Physiological Measurements & Instrumentation Laboratory (AM5023)
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EXPERIMENT: Tone, stiffness and hardness of the plantar region of the foot

AIM:
To measure the tone, stiffness and hardness of the plantar region of the left and right foot.

OBJECTIVES:
i. Measure the tone and stiffness of the plantar fascia muscles at 8 points on the foot using the MyotonPro hand-held device.
ii. Measure the hardness of the plantar region at 8 points of the foot using a durometer.
iii. Check for the reproducibility of myoton and durometer readings and compute the coefficient of variation.
iv. Analyze the obtained values for the left and right foot.

APPARATUS & SOFTWARE USED:
i. Myoton PRO - Digital Palpation Device
ii. Durometer Shore A - Anderson Materials Evaluation
iii. MATLAB software for further analysis

Figuure 1: Durometer(left); Myotone(right)

THEORY:

MyotonPRO:

MyotonPRO is a hand-held device that is placed on the skin over the muscle. A brief, gentle tap from the probe causes the muscle to oscillate. The oscillations are analyzed automatically by the device to calculate the muscle's mechanical characteristics, such as its tone, stiffness and elasticity. The main potential uses of Myoton technology are to detect early signs of stiffness to aid prevention of muscle injuries in sport, assessment of muscle in diabetes, musculoskeletal and neurological disorders, and monitor effects of treatment.

The Device measures (computes simultaneously) the following five parameters: [1]

F – Oscillation Frequency [Hz]

Characterises the Tone (intrinsic tension on the cellular level) of a muscle in its passive or resting state without any voluntary contraction (EMG signal silent). Overly high muscle tone and subsequently high intramuscular pressure restricts the blood supply, causing muscle fatigue and slow muscle recovery. Oscillation Frequency in the contracted state describes the State of Tension of a muscle.

BIOMECHANICAL PROPERTIES

S – Dynamic Stiffness [N/m]

Stiffness is the biomechanical property of a muscle that characterises the resistance to a contraction or to an external force that deforms its initial shape. In case of abnormally high stiffness, a greater effort is required from the agonist muscle to extend a stiff antagonist, which leads to an inefficient economy of movement. The term Dynamic Stiffness is originated from the dynamic measurement method applied in Myoton technology. The inverse of stiffness is compliance.

D – Logarithmic Decrement of natural oscillation characterises elasticity, but more directly the dissipation of the oscillation, when a tissue recovers the shape after being deformed. Elasticity is the biomechanical property of tissue that characterises the ability to recover its initial shape after being deformed. Elasticity is inversely proportional to the decrement. Therefore, if the decrement of a tissue decreases, then the tissue elasticity increases. In theory, a decrement of 0 (zero) represents absolute elasticity (i.e. there is no dampening of a tissue's oscillation: In case of absolute elasticity $a1 = a3$.) The inverse of elasticity is plasticity.

VISCO-ELASTIC PROPERTIES

R – Mechanical Stress Relaxation Time [ms] is the displacement recovery time.

Relaxation time R is the time between maximum deformation t1 and initial shape tR.

C – Creep

Ratio of Deformation and Relaxation time characterises Creep (Deborah number).

Creep is the gradual elongation of a tissue over time when placed under a constant tensile stress

