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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 al⁴ 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 arthroplasty).

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 affected² 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 through 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

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

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

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.

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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.

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