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CHANGES OVER TIME IN THE STRAIN ON THE INFERIOR ILIO-FEMORAL LIGAMENT DURING A SUSTAINED 5-MINUTE HIGH-FORCE LONG AXIS DISTRACTION MOBILIZATION: A CADAVERIC STUDY

Running head: Changes in ligament strain during hip mobilization

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Conflicts of interest

The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article.

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ABSTRACT

Objective: To analyze the changes over time in the strain on the inferior ilio-femoral (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 nine fresh-frozen cadavers (mean age, 75.6 ± 7.8 years).

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 15s for the first 3min and every 30s for the next 2min.

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 15s

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(7.3 ± 7.2 %). At 30s, 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 45s of high-force LADM(F= 18.11; p<0.001).

Conclusion: 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 45s to produce a significant change in the strain of capsular-ligament tissue.

Keywords: dosage; joint mobilization; hip joint; ligament; strain.

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ABBREVIATIONS

ANOVA: analysis of variance

F: female

IIF: inferior ilio-femoral

LADM: long axis distraction mobilization

M: male

Min: minutes

N: newton

ROM: range of motion

S: seconds

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INTRODUCTION

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

The mechanical response of capsular ligaments depends on the magnitude of the applied force.[7,8] 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.[8] 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 force, oscillation frequency, number of repetitions (set) and treatment time.[2]

The treatment time for restricted hip joints is usually between 10 to 30 minutes and is based on clinical practice at participating sites,[3] physical therapist's experience[1,4–11] and patient feedback.[1,8,11] 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. included in a protocol following hip arthroscopy three gentle inferior and/or lateral traction mobilizations for a period of 10 seconds to reduce hip capsule tightness.[11] Vaarbakken and Ljunggren applied a forceful hip long axis distraction mobilization from 15-40 s for 15 minutes to reduce stiffness, activity limitations in daily living, recreations and sport in patients with hip disability.[9] Estébanez et al. applied thirteen 30-s high-force LADMs followed by 15-s rest period for 10 minutes, to increase range of motion in patients with hip osteoarthritis.[1] 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 ilio-femoral (IIF) ligament during a sustained 5-min high-force LADM.

METHODS

Study design and ethics

A cadaveric study that took place at the anatomy laboratory from X 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-min 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: prior 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 M, 3 F) 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 ± 7.8 years. The frozen cadavers were stored at -20ºC until 24 hours before preparation following the procedure used in other cadaveric biomechanical studies.[12–14] Research has shown that ligament tissue mechanical properties are not altered as a result of freezing.[15–17]

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Experimental procedure

After thawing, 10-15 passive hip mobilizations to the end-range were performed to preserve smooth joint motion and reduce hysteresis of the ligaments.[18] 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° flexion, 30° abduction and slight external rotation[19] 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°C.

High-force LADM adapted from real clinical practice was performed by a single physical therapist, blinded to the measurements, who received training in Orthopaedic 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, Boston, USA) 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.[20]

For high-force LADM, the therapist pulled caudally with a force exceeding the 'first stop' and feeling the maximal resistance to the movement.[21] Constant high-force LADM was sustained for 5min. Figure 1a illustrates the experimental procedure.

Measurements of ligament strain

A skin flap (size 15 x12 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

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stabilizers in the hip joint.[22–24] Furthermore, high-force LADM has no effect on psoas muscle.[25] Therefore, remove skin, fascia, muscle, nerves and vessels could have no effect on mechanical properties of IIF ligament A differential variable reluctance transducer (DVRT; MicroStrain, Burlington, VT, USA) with a 6-mm stroke length and resolution of 1.5 μm was used to measure strain on IIF ligament (on the centre of the ligament). Figure 1b illustrates strain gauge in the IIF ligament. The DVRT was calibrated using the equations provided by the manufacturer.