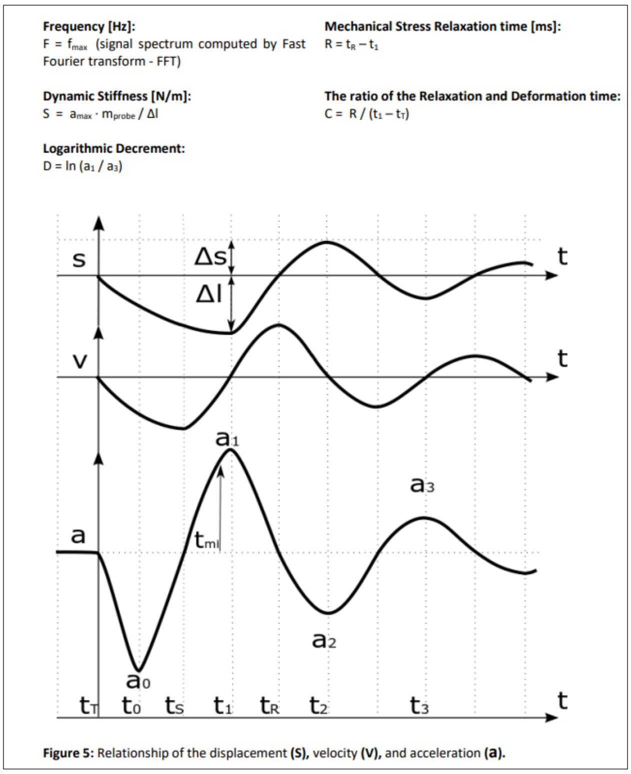

Figure 2: Myoton User manual

Durometer:

Durometer or Shore durometer is a standardized way to measure the hardness of materials like rubber (elastomers) and plastics. Durometer measurement scales range from 0 to 100 and it is a dimensionless unit. Higher numbers on the scale indicate a greater resistance to indentation and thus harder materials. Lower numbers indicate less resistance and softer materials.

Durometer measures the depth of an indentation in the material created by a given force on a standardized presser foot. This depth is dependent on the hardness of the material, its viscoelastic properties, the shape of the presser foot, and the duration of the test. The resistance of indentation is calculated when the needle is pressed onto a surface and its work is put into a spring inside of the durometer. To determine the overall hardness, the needle must be pressed in at least three different locations (where the material has a minimum thickness of 6mm), and the average of the measurements must be calculated.

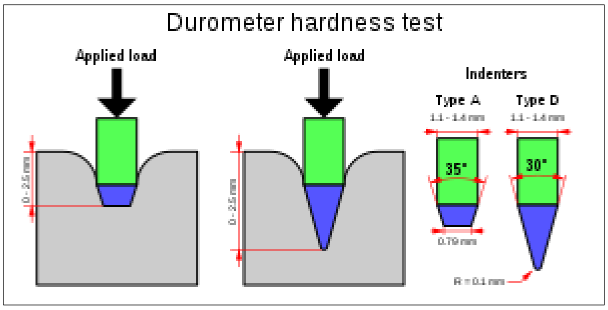

Figure 3: Shore durometer (Wikipedia)

PROCEDURE:

i. The subject was made to lie down on the belly. The foot was placed in a relaxed position on a rolled mat, such that the foot was not bent nor under tension.
ii. The eight points were marked on the foot Figure 4.
iii. The Myoton Pro device was held perpendicular to the surface at the eight points. Three reading were taken at each point and averaged for all the five parameters returned.
iv. Following this, the durometer was pressed perpendicular at the same eight points to measure hardness. Three readings were taken and averaged.
v. Further analysis was performed in MATLAB.

Figure 4: 8 points on the foot

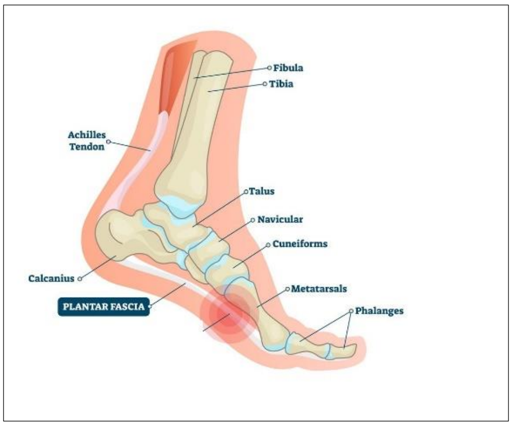

Figure 5: Plantar Fascia muscle

RESULTS & OBSERVATIONS:

Right Foot				
	Stiffness S(N/m) Myotone		Hardness Durometer	
Point on foot	Average S	Coefficienct of variation(%)	Average Hardness	Coefficienct of variation
1	612.6666667	4.482882928	22.16666667	7.921544175
2	903	2.827717682	23.16666667	19.46438742
3	592	1.787669805	20.5	2.43902439
4	565	3.657341296	22.16666667	4.695487217
5	527	5.561423488	22.16666667	7.250865234
6	471.6666667	2.123671972	19.83333333	3.850903945
7	498	3.038704006	25.16666667	10.94219314
8	573	1.887723181	25.16666667	1.147053515

Left Foot				
	Stiffness S(N/m) Myotone		Hardness Durometer	
Point on foot	Average S	Coefficienct of variation (%)	Average Hardness	Coefficienct of variation
1	640.3333333	6.324991483	23.5	15.34277138
2	886	0.298617529	24	9.547032698
3	574.6666667	1.559667014	24.83333333	9.515065019
4	641.3333333	4.361261267	24.16666667	3.160397031
5	660.6666667	9.113633857	27.83333333	7.260093205
6	511.3333333	3.858839266	23.66666667	5.316784814
7	531	2.63653484	27.5	6.298366573
8	539.3333333	2.469095718	28.83333333	7.008298065

It can be observed that the durometer has a higher coefficient of variation compared to the myoton readings. This suggests that the myoton is more reliable for stiffness compared to the hardness calculated by the durometer.

Point on foot	Tone (Hz) Right	Tone (Hz) Left	Stiffness S(N/m) Myotone Right	Stiffness S(N/m) Myotone Left	D – Logarithmic Decrement (1/Elasticity) Right	D – Logarithmic Decrement (1/Elasticity) Left	Hardness Durometer Right	Hardness Durometer Left
1	26.23333333	26.63333333	612.6666667	640.3333333	1.303333333	1.326666667	22.16666667	23.5
2	38.03333333	39.1	903	886	1.186666667	0.923333333	23.16666667	24
3	24.76666667	24.9	592	574.6666667	1.206666667	1.22	20.5	24.83333333
4	25	27.43333333	565	641.3333333	1.163333333	1.243333333	22.16666667	24.16666667
5	25.53333333	29.3	527	660.6666667	1.123333333	1.63	22.16666667	27.83333333
6	22.36666667	24.63333333	471.6666667	511.3333333	1.456666667	1.56	19.83333333	23.66666667
7	24.46666667	24.93333333	498	531	1.243333333	1.3	25.16666667	27.5
8	27	26.43333333	573	539.3333333	1.233333333	1.343333333	25.16666667	28.83333333

The tone of left and right foot is comparable. Point 2 has the highest frequency. Point 6 (Inner curved area of the foot) has the lowest frequency in both the feet.
The Stiffness values vary in both feet. Similar to the tone, Point 2 has the highest stiffness and Point 6 has the lowest stiffness.

