

## ORIGINAL RESEARCH

# Changes Over Time in the Strain on the Inferior Iliofemoral Ligament During a Sustained 5-Minute High-Force Long-Axis Distraction Mobilization: A Cadaveric Study\*

Elena Estébanez-de-Miguel, PhD,<sup>a</sup> Elena Bueno-Gracia, PhD,<sup>a</sup>  
Vanessa González-Rueda, PhD,<sup>b,c</sup> Albert Pérez-Bellmunt, PhD,<sup>b</sup>  
Santos Caudevilla-Polo, PhD,<sup>a</sup> Carlos López-de-Celis, PhD<sup>b,c</sup>

From the <sup>a</sup>Department of Physiatrist and Nursery, Faculty of Health Sciences, University of Zaragoza, Zaragoza; <sup>b</sup>Faculty of Medicine and Health Sciences, Universitat Internacional de Catalunya, Barcelona; and <sup>c</sup>Fundació Institut Universitari per a la recerca a l'Atenció Primària de Salut Jordi Gol i Gurina (IDIAPJGol), Barcelona, Spain.

**Abstract**

**Objective:** To analyze the changes over time in the strain on the inferior iliofemoral (IIF) ligament when a constant high-force long-axis distraction mobilization (LADM) was applied over 5 minutes.

**Design:** A cross-sectional laboratory cadaveric study.

**Setting:** Anatomy laboratory.

**Participants:** Thirteen hip joints from 9 fresh-frozen cadavers (mean age, 75.6±7.8 years; N=13).

**Interventions:** High-force LADM in open-packed position was sustained for a period of 5 minutes.

**Main Outcome Measure(s):** Strain on IFF ligament was measured over time with a microminiature differential variable reluctance transducer. Strain measurements were taken at every 15 seconds for the first 3 minutes and every 30 seconds for the next 2 minutes.

**Results:** Major changes in strain occurred in the first minute of high-force LADM application. The greatest increase in strain on the IFF ligament occurred at the first 15 seconds (7.3±7.2%). At 30 seconds, the increase in strain was 10.1±9.6%, the half of the total increase at the end of the 5-minute high-force LADM (20.2±8.5%). Significant changes in strain measures were shown to occur at 45 seconds of high-force LADM (F=18.11; P<.001).

**Conclusions:** When a 5-minute high-force LADM was applied, the major changes in the strain on IIF ligament occurred in the first minute of the mobilization. A high-force LADM mobilization should be sustained at least 45 seconds to produce a significant change in the strain of capsular–ligament tissue.

Archives of Physical Medicine and Rehabilitation 2023;000:1–6

© 2023 by the American Congress of Rehabilitation Medicine. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Hip capsular thickening and shortening are related to a decreased range of motion (ROM).<sup>1,2</sup> Physical therapists use joint-mobilization techniques to increase ROM in restricted hip joints.<sup>3–5</sup> Two studies have shown that the increase in ROM after joint mobilization is related to changes in the histologic characteristics<sup>6</sup> and the strain<sup>7</sup> of capsular ligament tissue.

The mechanical response of capsular ligaments depends on the magnitude of the applied force.<sup>7,8</sup> It has been reported that it is necessary to apply a hip long-axis distraction mobilization (LADM) that exceeds the maximal resistance of the tissues or the first stop (high-force) to increase hip ROM.<sup>8</sup> However, it would be useful to consider not only the magnitude but also the duration of the mobilization force, because the treatment dosage is characterized by the magnitude, amplitude and direction of the applied

\* Estébanez-de-Miguel and Elena Bueno-Gracia contributed equally to this work.  
Disclosures: none.

force, oscillation frequency, number of repetitions (set), and treatment time.<sup>2</sup>

The treatment time for restricted hip joints is usually between 10 and 30 minutes and is based on clinical practice at participating sites,<sup>3</sup> physical therapist's experience,<sup>1,4-11</sup> and patient feedback.<sup>1,8,11</sup> During treatment time, different manual therapy techniques are performed and the intensity, duration, and the number of repetitions of each technique are usually adjusted according to the patient's symptom response to the intervention. The research outlining hip joint mobilizations provides insufficient detail of the interventions, and few studies define the treatment dosage. Heerey et al<sup>11</sup> included in a protocol after hip arthroscopy 3 gentle inferior and/or lateral traction mobilizations for a period of 10 seconds to reduce hip capsule tightness. Vaarbakken and Ljunggren<sup>9</sup> applied a forceful hip LADM from 15 to 40 seconds for 15 minutes to reduce stiffness and activity limitations in daily living, recreation, and sport in patients with hip disability. Estébanez-de-Miguel et al<sup>1</sup> applied thirteen 30-second high-force LADMs followed by a 15-second rest period for 10 minutes to increase range of motion in patients with hip osteoarthritis. The lack of evidence to choose the appropriate time hip joint mobilization duration requires better reporting.

