzer F, Klauser A, Kogler M, et al. MR arthrography of the hip with and without leg traction: Assessing the diagnostic performance in detection of ligamentum teres lesions with arthroscopic correlation. *Eur J Radiol.* 2016;85: 489-497.
 41. Schmaranzer F, Klauser A, Kogler M, et al. Improving visualization of the central compartment of the hip with direct MR arthrography under axial leg traction: a feasibility study. *Acad Radiol.* 2014;21:1240-1247.
 42. Chang CY, Gill CM, Huang AJ, et al. Use of MR arthrography in detecting tears of the ligamentum teres with arthroscopic correlation. *Skeletal Radiol.* 2015;44:361-367.
 43. Cheatham SW, Enseki KR, Kolber MJ. Postoperative rehabilitation after hip arthroscopy: a search for the evidence. *J Sport Rehabil.* 2015;24:413-418.