# Measurement of viscous and elastic properties of soft tissue by myotonometer

**Petr Sifta[1], Vaclav Bittner[2]**

[1] Charles University in Prague, Faculty of Physical Education and Sport, Department of anatomy and Biomechanics, The Czech Republic

[2] Technical University in Liberec, Fakulty of Education, Department of Physical Studies, The Czech Republic

**Questions**

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

**Hypothesis**

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

**Methodology:**

**1) 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.

**2) Methodology:**

If the patient meets the given criteria (diagnosis - spasticity, mobility – able to walk, clonus – quick dorsiflection in the ankle joint creates repetitive reflexive answers in the triceps surae muscle), the patient was given 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 lengthy experimentation, we decided upon a constant speed of 2,5 mm/s (in our experiment 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) of insertion and withdrawal. 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.

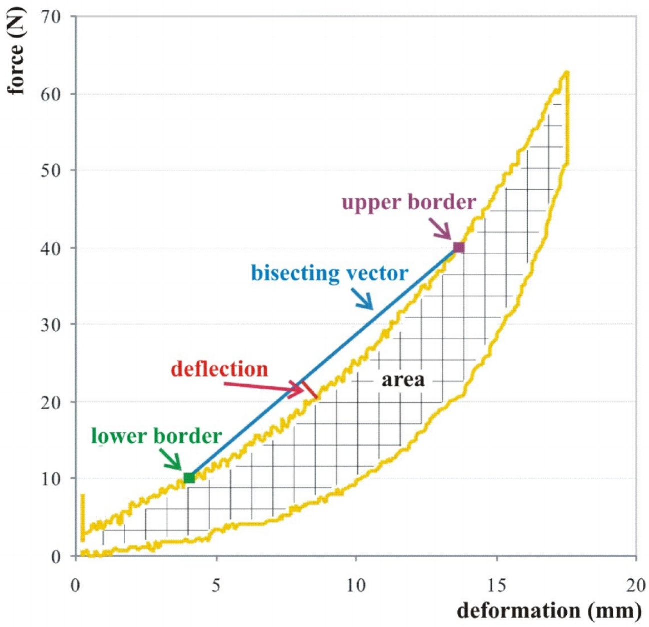
After examining the patient, a certain amount of botulinum A toxin is injected (in Šifta 2004, Dietz, V., Berger, W. 1983, Jörg, W. et al., 2000) into soleus muscle and the centre of the gastrocnemius muscle - medial head. Patients were examined again after 14 days using the same procedure. The

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®.

**3) Myotonometer device:**
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.

**4) 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 (graph number 1), having two parts.

Graph number 1: Properties of hysteresis curve




Source: own drawning

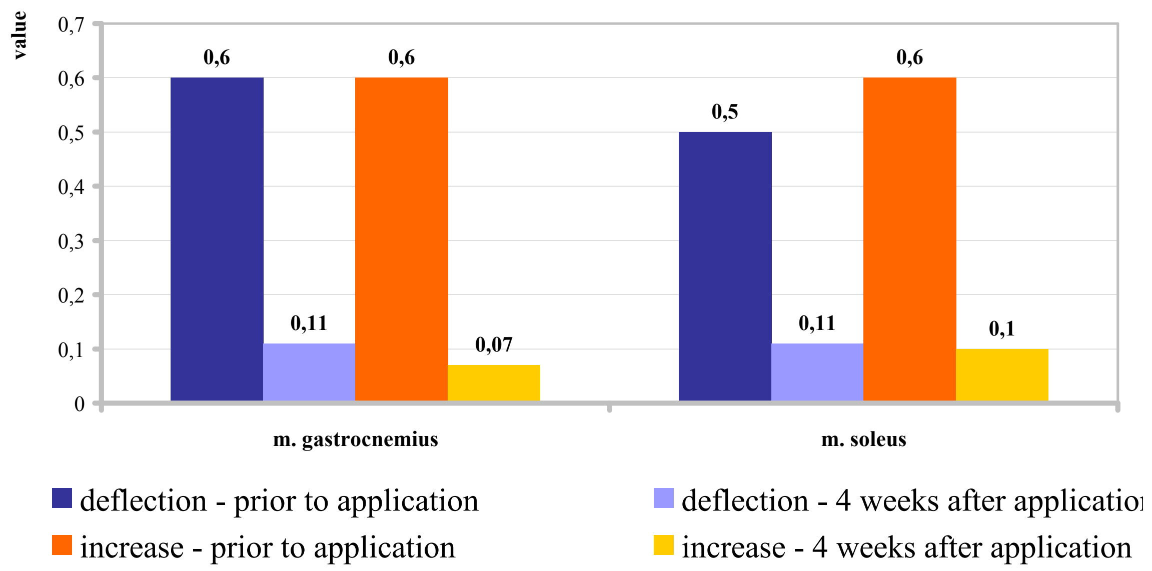
The very first part is the exponential ascending curve representing the first five seconds of the experiment, the myotonometer being inserted into the soft tissue. Second part of the hysteresis curve is the descending exponential curve representing the second five seconds of experiment. We set the lower 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 hystersion curve, a perpendicular line is drawn. The length of the perpendicular is directly proportional to the size of deflection of the hystersion curve and represents elasticity of muscle stiffness (Sobotka 1981, Šifta 2005, Pandayan, A.D., Price, C.I.M. at al, 2001). When we examined and studied the data of our patients and the results from myotonometer examination 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. (Singer, B., Dunne, J., Allison, G. 2002, Šifta, P. 2006). Aside from these two parameters, the degree of dissipation of energy can be determined from the hystersion loop by calculating the **area** encompassed by the loop. (Stupka, M. 2001). As a result, the larger the area is, the more energy dissipates, and the less the muscle is plastic (Sobotka, 1981, Singer, B., Dunne, J., Allison, G., 2002).

**Results**

We can deduce the following general conclusions from observing the two stated parameters. **deflection** of the hystersion tangent (bisector) and its **increase**. The expected difference in increase of the hystersion 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 (Šifta, P., Süssová, J., Zahálka, F., 2004, Šifta, P., Otáhal, S., Süssová, J., 2005).

Graph number 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

- 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 (Šifta, P., Otáhal, S., Süssová, J. 2006, Šifta, P., 2005).

**Conclusion**

In conclusion, one can state that the proposed hypothesis regarding the possibility of measuring and detecting tendo – deformational characteristics of 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.

In 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 reological 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.

**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 hystersion curves selected clearly illustrate the change of reological properties of healthy and spastic muscle fibres before and after pharmacological intervention.

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