Measurement of Rheologic Properties of Soft Tissue (Muscle Tissue) by Myotonometer

Petr Šifta, Václav Bittner, Martin Kysela, Matěj Kolář

Abstract**—**The purpose of the research described in this work is to answer how to measure the rheologic (viscoelastic) properties tendo–deformational characteristics of soft tissue. The method would also resemble muscle palpation examination as it is known in clinical practice. For this purpose, an instrument with the working name "myotonometer" has been used.

At present, there is lack of objective methods for assessing the muscle tone by viscous and elastic properties of soft tissue. That is why we decided to focus on creating or finding quantitative and qualitative methodology capable to specify muscle tone.

Keywords**—**Rheologicproperties, tendo–deformational characteristics, viscosity, elasticity, hypertonus, spasticity.

I. Introduction

OUR purpose is to assess the rheologic properties of soft tissue by using a method similar to palpation examination [1], [2] to obtain data to evaluate the degree of spastic syndrome and the muscle tone in general. At present only Ashworth scale is used to predict the muscle tone and this scale is inadequate. There is a great need to come up with a new methodology which would be able to assess the muscle tone. The resulting hysteresis curves coming from myotononometer should determine rheologic properties of soft tissue (muscle tissue). According to predetermined rheologic properties we classify the muscle tone. There are two fundamental questions based on these findings:

1. Is it possible to assess the spasticity by using the mechanical properties of soft tissue, viscosity and elasticity?
2. What are the rheological properties of healthy and spastic muscle tissue?

II. Hypothesis

In striving to achieve the aims of this thesis, the hypothesis, tendo-deformational characteristics of spastic muscles can be measured and detected by using an instrument called the "myotonometer", is assumed. Based on such measured values, the qualitative and quantitative degree of spasticity of afflicted muscle can be assessed.

Petr Šiftais with the Faculty of education, Technical University of Liberec; Faculty of physical education and sport, Charles University in Prague, the Czech Republic (e-mail:petrsifta@seznam.cz).

Václav Bittner, Martin Kysela, andMatějKolářare with the Faculty of education, Technical University of Liberec, the Czech Republic.

III. Methodology

A. Examined Group

Twenty-three patients from ages 8 till 57 were examined, 13 men (average age 35), 10 women (average age 42). Nine patients suffered from stroke, five from traumatic lesion of the brain, four from multiple sclerosis, and five from cerebral palsy. This group of patients was selected to represent all neurological diagnosis representing spasticity.

B. Methodology

Criteria for selecting patients are given. It is diagnosis = spasticity, mobility = able to walk, clonus = quick dorsiflection in the ankle joint creates repetitive reflexive answers in the triceps surae muscle. The picked up patients undergo a palpation exam to find the area with the greatest muscle resistance and underwent an examination using the myotonometer device in the affected and healthy lower limb for comparison. The results were compared with the same patient. Results between patients were not compared since each patient had a different diagnosis, thus different muscle stiffness. The register point of the myotonometer was inserted into the muscle group in the muscle of greatest resistance as determined from palpation of the muscle. The result of this examination is a hysteresis curve which represents the relationship of applied force (N) on deformation of the muscle group (mm).

Our work focused on measurement of the triceps surae muscle, and its two heads – soleus and the medial head of gastrocnemius muscle, representing postural muscles. It is easy to find, it lies on the surface. Each time we compared the affected part and non-affected part of the body. The examined patient lies on the belly and his/her lower extremity is relaxed while the tensometric sensor of myotonometer is inserted into the soft tissue of the calf. The whole examination takes 10 seconds. The whole process has two stages, the insertion of the myotonometer into the soft tissue, taking five seconds and, withdrawal of the myotonometer, taking another five seconds. After long time experimentation, we decided upon a constant speed of 2,5 mm/s of insertion and withdrawal. In our previous experiments we worked with other speed velocities; if the speed is lesser than 2,5 mm it does not represent resemblance of palpation examination of muscle tissue; if the speed is higher than 2,5 mm/s it creates hyperreflexologic answers in terms of inadequate spasticity. If the speed is higher, the muscle tissue is stiffer and the patient suffers from pain. If the speed is lower, the whole process takes longer and is not adequate for palpation examination.

After examining the patient, a certain amount of botulinum A toxin is injected [3]-[5], into soleus muscle and the centre of the gastrocnemius muscle - medial head. Patients were examined again after 14 days using the same procedure. The results of examination of the affected part before and after injecting botulinum A toxin are then compared to one another, and similarly, the healthy part with the affected part before and after injecting botulinum A toxin.

The amount of botulinum A toxin is 3,5 unit per kilogram of weight of patient. In our case we use Dysport®.