Understanding the mechanical deformation process of hip capsular ligament tissue during a joint mobilization may help to determine the appropriate dosage of a high-force hip mobilization to produce a significant increase in ligament strain. The purpose of this study was to analyze the changes over time in the strain on the inferior iliofemoral (IIF) ligament during a sustained 5-minute, high-force LADM.

## Methods

### Study design and ethics

A cadaveric study that took place at the anatomy laboratory from Universitat Internacional de Catalunya was designed. Ethical approval was obtained from the institutional ethics committee (CBAS-2019-01-C). A repeated-measures design was carried out to compare the strain on the IIF ligament at different times during a 5-minute high-force LADM.

### Body donors

Nine fresh-frozen cadavers were used. Initially, 18 hip joints were potentially eligible for the study, but 5 of them were excluded because of the following reasons: previous hip surgery (3), severe osteoarthritis (1), and tumor in the pelvis region (1). Finally, a total of 13 hip joints from 9 fresh-frozen cadavers (6 male, 3 female) were used in this study. The sample included 7 right and 6 left hip joints. The mean age of the cadavers at the time of death was  $75.6 \pm 7.8$  years. The frozen cadavers were stored at  $-20^{\circ}\text{C}$  until 24 hours before preparation, following the procedure used in other cadaveric biomechanical studies.<sup>12-14</sup> Research has shown

that ligament tissue mechanical properties are not altered as a result of freezing.<sup>15-17</sup>

### Experimental procedure

After thawing, 10 to 15 passive hip mobilizations to the end-range were performed to preserve smooth joint motion and reduce hysteresis of the ligaments.<sup>15</sup> Then, the cadaver was stabilized with a belt just below the anterior superior iliac spines and a fixation pole attached below the isquiopubic ramus. Hip joint was placed in open-packed position of  $30^{\circ}$  flexion,  $30^{\circ}$  abduction, and slight external rotation<sup>18</sup> and the femur was stabilized in this position with a wedge cushion. A joint distraction cuff was placed around the distal part of the femur for the mobilization to avoid mechanical stress in knee and ankle joints. Room temperature was maintained at  $22^{\circ}\text{C}$ .

High-force LADM adapted from real clinical practice was performed by a single physical therapist, blinded to the measurements, who received training in orthopedic manual therapy and had more than 15 years of clinical experience. The physical therapist was wearing a mobilization belt around her pelvis, attached to the cadaver's distraction cuff for mobilization. A dynamometer (475055 Digital Force Gauge; Extech) was placed between mobilization belt and distraction cuff in alignment with the direction of LADM to measure and ensure that magnitude of the force applied during the mobilization was constant.<sup>19</sup>

For high-force LADM, the therapist pulled caudally with a force exceeding the "first stop" and feeling the maximal resistance to the movement.<sup>20</sup> Constant high-force LADM was sustained for 5 minutes. Figure 1a illustrates the experimental procedure.

### Measurements of ligament strain

A skin flap (size  $15 \times 12$  cm) was created at the anterior aspect of the hip joint. The skin, fascia, muscles, nerves, and vessels were removed, leaving the IIF ligament clearly exposed. Previous studies have shown that capsular tissue and labrum are the primary stabilizers in the hip joint.<sup>21-23</sup> Furthermore, high-force LADM has no effect on psoas muscle.<sup>24</sup> Therefore, removed skin, fascia, muscle, nerves and vessels would have no effect on mechanical properties of the IIF ligament. A differential variable reluctance transducer (MicroStrain) with a 6-mm stroke length and resolution of  $1.5 \mu\text{m}$  was used to measure strain on IIF ligament (on the center of the ligament). Figure 1b illustrates strain gauge in the IIF ligament. The differential variable reluctance transducer was calibrated using the equations provided by the manufacturer.

