MYOMETRICALLY MEASURED MECHANICAL PROPERTIES OF THE M. TRAPEZIUS IN WATER IMMERSION

R. Viir*, A. Vain°

*Ragnar Viir Ky (c/o Kuntoutus - Karppinen Oy), Helsinki/Finland;
Väraska Health Resort, Väraska/Estonia
°Institute of Experimental Physics and Technology, University of Tartu, Tartu/Estonia

Introduction
For thousands of years people have enjoyed being in water, empirically feeling that this would be good for their health. A human body, like every body, is subject to Archimedes’ Law while it is in water. This occurrence can be felt by one at that precise moment when enough water is drained from a full bathtub to allow the full gravitational force to press his/her body to the bottom of the tub, causing the feeling similar to the one felt in the accelerating car. Water immersion (WI) presents the possibility to model the conditions for gravitational physiology as well as for water therapies. Long space flights affect negatively musculoskeletal functioning and structure because the constant influence of gravity is absent. On the other hand, there is uncountable number of patients with different problems with positive experiences of their regular water activities. The study of Gabrielsen et al. (Gabrielsen et al., 2000) indicates that it is beneficial for heart failure patients to be subjected to water immersion, because systemic vascular resistance decreased during WI in the patients to the same level as in normal controls. The basic aspects of muscle functioning are characterised with determination of force/length relationships both of the contractile component and of the series elastic component, and with determination of the contractile component force/velocity characteristics (di Prampero et al., 2000)

Our interest is focused on the mechanical properties and function of the relaxed muscle, as cells, muscle fibres or an organism perceive gravity mechanically.

The aim of the study is to demonstrate quantitatively and directly measured biomechanical properties: stiffness and elasticity (estimated via the logarithmic decrement of damping) of the relaxed m. trapezius’ response to the above-mentioned return of full gravitational force.

Methods
The subjects were 8 adolescent female swimmers (age 8 - 16 years, 152.9±12.5 cm, 43.6±9.6 kg) and 11 adult women (age 61 - 85 years, 158.9±5.5 cm, 67.6±11.6 kg). Two biomechanical properties (stiffness and elasticity) of the skeletal muscles were measured using the myometer (Vain, 1997, 2000).

The essence of the method lies in the following. The pickup of the device with the contact area S and effective weight P is placed on the skin surface above the peripheral muscle under investigation (Fig. 1). In result the tissues above the muscle are in compressed state (Fig. 2, displacement of tissues ΔS).

The electromagnet of the device produces a short (some milliseconds, t_k in Fig. 2) constant force impulse, which is forwarded via the pickup to the contact area. The impulse terminates in quick release at the time moment t_2. The muscle under investigation reacts to such mechanical influence performing damped natural oscillation (Fig. 2). This oscillation is picked up using the acceleration transducer, situated on the testing end of the device. The acceleration value of the first period of the oscillation, calculated from the oscillation graph, characterises the deformation of the muscle, caused by the testing end and is used to calculate the stiffness of the muscle C = m·a_max / Δl [N/m].

From the resulting acceleration waveform the period T of the natural oscillation, performed by the oscillating muscle mass together with the testing end mass, can be calculated. The quantity of mechanical energy of elasticity, dissipated during the first period of the oscillation, is characterised by the logarithmic decrement of
damping $\Theta = \ln(a_3/a_5)$. The muscle oscillation frequency $f = 1/T$ [Hz], where $T$ denotes the oscillation period in seconds.

On each subject the myometric measurement of the m. trapezius upper region on the left and right side of the body was performed 20 times in the supine position in a special ergonomic tub while being and not being immersed in water of thermoneutral temperature (+32°C). The bottom profile of the tub, invented by the author of the present paper, gives maximal relaxation to the entire muscular system and, with its support for the elbows, ensures that the arms remain in the same position.

**Results & Discussion**

For all adult women the muscle oscillation frequency and stiffness in water (10.44±1.18Hz; 149.1±24.8N/m) were statistically significantly lower (p<0.001) than in the same supine position without water (12.06±1.36Hz; 170.6±22.5N/m), the logarithmic decrement of damping increased from 1.328±0.21 to 1.825±0.556 (p<0.05).

In the group of swimmers such change in muscle tone was not observed (stiffness 138.3±11.3 and 136.6±9.4 N/m, frequency 10.86±0.37 and 10.92±0.50 Hz, decrement 0.859±0.174 and 0.823±0.153 correspondingly (p>0.05)). In the group of adults the frequency decrease in water immersion was 13.4%, elasticity decrease was 37.2%, stiffness decrease 12.7%. For adolescent female swimmers the changes were 5.7%, 2.9% and 6.6% correspondingly. When the water was removed, the trends of changes of muscle tone parameters of
adult women were opposite to the changes caused by immersion (10.6%, 21.9% and 8.6% correspondingly). The changes caused by removing the water for swimmers were 3.9%, 1.8% and 1.3% correspondingly. The measured parameter values for the adult women: frequency 10.44±1.18 and 11.55±1.11Hz, decrement 1.825±0.556 and 1.427±0.321, stiffness 149.06±24.8 and 161.9±21.8N/m. For swimmers: frequency 10.64±0.15 and 11.08±0.3Hz, decrement 0.674±0.027 and 0.662±0.03, stiffness 141.8±4.0 and 143.7±3.6N/m (Fig. 3).

![Bar charts showing changes in stiffness, frequency, and decrement for swimmers and adult women.](image)

Fig. 3. Comparative analysis of the changes in stiffness (a), natural oscillation frequency (b) and elasticity (c) of *m. trapezius* of swimmers and adult women in result of water procedures (WI).

The results of our study allow us to conclude that the myometrically measured biomechanical properties of skeletal muscles give us a possibility to modernise our understanding of the functioning of relaxed muscles and of the water therapy as well as all water activities.

References


Acknowledgements
This study has been supported by the Värskä Health Resort (Estonia).