C. MyotonometerDevice

This biomechanical device has been constructed to evaluate the viscoelastic properties of soft tissue. The heart of the device is a tensometric sensor connected to a computer through an A/D amplifier. The instrument also features a motor, and a ball and socket joint to adjust the tensometric sensor on the calf of the patient. The myotonometer is inserted using constant velocity into the examined soft tissue to determine the resistance of tissue. We predict that each type of soft tissue (fat, fibrous, muscle) has specific resistance to the constant force being applied.

D. Interpretation of Hysteresis Curve: Tendo–Deformational Characteristics

Outputs of measurement are the values of the tensometer and position of the sensor, which are recorded in relation to time in a simple collection. To process and evaluate the date a simple program was developed by using the Matlab program. All collected values are represented as a hysteresis curve (Fig. 1), having two parts.

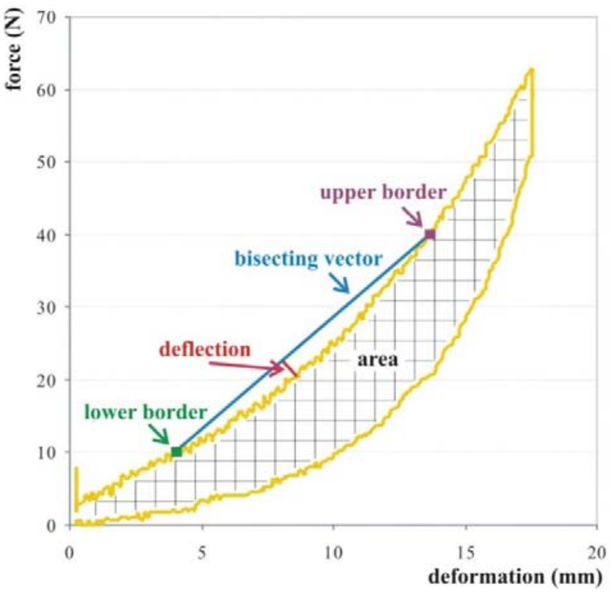

Fig. 1 Properties of hysteresis curve

The very first part is the exponential ascending curve representing the first five seconds of the experiment, the myotonometer being inserted into the soft tissue. Second part of the hysteresis curve is the descending exponential curve representing the second five seconds of experiment. We set the lower limit of our experiment at 10N to the **lower limit** to eliminate cutaneus, subcutaneous, connective tissue, fat tissue. We set the higher limit of our experiment at 40N to protect the patient. These limitations are connected by a bisecting vector which expresses the slope of the examined phenomenon. In locations where the bisecting vector is furthest away from the increasing part of the hysteresis curve, a perpendicular line is drawn. The length of the perpendicular is directly proportional to the size of deflection of the hysteresis curve and represents elasticity of muscle stiffness [6]-[8]. When we examined and studied the data of our patients and the results from myotonometerexamination we found two parameters that determine tendo – deformational characteristics: first, the **bisecting** vector – the steeper this parameter,the stiffer the muscle. The second **deflection** of the ascending curve – the more the ascending curve is deflected, the less the affected muscle is spastic [9], [10]. Aside from these two parameters, the degree of dissipation of energy can be determined from the hysteresis loop by calculating the **area** encompassed by the loop [11]. As a result, the larger the area is the more energy dissipates, and the less the muscle is plastic [6], [9].

IV. Results

We can deduce the following general conclusions from observing the two stated parameters. **deflection** of the hysteresis tangent (bisector) and its **increase**. The expected difference in increase of the hysteresis curve of healthy and spastic muscle before and after application of botulinum A toxin shows equalization of this parameter in all patients in case of m. soleus and in 16 patients of 23 in the case of medial head of gastrocnemic muscle. (An example of the results of one patient is shown in graph number 3 below). All the results from measurement, deflection and increase, are registered and statistical analysis from all 23 patients is done.

- If we compare the deflection parameter of healthy and spastic muscle groups (always in the same patients) before application, then all measurements showed different values of this parameter. The amount of muscle stiffness of spastic muscle and non-spastic muscle differs. After application of botulinum A toxin, deflection parameters changed for the better. Significant increase of deflection in spastic muscle occurred. If we compare the increase of the bisector of healthy and spastic muscle groups (again in the same patients), then all measurements showed equalization of this parameter. Graph number 2 bellow demonstrates the difference between spastic and non-spastic muscles for both analyzed parameters. The difference between these parameters after application of botulinum A toxin decreases. The values in the graph represent the arithmetic mean of the difference between spastic and healthy muscle group, calculated from recorded data from all 23 patients [3], [7].
- Investigation into the rise and deflection of the hystersion loop of spastic muscle before and after application of botulinum A toxin showed that deflection improved in spastic muscle in all measurements and that the rise decreased in the majority of patients as expected [7], [10].