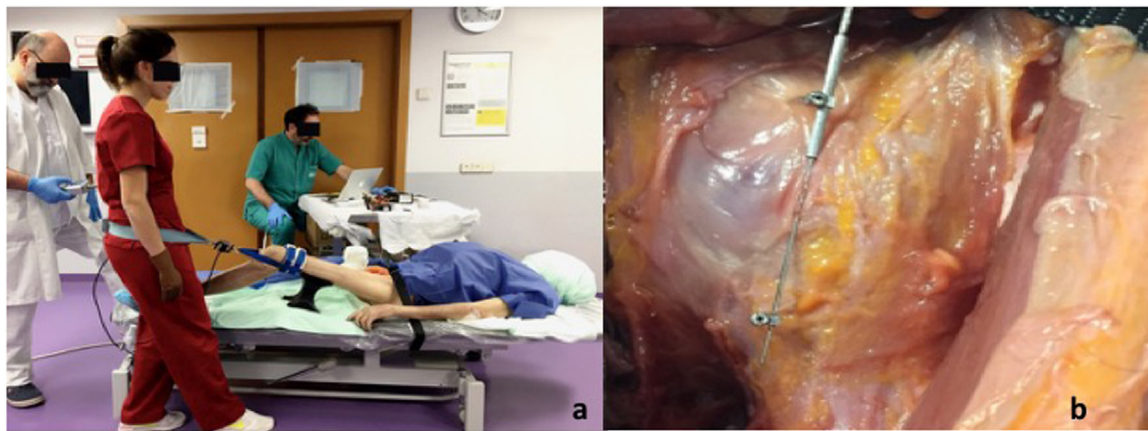
The physical therapist started to perform the LADM, and when she reported feeling the maximal resistance of the tissue (high-force LADM), strain measurement at baseline was recorded. The same magnitude of LADM force applied was sustained for 5 minutes and strain measurements on IIF ligament were recorded every 15 seconds for the first 3 minutes and every 30 seconds for the next 2 minutes. The percentage of change in strain was calculated using the formula  $(\text{strain } [\%] = \Delta L [\text{mm}] / L_0 [\text{mm}] \times 100)$ . The percentage change was calculated in reference to the strain at the beginning of the high-force LADM (baseline).

### Statistical analysis

SPSS Statistics, Version 26.0 (IBM Corp), was used for statistical analysis. The alpha level was set at .05. Descriptive statistics were calculated for the strain measurements and the magnitude of the

#### List of abbreviations:

IIF	inferior iliofemoral
LADM	long-axis distraction mobilization
ROM	range of motion



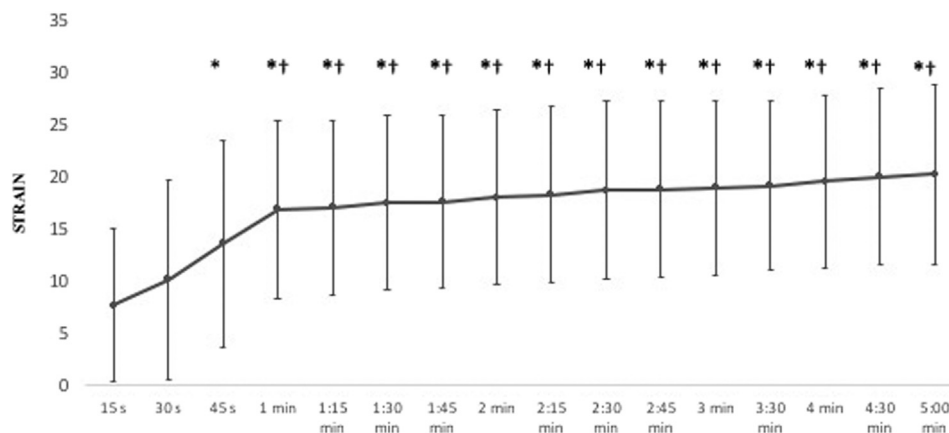
**Fig 1** Experimental set-up. (a) Long-axis distraction mobilization. (b) The strain gauge inserted into the IFF ligament.

applied force. A 1-way, repeated-measures analysis of variance was applied to determine any change in the strain among the time points. Bonferroni multiple comparison was used for post hoc testing.