Physical therapist started to perform the LADM and when she reported to feel 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 5min and strain measurements on IIF ligament were recorded every 15s for the first 3min and every 30s for the next 2min. The percentage of change in strain was calculated using the formula (strain (%) = ΔL (mm) / L_0 (mm) x 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 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 applied force. A 1-way, repeated-measures ANOVA 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 ± 11.1 N. The strain on IIF increased 20.2 ± 8.5 % after 5-minute high-force LADM. The greatest increase in strain occurred at 15s (7.3 ± 7.2 %). At 30s the mean increase in strain on IFF was the half of the total strain increase (10.1 ± 9.6 %) at the end of the 5-minute high-force LADM. At 45 and 60s the strain was 13.63 ± 9.8 and 16.9 ± 8.5%, respectively. During the remaining 4min, strain on IFF ligament increased 3.3 ± 4.5%, until reaching 20.2 ± 8.5 %.

1-way repeated-measures ANOVA showed significant differences ($F= 18.11$; $p<0.001$) in strain measurements. Bonferroni test showed significant differences between the strain at 15s and the other strain measurements made after 45s of high-force LADM ($p<0.05$) and between the strain at 30s and the other strain measurements made after 1min of high-force LADM ($p<0.05$). Figure 2 illustrates the changes in strain on IIF ligament for 5-min high-force LADM in all sample and Figure 3 illustrates the changes in strain in the cases sample to show the variance across them.

DISCUSSION

This is the first cadaveric study to assess the time effect in changes in strain on IIF ligament during a constant 5-min 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 15s. At 30s, 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 45s. Therefore, a high-force LADM mobilization should be sustained at least 45s 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 30-60s.[26] Kaltenborn also suggested that joint mobilization techniques in large joints should be sustained for 30 to 40s with the assistance of a mobilization belt to stretch the tissue.[21]

Estébanez-de-Miguel et al. showed a significant increase of hip ROM associated to an increase of 20% in the strain on IIF ligament after 5-minute high-force LADM.[20] The findings of the present study show that the strain increased to 14% at 45s and 17% at 60s. Therefore, the results of these cadaveric studies suggest that it could be enough to sustain a high-force LADM between 45-60 s to produce an increase in hip ROM. However, further in vivo studies 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-min 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.[27,28] It has been suggested that a progressive recruitment would occur during creep.[29] Different fibers in the same tissue have different crimped lengths.[30] 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 provoke an increase of ROM.

The restricted hip mobility is common in hip disorders as OA[31] and can contribute to low back pain[32–35] as well as to more distal lower extremity pathologies.[36,37] When hip joint mobility restrictions are diagnosed, hip joint mobilization is an appropriate intervention to manage the movement limitations.[38,39] High-force LADM has demonstrated to be effective to increase hip ROM.[1,9,39,40]

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In clinical practice, manual mobilization techniques are not usually sustained during 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 45s 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[25], remove 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 translatoric joint mobilization techniques. In our

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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 45s to produce a significant change in the strain of capsular-ligament tissue.

Conflicts of Interest: The authors declare no conflicts of interest.

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FIGURE LEGENDS

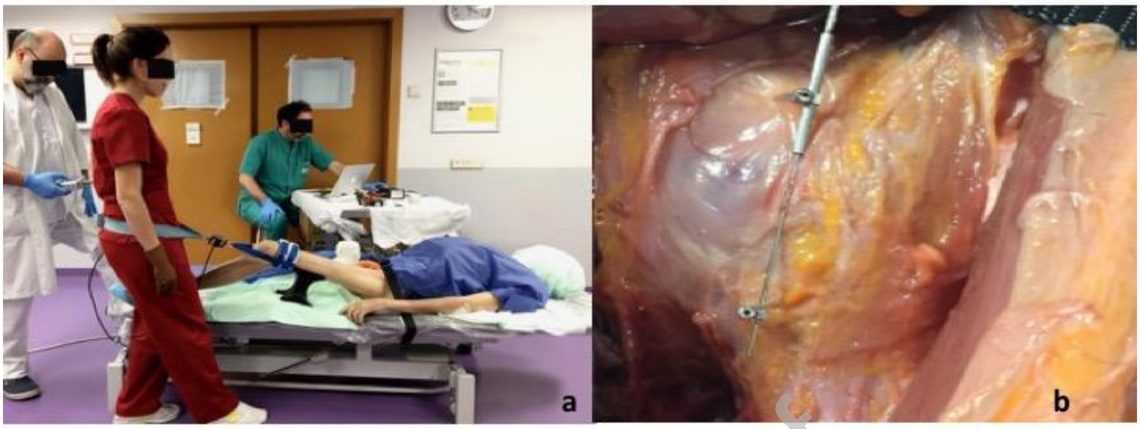

Figure 1: Experimental set-up. a) Long-axis distraction mobilization, b) The strain gauge inserted into the inferior ilio-femoral ligament.