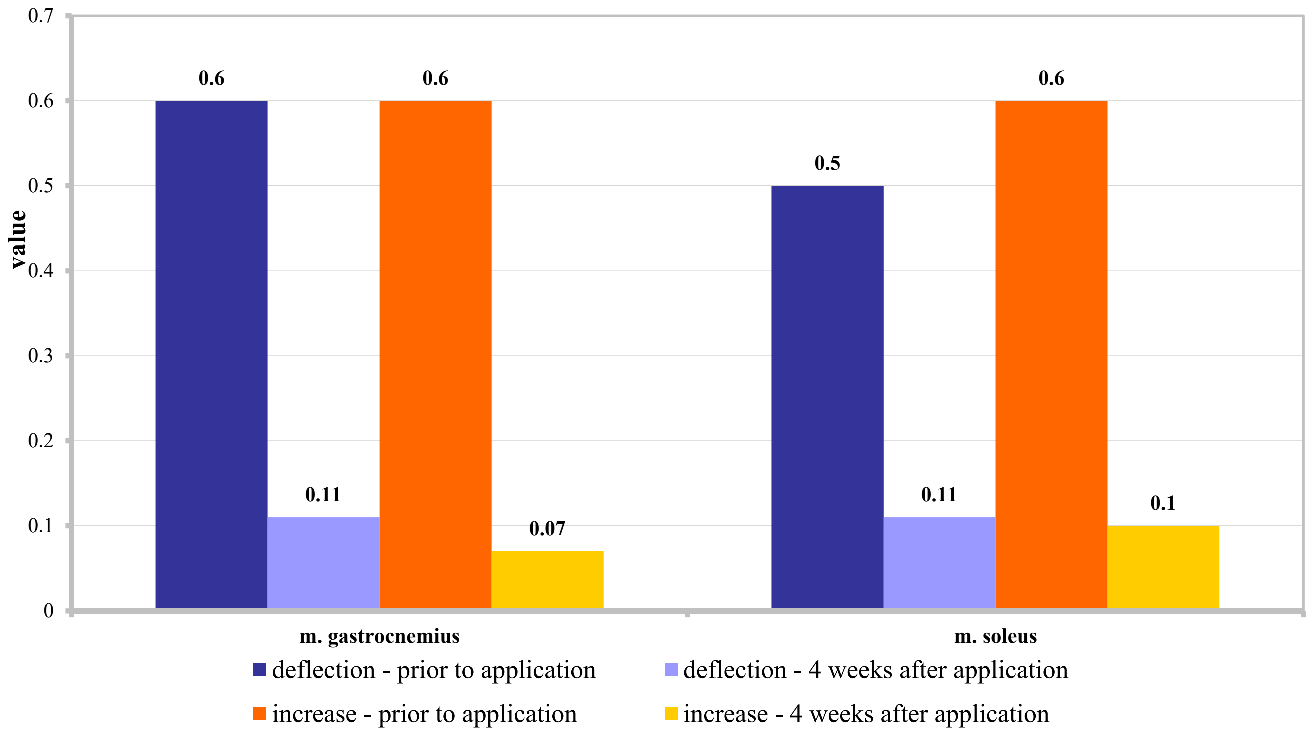

Fig. 2 Change of deflection and increase parameter in spastic and non-spastic muscle groups prior and after therapy
N.B.: the value on the Y axis represents the arithmetic mean of the difference between spastic and healthy muscle groups; value is given in N/mm

V. Conclusion

In conclusion, one can state that the proposed hypothesis regarding the possibility of measuring and detecting tendo – deformational characteristicsof spastic muscle with the aid of a myotonometer and subsequent determination of the spasticity has been confirmed. The results of measurements and their interpretation show that the described instrument is capable of measuring the desired parameters and the interpretation software can evaluate the effect of the application of botulinum A toxin in lowering muscle tension of spastic tissue.

To answer to the first question in the introduction, using the method described is capable of determining the mechanical properties of soft tissue. However, there is still much work to do, in terms of changing the different load zones and its investigation for example.

The last defined problem, describing the rheological properties of healthy and spastic muscle was successfully resolved during the research.

Finally, it is clear that further work has to be done to fulfill our goals stated in our questions.

VI. Summary

We can state that reologic properties of soft tissue (muscle tissue) can be measured by using a myotonometer having been clearly confirmed by results. The evaluated hysteresis curves selected clearly illustrate the change of rheological properties of healthy and spastic muscle fibres before and after pharmacological intervention.

Acknowledgment

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