## Results

The magnitude of hip mobilization force was  $324.3 \pm 11.1$  N. The strain on IIF increased  $20.2 \pm 8.5\%$  after 5-minute high-force LADM. The greatest increase in strain occurred at 15 seconds ( $7.3 \pm 7.2\%$ ). At 30 seconds, the mean increase in strain on IFF was the half of the total strain increase ( $10.1 \pm 9.6\%$ ) at the end of the 5-minute high-force LADM. At 45 and 60 seconds, the strain was  $13.63 \pm 9.8\%$  and  $16.9 \pm 8.5\%$ , respectively. During the remaining 4 minutes, strain on IFF ligament increased  $3.3 \pm 4.5\%$  until reaching  $20.2 \pm 8.5\%$ .

One-way repeated-measures analysis of variance showed significant differences ( $F = 18.11$ ;  $P < .001$ ) in strain measurements. Bonferroni test showed significant differences between the strain at 15 seconds and the other strain measurements made after 45 seconds of high-force LADM ( $P < .05$ ) and between the strain at 30 seconds and the other strain measurements made after 1 minute of high-force LADM ( $P < .05$ ). [Figure 2](#) illustrates the changes in strain on IIF ligament for 5-minute high-force LADM in all sample, and [figure 3](#) illustrates the changes in strain in the cases sample to show the variance across them.



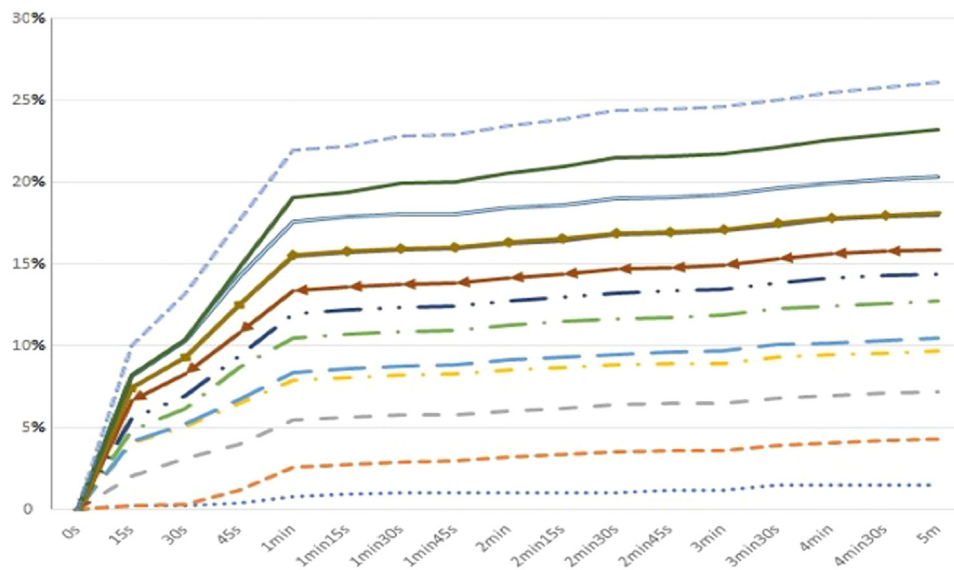
**Fig 2** Strain over time on IFF ligament during 5-minute LADM. \* $P < .05$  between the measurement at 30 seconds and other time durations. † $P < .05$  between the measurement at 45 seconds and other time durations.

## Discussion

This is the first cadaveric study to assess the time effect in changes in strain on IIF ligament during a constant 5-minute high-force LADM. The major changes in strain occurred during the first minute of the high-force LADM. The greatest increase in strain on IIF ligament occurred at the first 15 seconds. At 30 seconds, the mean strain was half of the total strain at the end of the 5-min high-force LADM. However, significant changes in strain measures were shown at 45 seconds. Therefore, a high-force LADM mobilization should be sustained at least 45 seconds to produce a significant change in the strain of capsular–ligament tissue.

In clinical practice, the treatment duration is variable. However, the results of the present study highlight that a critical level of high-force LADM duration is needed to produce a lengthening of the hip capsular–ligament tissue. These findings are consistent with Maitland approach, where mobilization techniques are applied for 30-60 seconds.<sup>25</sup> Kaltenborn et al<sup>20</sup> also suggested that joint-mobilization techniques in large joints should be sustained for 30-40 seconds with the assistance of a mobilization belt to stretch the tissue.

