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plasminogen deficiency: a series of 50 patients. *Blood* 2006; **108**: 3021–6.
12 Heinz C, Kremmer S, Externbrink P, Steuhl KP. Ligneous conjunctivitis in a patient with plasminogen type I deficiency-case report with review of literature. *Klin Monbl Augenheilkd* 2002; **219**: 156–8.
13 Yohe SL, Reyes M, Johnson DA, Fry CL, Scribbick FW, Kinney MC. Plasminogen deficiency as a rare cause of conjunctivitis and lymphadenopathy. *Am J Surg Pathol* 2009; **33**: 313–19.
14 El-Darouti M, Zayed AA, El-Kamah GY, Mostafa MI. Ligneous conjunctivitis with oral mucous membrane involvement and decreased plasminogen level. *Pediatr Dermatol* 2009; **26**: 448–51.
15 Olszewer E. *Manual de avaliação clínica e funcional com aplicabilidade ortomolecular (interação terapêutica nutricional) / Efrain Olszewer – São Paulo: Ícone 2008.*

# Estimation of tensile properties of the Achilles tendon in haemophilic arthropathy of the ankle: case study

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The progressive deterioration leading to disability in patients with haemophilic arthropathy (HA) of the ankle is mainly characterized by structural damage to the tibiotalar and subtalar joint, coupled with biomechanical changes associated with the loss of mobility and pain. These changes include: distal widening of the tibia, valgus hind foot and flat feet. In advanced stages of arthropathy of the ankle the orthopaedic choice options are the arthrodesis or prosthesis (joint replacement) [1].

Early degenerative changes of HA are associated with disabilities having a significant clinical impact on haemophilia patients and require physiotherapy. For this reason, the care of patients with HA requires comprehensive scores. Haemophilic arthropathy of the ankle is still currently evaluated through clinical and functional assessment, image scores and pain measurement [2].

The bleeding of the ankle joint causes: severe pain, limited movement and swelling with cartilage and synovial involvement. The consequent joint disorders, product of this bleeding, may produce capsular and tendon shortening helping to develop joint contractures [3].

One way to assess the viscoelastic behaviour of the tendons is to calculate tendon hysteresis and stiffness. The loading and unloading curves during cyclic tensile testing of tendon structures produce a loop, which determines the hysteresis. The percentage values of hysteresis are considered representative of the amount of energy dissipated as heat in the load–unload cycles of the tendon during various everyday activities. Furthermore, stiffness can be determined based on any tendon, the medial gastrocnemius being the most explored, due to its importance in human locomotion and its easy accessibility via ultrasound imaging because of its shallowness [4,5].

To evaluate the properties of the medial gastrocnemius tendon movement, ultrasound imaging has been widely used, specifically by detecting the displacement of the muscle-tendon junction (MTJ) during the isometric contraction of the plantar flexors. The area between the load and unload curve generated between the MTJ displacement and specific isometric force of the muscle to be evaluated, was used to estimate the percentage of live tendon hysteresis; some works showed hysteresis values of the Achilles tendon in healthy subjects of 17% $\pm$ 12% and 18% $\pm$ 3% [6,7].

The purpose of this letter is to show the hysteresis of the Achilles tendon during isometric contraction in a haemophilic subject with ankle arthropathy compared to that observed in a healthy subject and a description of the measurement protocol used.

Upon approval by the Ethics Committee of the *Servicio de Salud Metropolitano Norte de Santiago de Chile* (Chilean Health Service), a haemophilic patient (HP) with a history of HA in his left ankle was recruited. The patient was asked to perform three maximal isometric contractions of the ankle plantar flexors, so as to reach the highest peak in 1 s, holding the position for 1 s and then relax after 1 s. This model of performance was chosen because it was the

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most comfortable for the HP. The patient performed the manoeuvre 1 week before the evaluation during 20 min. The aim was to explain the task and perform 20 submaximal executions to reproduce the loading and unloading curve of homogeneous form between tests. At the time of measurement, the patient had no pain in the ankle. Prior to the final evaluation, a test run of 10 submaximal contractions was performed by visual feedback to stabilize the tendon and practice the manoeuvre.

