MECHANICAL HYSTERESIS TESTS FOR PORCINE TENDONS

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Introduction

Mechanical hysteresis of tendons describes the energy dissipated due to material viscoelastic properties. The measurement of the tendons ability to store and efficiently return energy during locomotion, allows to assess tendons thermal damage and the amount of metabolic energy that can be saved during locomotion, what is important for biomechanics of sport or rehabilitation [1-3]. The porcine tendon model is commonly used for the biomechanical investigation of various reconstruction techniques of tendon grafts [4].
The study was conducted to determine hysteresis of porcine tendons under ten cycles of loading.

Materials and Methods

Fifteen tendons taken from the lower limbs from fully mature domestic pigs, weighting approximately 100 [kg] were used in this investigation. Tendons were frozen at -18 ± 2 [°C] until tensile testing, and then thawed in the room temperature one hour prior the experiment. The average diameter was 6,4 ± 0,9 [mm]. Repeated ten loading-unloading cycles were made for three levels of load: 50 [N], 100 [N] and 150 [N]. The test was made with the use of MTS Insight 50 testing machine at a constant rate of strain 5 [mm/min]. Initial sample length was 50 [mm]. Three hysteresis loops for each level of load were registered (1st, 5th, 10th) and used for calculation value of dissipated energy (the area of loop), total work performed on the tendon during stretching and mechanical hysteresis (dissipated energy/total energy) in each loading cycle. Two samples for each load level were used. The calculated values of energies were shown as the average values with a standard deviation (X ± SD).

Results and Discussion

In FIG. 1, hysteresis loops for porcine tendons for three levels of load were shown. For all load levels, the hysteresis is significant over the first loading cycle, but decays quickly after this cycle and between fifth and tenth cycle become nearly steady what correspond to the preconditioned sate of the tendon.
The value of dissipated energy was the highest in the first cycle of loading-unloading (TABLE 1). The value of dissipated energy in fifth cycle was lower by 72, 74 and 77% for the load level 50, 100 and 150 [N] respectively.

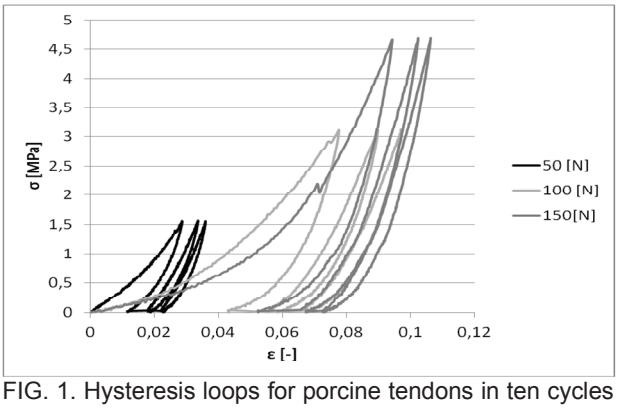

FIG. 1. Hysteresis loops for porcine tendons in ten cycles of loading-unloading.

TABLE 1. Comparision of specific energies calculated for porcine tendons.

Level of load [N]	Energy stored (dissipated) [mJ]	Energy returned [mJ]	Mechanical hysteresis [%]
50	17,40 ± 3,17	14,12 ± 2,80	55,2 ± 1,3
	4,86 ± 0,44	11,70 ± 0,06	29,3 ± 0,2
	3,92 ± 0,33	11,88 ± 0,72	24,8 ± 2,2
100	86,27 ± 2,99	49,93 ± 1,99	63,3 ± 1,5
	22,36 ± 0,54	46,24 ± 1,34	32,6 ± 0,4
	17,08 ± 0,63	44,24 ± 0,89	27,8 ± 0,7
150	117,57 ±3,67	83,52 ± 2,24	58,5 ± 1,6
	26,64 ± 0,80	77,30 ± 1,80	25,6 ± 0,4
	21,18 ± 0,63	75,19 ± 0,97	22,0 ± 0,6

The values of mechanical hysteresis were between 22 and 32% in fifth and tenth cycle (TABLE 1), where stabilization of the dissipated energy was observed. This is in good agreement with hysteresis values given by Maganaris et al. [2] for isolated human tendons in the range between 3 and 38% in tensile testing *in vitro* and between 5-25% in testes *in vivo*. Finni et al. [1] based on literature review, reported that the hysteresis value was between 5-19% for selected animals tendons and between 5-40% for human tendons tested *in vivo*.
A permanent strain set existed immediately after the first loading cycle. The residual strain after first cycle of test was 0,027/0,077/0,094 for the load levels 50, 100 and 150 [N] respectively (FIG. 2). After tenth cycle it was 0,035/0,097/0,106 for the load levels 50, 100 and 150 [N] respectively. The increase in the value of residual strain results from the viscoelastic nature of tendon.

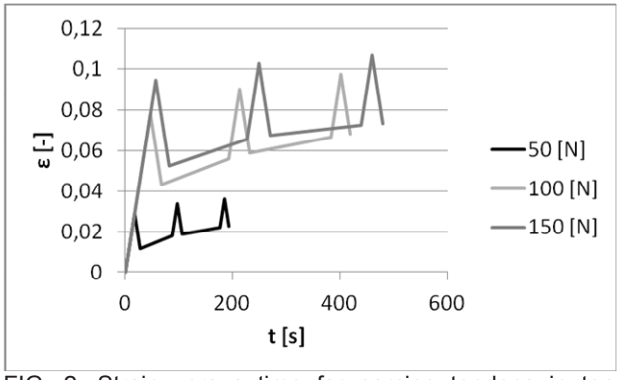

FIG. 2. Strain versus time for porcine tendons in ten cycles of loading-unloading.

Conclusions

The investigation showed that hysteresis of porcine tendon is in the range of hysteresis values reported in the literature [1,2]. The differences in reported hysteresis values are quite large due to many factors. The most significant factors are inter study methodological differences (tendon gripping, cross-sectional area), anatomical site and ageing [2].

References

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