Estébanez-de-Miguel et al<sup>19</sup> showed a significant increase of hip ROM associated with an increase of 20% in the strain on IIF ligament after 5-minute high-force LADM. The findings of the present study show that the strain increased to 14% at 45 seconds and 17% at 60 seconds. Therefore, the results of these cadaveric



**Fig 3** Descriptive graphic of the strain over time on IFF ligament during 5-minute LADM in sample cases.

studies suggest that it could be enough to sustain a high-force LADM between 45 and 60 seconds to produce an increase in hip ROM. However, further studies in vivo are required to provide evidence about this finding.

This study could explain the plastic mechanical deformation of IIF ligament when a sustained distraction force is applied once the ligament has been previously stretched (high-force). The changes in strain observed for the 5-minute high-force LADM could highlight the hypothesis that the creep of fibers on one hand, and the recruitment of fibers on the other, contribute to the time-varying length function of a tissue under constant load.<sup>26,27</sup> It has been suggested that a progressive recruitment would occur during creep.<sup>28</sup> Different fibers in the same tissue have different crimped lengths.<sup>29</sup> Thus, when the tissue is stretched, fibers will be elongated progressively. This is an important factor for clinical practice, because the increase of tissue length provokes an increase of ROM.

The restricted hip mobility is common in hip disorders such as osteoarthritis<sup>30</sup> and can contribute to low back pain<sup>31-34</sup> as well as to more distal lower-extremity pathologies.<sup>31,35</sup> When hip joint mobility restrictions are diagnosed, hip joint mobilization is an appropriate intervention to manage the movement limitations.<sup>36,37</sup> High-force LADM has demonstrated to be effective to increase hip ROM.<sup>1,9,10,37</sup>

In clinical practice, manual mobilization techniques are not usually sustained for 5 minutes. However, analysis of the mechanical deformation process of hip capsular ligament tissue over this time has allowed to describe the changes in the strain of tissue. These results could be helpful to guide the clinicians to determine the best treatment time dosage. The present study suggests the appropriate duration of one hip high-force LADM. However, the number of sets may be as important as the duration of joint mobilization to ensure the plastic deformation of capsular–ligament tissue. We suggest that shorter joint mobilizations would need more sets. Future studies are required to examine the relationship between duration and sets of joint mobilization. Determining the sets in relation to the duration of high-force LADM would be very useful in clinical practice to state the recommended dosage according to the sociodemographic and clinical characteristics of the patients with restricted hip joints.

This study provides more evidence about dosage of joint mobilization showing that high-force LADM should be sustained during at least 45 seconds to produce a significant change in the strain on hip ligament tissue.

### Study limitations

There are potential limitations to this study. First, findings of the present study were generated from fresh-frozen cadavers. Therefore, generalization to the living patient population should be considered with caution. Although previous studies showed that LADM is specific for hip capsular–ligament tissue,<sup>24</sup> removed skin, fascia, or other structures could alter the mechanical behavior of ligament tissue. Changes in strain were measured on IIF ligament during high-force LADM. Therefore, findings cannot be generalized to all capsular–ligament tissue or hip joint mobilization techniques. Future studies are required to analyze the mechanical response over time of other capsular–ligament structures during different translatory joint mobilization techniques. In our study, the set times for outcome measure (strain on IIF ligament) were based on literature. It would be interesting to assess the strain continuously over time to determine the appropriate duration of high-force LADM more accurately.

### Conclusions

When a 5-minute high-force LADM was applied, the major changes in the strain on IIF ligament occurred in the first minute of the mobilization. A high-force LADM mobilization should be sustained at least 45 seconds to produce a significant change in the strain of capsular–ligament tissue.

### Keywords

Dosage; Hip joint; Joint mobilization; Ligament; Rehabilitation; Strain

## Corresponding author

Elena Estébanez de Miguel. Facultad de Ciencias de la Salud. Universidad de Zaragoza. C/ Domingo Miral s/n, 50011 Zaragoza, España. E-mail address: [elesteba@unizar.es](mailto:elesteba@unizar.es).

## Acknowledgments

We sincerely thank those who donated their bodies to science so that anatomic research could be performed. Results from such research can potentially increase humankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude.

