Assessment of tensile mechanical properties of the Achilles tendon in adult patients with haemophilic arthropathy.

Cruz-Montecinos, Carlos; Pérez-Alenda, Sofía; Contreras-Sepúlveda, Felipe; Querol, Felipe; Cerda, Mauricio; Maas, Huub

published in
Haemophilia
2019

DOI (link to publisher)
10.1111/hae.13622

document version
Publisher's PDF, also known as Version of record

Received: 23 May 2018 | Revised: 24 June 2018 | Accepted: 24 September 2018

DOI: 10.1111/hae.13622

WILEY Haemophilia

Assessment of tensile mechanical properties of the Achilles tendon in adult patients with haemophilic arthropathy. Reproducibility study

Dear Editor,

Arthropathy in the knee and/or the ankle is a common clinical presentation in people with haemophilia (PWH). Repetitive intraarticular bleeding causes the disruption of the joint cartilage and the inflammation of the synovium.[1] The cartilage damage and chronic inflammation of the synovium result in degenerative joint damage similar to that found in rheumatoid arthritis.[1]

Ankle arthropathy in PWH is commonly present in both the tibiotalar and subtalar joints, and affects the range of joint motion, proprioception and maximal ankle torque.[2,3] Based on the low-amplitude sinusoidal displacements of the ankle, Lobet et al[4] reported the passive musculoarticular ankle stiffness in PWH, assessing the mechanical properties of the tissues surrounding the ankle joint (ie gastrocnemius-soleus muscle-Achilles tendon unit, capsule, ligaments). A significantly higher stiffness in the affected ankles with severe unilateral joint involvement than that in the unaffected ankles was found, but not compared with non-haemophilic subjects.[4] One source of such increased joint stiffness is changes in the mechanical properties of the tendons crossing the ankle joint, but such assessments have not been performed in PWH.[5]

Muscle-tendon tracking using ultrasound[5,6] is a quite inexpensive and non-invasive technique to estimate the mechanical tendon properties.[7] The Achilles tendon (AT), connecting the Triceps Surae muscles (soleus, medial and lateral gastrocnemius) to the skeleton, is the strongest tendon crossing the ankle joint. The mechanical properties of AT are important for the generation of ankle plantar flexion torque during gait.[8] Moreover, its properties may be affected by loss of mobility and chronic inflammation.[9,10] The assessment of the mechanical properties of the AT could be used to complement the standard radiological and physical evaluation of the ankle in PWH (ie Gilbert score, Hemophilia Joint Health Score, Petterson score, etc). Furthermore, assessment of the tensile properties of AT could be used to revise physical therapy guidelines for improving ankle joint functionality and may contribute to orthopaedic surgery decision making (ie ankle arthrodesis vs total ankle artroplasthy).

For healthy subjects, high within-day reproducibility for stiffness has been reported.[7] For PWH, the reproducibility of such assessments is not directly evident, because their proprioception is affected[2] and the fact that reproducing similar loading and contraction velocities during a voluntary isometric task could be a challenge.

The primary aim of this letter is to determine the within-day reproducibility of measuring the displacement of the myotendinous junction (MTJ) and assessment of the stiffness of the AT in haemophilia patients with ankle arthropathy. A secondary aim is to assess the relationship between tendon properties to maximal torque, control of task execution and the degree of ankle arthropathy.

Upon approval by the Ethics Committee of the *Servicio de Salud Metropolitano Norte de Santiago de Chile* (Chilean Health Service), 10 PWH with a diagnosis of ankle arthropathy and treated with prophylaxis were recruited. Haemophilia patients were excluded if they present inhibitors to factor VIII or factor IX or if they had a history of ankle surgery, knee flexion contracture, equinus foot, intraarticular or muscular bleeding in the lower or upper limbs or an ankle sprain within the last 3 months. The Gilbert ankle score was assessed to determine the degree of ankle arthropathy.