To calculate the hysteresis, MTJ displacement and maximum torque exerted during the isometric contraction were measured. To do this, an ultrasound scanner with a linear transducer of 5–10 MHz (SonoSite Titan; Sonosite Inc., Bothell, WA, USA) was used, synchronized with a 1000-Hz load cell, with a resolution of 0.25 N. The patient sat with his hip at 80° flexion, full extension of the knee and the ankle in a neutral position. The ultrasound transducer was placed on the back of the medial calf in the longitudinal axis at the level of the distal MTJ. The patient repeated the test three times, pausing for 2 min between each repetition to prevent fatigue. The results of the three tests were averaged. To estimate the medial tendon force (Ft), the formula of previous studies was used, that is, $T \times d^{-1}$ [4], where $T$ is the plantar torque exercised and $d$ is the moment arm length of the medial gastrocnemius at 0° of dorsiflexion [8].

Stiffness calculation was determined by dividing the MTJ displacement at 100% of the maximum voluntary contraction (MVC) by the maximum specific force exerted by the medial gastrocnemius [4]. To determine the Ft curve and MTJ displacement, data were collected every 5% of the MVC [4]. Hysteresis of the Achilles tendon was calculated by subtracting the area under the load curve (A1) and area under the unloading curve (A2), divided by the area under the load curve * 100 [4].

For each performance by the patient, execution speed was determined by the % of MVC per second, to standardize the loading and unloading period in each of the tests.

The subject studied is an 18-year-old male with haemophilia A, receiving biweekly prophylactic treatment, 68 kg in weight and 1.71 m tall. Arthropathy of his left ankle according to the radiological Pettersson score is 7 points of 13. The clinical assessment Gilbert score is 7 of 13 (range of joint motion of 0° dorsiflexion and 20° plantar flexion. Moderate pain 2/3). At the time of measurement, he was performing physical rehabilitation twice weekly. The control subject is a 21-year-old male with no history of musculoskeletal disorders, 1.65 m in height and 70 kg in weight.

Table 1 shows the results. Stiffness and hysteresis values are higher in the HP respect healthy subject. The values for the healthy subject are as those observed in the literature [6,7]. However, it is important to consider that there are methodological variables that can lead to errors in hysteresis estimation, such as synchronizing the torque measurement and ultrasound recording [9]. Other variables that could influence the variability in the outcome of such hysteresis are fluctuations during unloading phase [9]. In addition, the results of the hysteresis and stiffness tendon could be influenced by other factors, like the determination of the length of the moment arm of the Achilles tendon during isometric contraction, because it affects the calculation of the tendon force.

**Table 1.** Comparison of the viscoelastic properties of the Achilles tendon.

| | Control | Patient with HA |
|---|---|---|
| Stiffness (N mm$^{-1}$) | 149.7 [146.1–152.6] | 241.4 [203.4–276.0] |
| Hysteresis (%) | 19.8 [13.8–24.7] | 39.1 [35.2–43.1] |
| MTJ displacement (mm | 11.4 [10.8–12.3] | 7.5 [5.6–9.9] |
| Velocity loading (% MVC*seg) | 95.6 [89.6–98.8] | 73.7 [77.6–97.9] |
| Velocity unloading (% MVC*seg) | 65.8 [59.2–72.6] | 68.5 [64.1–76.5] |

HA, haemophilic arthropathy; MTJ, muscle-tendon junction. MVC,Maximum voluntary contraction
Values are expressed as mean and [minimum–maximum] of three tests.

In the case of patients with ankle HA, assuming the geometry of the articular surface is irregular, in our opinion, there is no methodology to estimate the length of the moment arm of the Achilles tendon. So that, we based on standard value from Hashizume *et al.* [8].

In relation to synchronizing the torque measurement and ultrasound recording, in this case a similar sampling rate to that used in Wang's analysis, 2012 was used [4]. Hysteresis values observed in patients with Achilles tendinopathy are 28% and those observed in our case report are 39%.

Moreover, the high values related to stiffness found in our patient with ankle HA, differ from those observed in patients with Achilles tendinopathy (132 N mm$^{-1}$) [4]. This increased stiffness is related to clinical record in patients with ankle HA, that is, decreased mobility, contractures of the muscles and tendons [3]. Finally, hysteresis and stiffness results obtained in this case report (Fig. 1) are higher than those reported in the literature [6,7], both in healthy subjects and in subjects with Achilles tendinopathy [4]. Regarding the high hysteresis and stiffness values found in HP, this relationship is controversial, for example, there has been an inverse relationship between the hysteresis and stiffness [1,6], this means that low percentage of hysteresis are related to high values of stiffness, however, this relationship was not observed in other studies [10].