## References

- Estébanez-de-Miguel E, Fortún-Agud M, Jimenez-del-Barrio S, Caudevilla-Polo S, Bueno-Gracia E, Tricás-Moreno JM. Comparison of high, medium and low mobilization forces for increasing range of motion in patients with hip osteoarthritis: a randomized controlled trial. *Musculoskelet Sci Pract* 2018;36:81–6.
- Snodgrass SJ, Rivett DA, Sterling M, Vicenzino B. Dose optimization for spinal treatment effectiveness: a randomized controlled trial investigating the effects of high and low mobilization forces in patients with neck pain. *J Orthop Sports Phys Ther* 2014;44:141–52.
- French HP, Cusack T, Brennan A, et al. Exercise and Manual Physiotherapy Arthritis Research Trial (EMPART) for Osteoarthritis of the Hip: A Multicenter Randomized Controlled Trial Archives of Physical Medicine and Rehabilitation. *Arch Phys Med Rehabil* 2013;94:302–16.
- Bennell KL, Egerton T, Martin J, et al. Effect of physical therapy on pain and function in patients with hip osteoarthritis: a randomized clinical trial. *JAMA* 2014;311:1987–97.
- Poulsen E, Hartvigsen J, Christensen HW, Roos EM, Vach W, Overgaard S. Patient education with or without manual therapy compared to a control group in patients with osteoarthritis of the hip. A proof-of-principle three-arm parallel group randomized clinical trial. *Osteoarthr Cartil* 2013;21:1494–503.
- Hando BR, Gill NW, Walker MJ, Garber M. Short- and long-term clinical outcomes following a standardized protocol of orthopedic manual physical therapy and exercise in individuals with osteoarthritis of the hip: a case series. *J Man Manip Ther* 2012;20:192–200.
- Beselga C, Neto F, Alburquerque-Sendín F, Hall T, Oliveira-Campelo N. Immediate effects of hip mobilization with movement in patients with hip osteoarthritis: a randomised controlled trial. *Man Ther* 2016;22:80–5.
- Brantingham JW, Parkin-Smith G, Cassa TK, et al. Full kinetic chain manual and manipulative therapy plus exercise compared with targeted manual and manipulative therapy plus exercise for symptomatic osteoarthritis of the hip: a randomized controlled trial. *Arch Phys Med Rehabil* 2012;93:259–67.
- Vaarbakken K, Ljunggren AE. Superior effect of forceful compared with standard traction mobilizations in hip disability? *Adv. Physiother* 2007;9:117–28.
- Hoeksma HL, Dekker J, Ronday HK, Heering A, Van Der Lubbe N, Vel C, et al. Comparison of manual therapy and exercise therapy in osteoarthritis of the hip: a randomized clinical trial. *Arthritis Rheum* 2004;51:722–9.
- Heerey J, Risberg MA, Magnus J, et al. Impairment-based rehabilitation following hip arthroscopy: postoperative protocol for the HIP arthroscopy international randomized controlled trial. *J Orthop Sports Phys Ther* 2018;48:336–42.
- Hidaka E, Aoki M, Muraki T, Izumi T, Fujii M, Miyamoto S. Evaluation of stretching position by measurement of strain on the ilio-femoral ligaments: an in vitro simulation using trans-lumbar cadaver specimens. *Man Ther* 2009;14:427–32.
- Hidaka E, Aoki M, Izumi T, Suzuki D, Fujimiya M. Ligament strain on the iliofemoral, pubofemoral, and ischiofemoral ligaments in cadaver specimens: biomechanical measurement and anatomical observation. *Clin Anat* 2014;27:1068–75.
- Stubbs T, Moon AS, Dahlgren N, et al. Anterior acetabular retractors and the femoral neurovascular bundle in anterior total hip arthroplasty: a cadaveric study. *Eur J Orthop Surg Traumatol* 2020;30:617–20.
- Woo SLY, Orlando CA, Camp JF, Akeson WH. Effects of postmortem storage by freezing on ligament tensile behavior. *J Biomech* 1986;19:399–404.
- Mahalingam VD, Behbahani-Nejad N, Ronan EA, et al. Fresh versus frozen engineered bone-ligament-bone grafts for sheep anterior cruciate ligament repair. *Tissue Eng Part C Methods* 2015;21:548–56.
- Moon DK, Woo SLY, Takakura Y, Gabriel MT, Abramowitch SD. The effects of refreezing on the viscoelastic and tensile properties of ligaments. *J Biomech* 2006;39:1153–7.
- Woo SL, Orlando CA, Camp JF, Akeson WH. Effects of postmortem storage by freezing on ligament tensile behavior. *J Biomech* 1986;19:399–404.
- Wise CH. *Orthopaedic manual physical therapy: from art to evidence*. Philadelphia: F.A. Davis Company; 2015.
- Estébanez-de-Miguel E, González-Rueda V, Bueno-Gracia E, Pérez-Bellmunt A, López-de-Celis C, Caudevilla-Polo S. The immediate effects of 5-minute high-force long axis distraction mobilization on the strain on the inferior ilio-femoral ligament and hip range of motion: a cadaveric study. *Musculoskelet Sci Pract* 2020;50:102262.
- Kaltenborn F, Evjenth O, Kaltenborn T, Morgan D, Vollowitz E. *Manual mobilization of the joints. Volume I : joint examination and basic treatment: the extremities*. Oslo (Norway): Norli; 2015.
- Smith M V, Costic RS, Allaire R, Schilling PL, Sekiya JK. A biomechanical analysis of the soft tissue and osseous constraints of the hip joint. *Knee Surg Sports Traumatol Arthrosc* 2014;22:946–52.
- Van Arkel RJ, Amis AA, Cobb JP, Jeffers JRT. 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.
- Myers CA, Register BC, Lertwanich P, et al. Role of the acetabular labrum and the iliofemoral ligament in hip stability: an in vitro biplane fluoroscopy study. *Am J Sports Med* 2011;39:85S–91S.
- Estébanez-de-Miguel E, López-de-Celis C, Caudevilla-Polo S, González-Rueda V, Bueno-Gracia E, Pérez-Bellmunt A. The effect of high, medium and low mobilization forces applied during a hip long-axis distraction mobilization on the strain on the inferior ilio-femoral ligament and psoas muscle: a cadaver study. *Musculoskelet Sci Pract* 2020;47:102148.
- Maitland G, Hengeveld E, Banks K, English K. *Maitland's vertebral manipulation*. 6th ed. Oxford: Butterworth-Heinemann; 2001.
- Thornton GM, Shrive NG, Frank CB. Ligament creep recruits fibres at low stresses and can lead to modulus-reducing fibre damage at higher creep stresses: a study in rabbit medial collateral ligament model. *J Orthop Res* 2002;20:967–74.
- Thornton GM, Oliynyk A, Frank CB, Shrive NG. Ligament creep cannot be predicted from stress relaxation at low stress: a biomechanical study of the rabbit medial collateral ligament. *J Orthop Res* 1997;15:652–6.
- Viidik A. Simultaneous mechanical and light microscopic studies of collagen fibers. *Z Anat Entwicklungsgesch* 1972;136:204–12.
- Woo SLY, Johnson GA, Smith BA. Mathematical modeling of ligaments and tendons. *J Biomech Eng* 1993;115:468–73.
- Cibulka MT, Bloom NJ, Ensey KR, Macdonald CW, Woehrlie J, McDonough CM. Hip pain and mobility deficits in hip osteoarthritis: revision 2017. *J Orthop Sports Phys Ther* 2017;47:A1–37.