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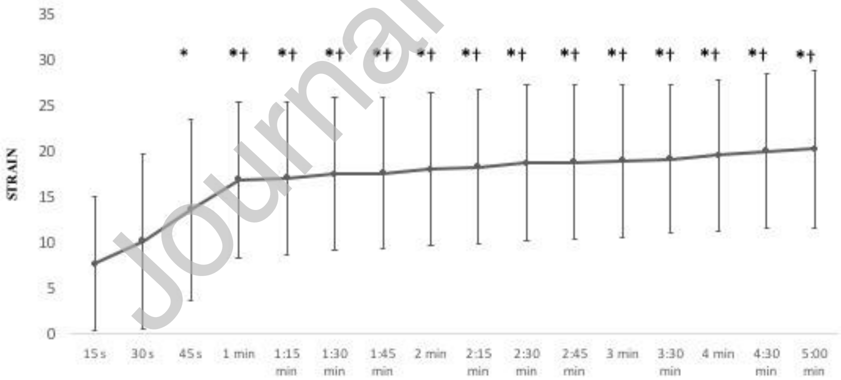

Figure 2. Strain over time on IFF ligament during 5-minute LADM.*P<.05 between the measurement at 30s and others time durations. † P<.05 between the measurement at 45s and others time durations.

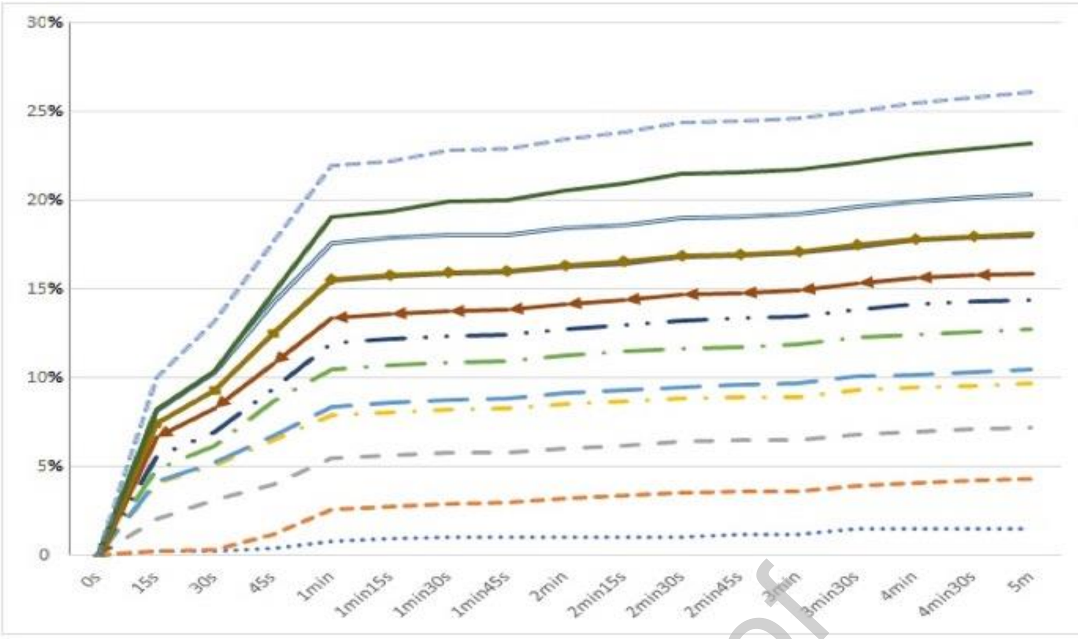

Figure 3. Descriptive graphic of the strain over time on IFF ligament during 5-minute LADM in sample cases.

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