In conclusion, the determination of the viscoelastic properties of the Achilles tendon in patients with HA could help supplement the physical assessment and establish treatment guidelines aimed at improving the

 

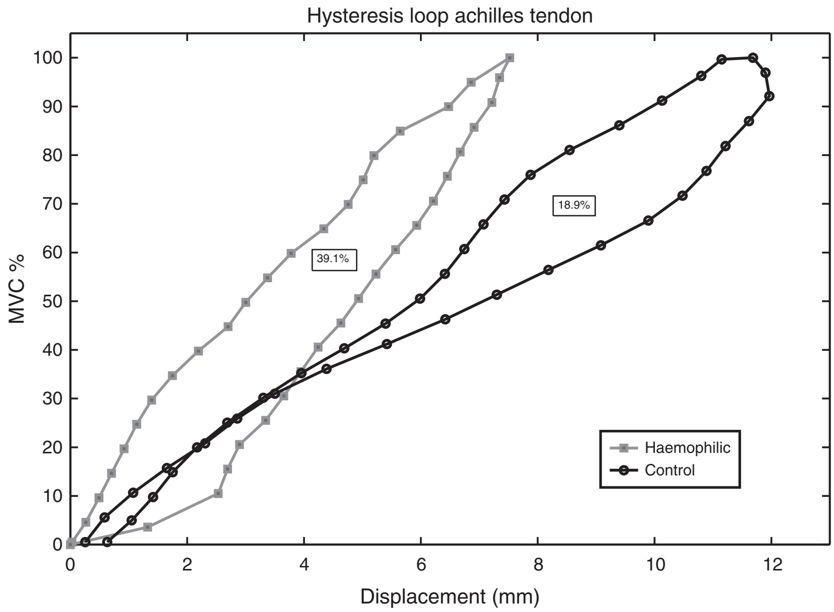


**Fig. 1.** Hysteresis curve in the control subject and in the patient with ankle haemophilic arthropathy.

viscoelastic properties of the tendon and, consequently, improving joint functionality. Assuming that changes in the initial stages of the ankle HA, the viscoelastic properties of Achilles tendon should differ from the advanced stages of the ankle HA. Therefore, the objectives and results of physiotherapy in the Achilles tendon must be redefined in terms of the stage of the ankle HA.

Future studies are required to establish more consistent and reliable methodology for patients with ankle HA, as well as the determination of the relationship between different degrees of arthropathy and changes in the viscoelastic properties of the tendon in these patients.

## Disclosures

The authors stated that they had no interests which might be perceived as posing a conflict or bias.

## References


1 Pasta G, Forsyth A, Merchan CR *et al.* Orthopaedic management of haemophilia arthropathy of the ankle. *Haemophilia* 2008; **14**: 170–6.

2 Kurz E, Anders C, Herbsleb M, Puta C, Czepa D, Hilberg T. Ankle muscle activation in people with haemophilia. *Haemophilia* 2012; **18**: 948–54.

3 Ribbans WJ, Rees JL. Management of equinus contractures of the ankle in haemophilia. *Haemophilia* 1999; **5**: 46–52.

4 Wang HK, Lin KH, Su SC, Shih TT, Huang YC. Effects of tendon viscoelasticity in Achilles tendinosis on explosive performance and clinical severity in athletes. *Scand J Med Sci Sports* 2012; **22**: 147–55.

5 Muraoka T, Muramatsu T, Fukunaga T, Kanehisa H. Elastic properties of human Achilles tendon are correlated to muscle strength. *J Appl Physiol* 2005; **99**: 665–9.

6 Farris DJ, Trewartha G, McGuigan MP. Could intra-tendinous hyperthermia during running explain chronic injury of the human Achilles tendon? *J Biomech* 2011; **44**: 822–6.

7 Maganaris CN, Paul JP. Tensile properties of the in vivo human gastrocnemius tendon. *J Biomech* 2002; **35**: 1639–46.

8 Hashizume S, Iwanuma S, Akagi R, Kanehisa H, Kawakami Y, Yanai T. In vivo determination of the Achilles tendon moment arm in three-dimensions. *J Biomech* 2012; **45**: 409–13.

9 Finni T, Peltonen J, Stenroth L, Cronin NJ. Viewpoint: on the hysteresis in the human Achilles tendon. *J Appl Physiol* 1985; **2013**: 515–7.

10 Fouré A, Cornu C, Nordez A. Is tendon stiffness correlated to the dissipation coefficient? *Physiol Meas* 2012; **33**: N1–9.