32. Reiman MP, Bolgla LA, Lorenz D. Hip function's influence on knee dysfunction: a proximal link to a distal problem. *J Sport Rehabil* 2009;18:33–46.
33. Tanaka S, Matsumoto S, Fujii K, Tamari K, Mitani S, Tsubahara A. Factors related to low back pain in patients with hip osteoarthritis. *J Back Musculoskelet Rehabil* 2015;28:409–14.
34. Redmond JM, Gupta A, Nasser R, Domb BG. The hip-spine connection: understanding its importance in the treatment of hip pathology. *Orthopedics* 2015;38:49–55.
35. Prather H, Cheng A, Steger-May K, Maheshwari V, Van Dillen L. Hip and lumbar spine physical examination findings in people presenting with low back pain, with or without lower extremity pain. *J Orthop Sports Phys Ther* 2017;47:163–72.
36. Currier LL, Froehlich PJ, Carow SD, et al. Development of a clinical prediction rule to identify patients with knee pain and clinical evidence of knee osteoarthritis who demonstrate a favorable short-term response to hip mobilization. *Phys Ther* 2007;87:1106–19.
37. Crow JB, Gelfand B, Su EP. Use of joint mobilization in a patient with severely restricted hip motion following bilateral hip resurfacing arthroplasty. *Phys Ther* 2008;88:1591–600.