To assess the maximal voluntary torque (MVT), the maximal value of three maximal voluntary isometric contractions of the ankle plantar flexors was measured in a sitting position with the hip at 80°, the knee in extended position (between 180 and 160°; adapted to the movement capacity of each patient), and the ankle fixed at 90° (Figure 1A). The subjects were instructed to maintain full support of the sole of the foot in the platform during the contractions. The ultrasound (US) transducer was placed at the level of MTJ of the medial gastrocnemius (MG) muscle. A US scanner with a linear transducer of 5-10 MHz (Sono-Site Titan; Sonosite Inc, Bothell, WA, USA) and a video recorder at 30 frames per second were used. The US system was synchronised with a load cell (sample rate 1000 Hz, resolution 0.25 N; ArtOficio, EMG VIII, Santiago, Chile).

In order to determine the mechanical properties of the AT, each patient repeated the isometric task five times in a ramp of 5 seconds (load phase) and a hold phase of 1 seconds at 80% MVT,[6] including rest periods of 2 minutes between each repetition to prevent fatigue. During familiarisation with the manoeuvre (10 submaximal isometric contractions) and the isometric execution, visual feedback was given on the ankle torque.

The displacement of the MTJ was assessed through automatic tracking based on an optical flow pyramidal algorithm.[6,7] The isometric ankle torque was calculated using the exerted force and the linear distance between the lines through the point of force application to the centre of rotation (defined as the axis trough the inferior tip of medial and lateral malleoli).[8] The AT moment arm at 0° ankle angle was measured as the perpendicular distance from the centre of rotation to the AT line of action.[8] The force exerted at the AT (FT) was calculated using ankle torque and the moment arm length. The

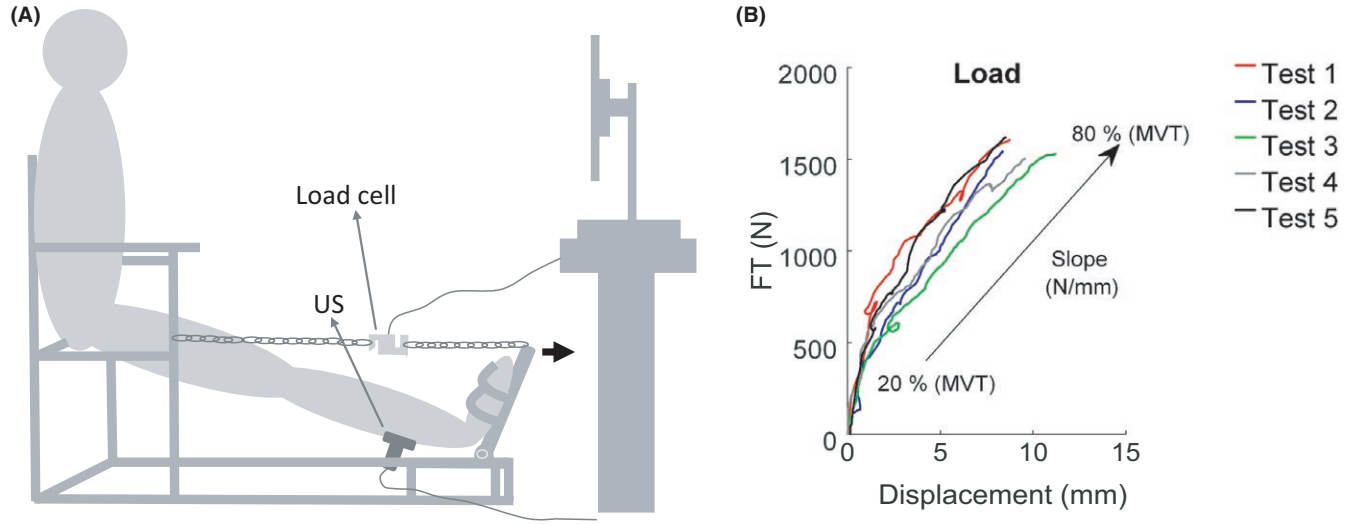

FIGURE 1 A, Schematic representation of the experimental setup. The grey arrow represents the direction of force application during voluntary isometric contraction. B, Example (one subject) of five repetitions of the stiffness calculation by slope between displacement and force tendon (FT) during load phase from 20% to 80% of the maximal voluntary torque (MVT) of the five repetitions

TABLE 1 The reproducibility of the tensile assessment of the Achilles tendon

Tensile variable	ICC	SEM	MDC	SEM %	MDC %
Displacement (mm)	0.77 (0.56-0.93)	0.12	0.32	1.82	5.05
Stiffness (N/mm)	0.81 (0.62-0.94)	4.15	11.51	2.04	5.67

ICC, intraclass correlation coefficient; MDC %, minimal detectable change in percentage; MDC, minimal detectable change; SEM,standard error measurement in percentage; SEM, standard error measurement.