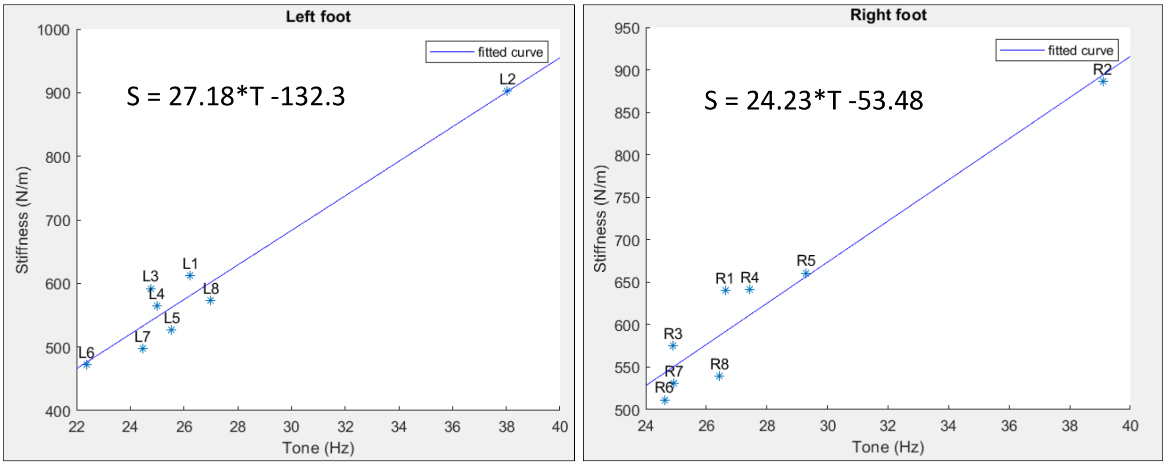

Figure 6: Stiffness (N/m) vs Tone (Hz)

Oscillation frequency characterizes the tone of a muscle in its passive or resting state without any voluntary contraction. Overly high muscle tone and subsequently high intramuscular pressure restricts the blood supply, causing muscle fatigue and slow muscle recovery. Stiffness characterises the resistance to a contraction or to an external force that deforms its initial shape.
From Fig 6, the tension in the muscle (tone) and stiffness seem to have a linear relationship.

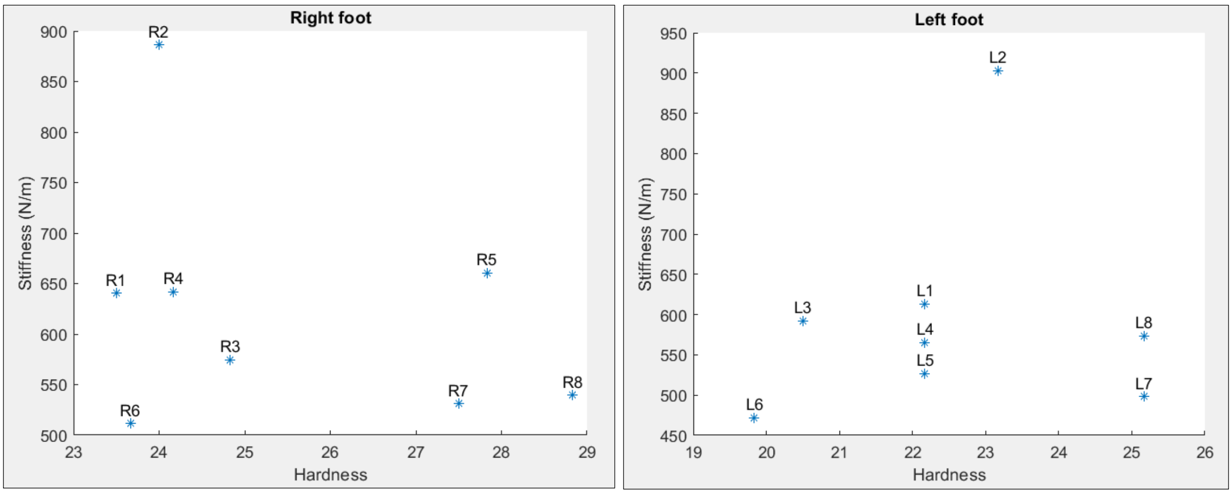

Figure 7: Stiffness (N/m) vs Hardness

From Figure 7, the stiffness obtained from myoton and hardness obtained from durometer seem uncorrelated.

CONCLUSIONS:

i. The durometer readings have a higher coefficient of variation compared to the myoton readings.
ii. The tension in the muscle (tone Hz) and stiffness seems to have a linear relationship.
iii. For the obtained data from the subject, the stiffness obtained from myoton and hardness obtained from durometer seem uncorrelated.

CRITICAL REMARKS:

i. The subject should place the foot in a relaxed position. There should be no bending of the heel or tension in the foot muscles while taking readings.
ii. The myoton can give incorrect readings if the operator's device holding hand is not supported and trembles.
iii. Muscle hardness readings obtained using the shore durometer is dependent on the operator's strength, angle, and level of skill.

REFERENCES:

https://www.myoton.com/