FT signal was down sampled to 30 Hz for later assessment of the stiffness of the AT by the slope of the MTJ displacement-FT curve between 20% and 80% of the MVT (Figure 1B).[6]

Ten ankles were measured in 10 patients with severe haemophilia A. Two patients had a history of primary knee arthroplasty on the same side. The average age of the participants was 33 ± 9 years of age; the body mass index was 24.2 ± 3; and the mean value of the Gilbert score for the ankle was 3 (min:1 max 7). The MVT was 67.9 Nm (CI 95%: 48.6-87.2) and the mean of the torque during the tests was 55.9 Nm (82.3% of MVT). Thus, the error of the subjects to reproduce an 80% of the MVT was 2.3%.

Displacement of the MTJ was 6.4 mm (CI 95%: 4.9-7.9 mm) and the stiffness was 203.1 N/mm (CI 95%: 117.3-289.0 N/mm). The reproducibility of assessing the MTJ displacement and the AT stiffness was high (Table 1). We found a positive correlation between the MVT and tendon stiffness (r = 0.58, P = 0.039), indicating that PWH with more MVT capacity have a higher stiffness of the AT. A negative relationship between tendon stiffness and ankle arthropathy severity was found (r = 0.62, P = 0.028), indicating that the stiffness of the AT was lower in patients with more severe arthropathy.

The principal finding of this study is that assessment of AT stiffness and displacement of the MTJ can be performed with high repeatability in PWH. In addition, this study provides the first data on the relationship between ankle arthropathy severity and AT stiffness. Reduced tendon stiffness in the more severe patients may be explained by the reduced intensity and/or volume of physical activity (ie walking).[10] Other variables such as inflammatory factors due to repetitive intraarticular bleeding and chronic synovitis near the AT may also contribute.[9]

Regarding the tendon stiffness and maximal torque capacity, a positive relationship between the MVT and tendon stiffness was found similarly to healthy young subjects (r = 0.54).[6] The AT stiffness observed in this study was similar to that found in young healthy males (mean 24 years) assessed using a similar methodology (187 N/mm).[6] However, in two patients we found a lower value of AT stiffness (71-73 N/mm) than in older men (mean 141 N/mm).[6] This suggests that the variation in PWH is higher than in the non-haemophilic group.

In older adults (age 70-81 years), stiffness of AT was found to be correlated (r = 0.52) with walking capacity.[8] During walking, the AT is strained during the first half of the stance phase.[8] The energy stored by AT is returned later in the stance phase to contribute to push off action of ankle. Changes in the tendon mechanical properties will affect efficiency of such tendon stretch-shortening and, hence walking capacity. This indicates the functional relevance of assessing mechanical properties of AT.

The present study focussed on one important tendon crossing the ankle joint, but also the properties of other tendons (eg those of the peroneus longus, tibialis anterior and flexor hallucis longus muscles) may be different in PWH. To obtain a full understanding of

the origin of increased ankle joint stiffness in PWH,[4] also the properties of other tendons should be investigated. In addition, we assumed that the previous methodology applied to healthy individuals could be used to assess ankle centre of rotation. However, considering that the geometry of the articular surface could be irregular in PWH, a more specific methodology needs to be implemented in future studies.

In sum, we conclude that the assessment of the AT stiffness in PWH is reproducible. The AT stiffness was negatively associated with ankle arthropathy severity. Future studies are needed to investigate the effects of a reduced stiffness of the AT and other tendons on gait characteristics in PWH with ankle arthropathy.

ACKNOWLEDGEMENTS

The authors thank the Chilean Society of Haemophilia for facilitating the recruitment of haemophilia patients. M.C. acknowledges support to projects FONDECYT 11161033, ACT1402, P09-015-F.

DISCLOSURES

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

AUTHORS' CONTRIBUTIONS

CCM performed the research, designed the research study, analysed the data and wrote the paper. SPA designed the research study, analysed the data and wrote the paper. FC performed the research and wrote the paper.FQ, MC and HM analysed the data and wrote the paper.

ORCID

Carlos Cruz-Montecinos http://orcid.org/0000-0002-3835-3368
Sofía Pérez-Alenda https://orcid.org/0000-0002-0841-5767
Mauricio Cerda https://orcid.org/0000-0003-3447-1815
Huub Maas https://orcid.org/0000-0002-2304-2735

Carlos Cruz-Montecinos[1,2,3]
Sofía Pérez-Alenda[3]
Felipe Contreras-Sepúlveda[4]
Felipe Querol[3]
Mauricio Cerda[5,6]
Huub Maas[7]

[1]*Department of Physical Therapy, Laboratory of Clinical Biomechanics, Faculty of Medicine, University of Chile, Santiago, Chile*
[2]*Laboratory of Biomechanics, Hospital San José, Santiago, Chile*
[3]*Department of Physiotherapy, University of Valencia, Valencia, Spain*
[4]*Chilean Society of Hemophilia, Santiago, Chile*
[5]*Anatomy and Developmental Biology Program, Institute of Biomedical Sciences, Faculty of Medicine, University of Chile, Santiago, Chile*
[6]*Biomedical Neuroscience Institute, Faculty of Medicine, University of Chile, Santiago, Chile*
[7]*Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, The Netherlands*

Correspondence
Carlos Cruz-Montecinos, Department of Physical Therapy, Laboratory of Clinical Biomechanics, Faculty of Medicine, University of Chile, Santiago, Chile.
Email: carloscruz@uchile.cl

REFERENCES

1. Van Vulpen L, Mastbergen SC, Lafeber F, Schutgens R. Differential effects of bleeds on the development of arthropathy - basic and applied issues. *Haemophilia*. 2017;23:521-527.
2. Hilberg T, Herbsleb M, Gabriel H, Jeschke D, Schramm W. Proprioception and isometric muscular strength in haemophilic subjects. *Haemophilia*. 2001;7:582-588.
3. Lobet S, McCarthy A, Hermans C, et al. Biomechanical markers and theoretical concepts related to haemophilic ankle and subtalar joint arthropathy: introducing the term 'haemophilic tarsal pan-arthropathy'. *Haemophilia*. 2017;23:e250–e258.
4. Lobet S, Cartiaux O, Peerlinck K, et al. Assessment of passive musculoarticular ankle stiffness in children, adolescents and young adults with haemophilic ankle arthropathy. *Haemophilia*. 2018;24(3):e103–e112.
5. Cruz-Montecinos C, Pérez-Alenda S, Oyarzún-Tejeda A, Cerda M, Querol-Fuentes F. Estimation of tensile properties of the Achilles tendon in haemophilic arthropathy of the ankle: case study. *Haemophilia*. 2015;21:e141–e143.
6. Stenroth L, Peltonen J, Cronin NJ, Sipila S, Finni T. Age-related differences in Achilles tendon properties and triceps surae muscle architecture in vivo. *J Appl Physiol*. 1985;2012(113):1537-1544.
7. Kongsgaard M, Nielsen CH, Hegnsvad S, Aagaard P, Magnusson SP. Mechanical properties of the human Achilles tendon, in vivo. *Clin Biomech (Bristol, Avon)*. 2011;26:772-777.
8. Lichtwark GA, Wilson AM. Interactions between the human gastrocnemius muscle and the Achilles tendon during incline, level and decline locomotion. *J Exp Biol*. 2006;209:4379-4388.
9. Matschke V, Jones JG, Lemmey AB, Maddison PJ, Thom JM. Patellar tendon properties and lower limb function in rheumatoid arthritis and ankylosing spondylitis versus healthy controls: a cross-sectional study. *The Scientific World Journal*. 2013;2013:1-8.
10. Stenroth L, Sillanpaa E, McPhee JS, et al. Plantarflexor muscle-tendon properties are associated with mobility in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2015;70:996-1002.