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STUDY OF THE FREE VIBRATIONS OVER THE MUSCULAR SYSTEM OF THE HUMAN BODY. PART I: MECHANICAL CHARACTERISTICS OF THE LEFT DELTOID

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Abstract: The paper presents the way of calculation and interpretation in determining the mechanical characteristics of the left deltoid of the human body. The work is preparatory to study the action of free vibrations on the left deltoid

Key words: muscular system, left deltoid, mechanical characteristics

1. INTRODUCTION

The human body consists of a set of levers, set in motion by the muscles. Muscles that move the human body are called skeletal muscles and are inserted into the bone skeleton. Complex movements performed by the muscles are possible through permanent communication between the sense organs and the muscles.

Each type of muscle has a certain function in maintaining the equilibrium state in the Earth's gravitational field, counterbalancing the gravitational force, or develops or coordinates a certain movement in the excursion of a profession [Osc 03]. The primary mobile muscles – deltoids – develop huge energies and that is why in this paper the attention has turned to the deltoid of the left shoulder.

2. DELTOID MUSCLE OF THE LEFT SHOULDER

Biological movement (life and locomotion of living organisms) is considered a superior form of movement, which has special qualities and mechanisms, which can only be explained by the application of the laws of mechanical movements, except with the adaptation of these laws under physical and chemical laws [Bud 11].

In understandingand interpreting biological movements, the application of the laws of mechanics, physics, or chemistry fail to render the whole complexity of phenomena, but only a singular aspect of the biological process.

In this idea we will consider the deltoid muscle of the left shoulder consisting of a grouping of three muscles = anterior, medial and posterior = which work together for the movement of the left arm in performing all possible movements [Chis 13].

Each muscle is considered as an individual entity, bound to the arm bone (Humerus) by a punctual ligament and fixed inthe upper part of the clavicle or shoulder blade by a longitudinal ligament, which achieves a fixed connection with these bones [Net 03]. Between the three muscles there are separation surfaces, corresponding to the connective tissue, which encloses the muscle fiber bundles of the same muscle. Between the muscle fibers there is relative movement, which is controlled by nerve fibers, whenever action is required.

2.1. Schematic representation of the left deltoid

The schematic representation of the left deltoid of the human body is done in the way, it is used to determine the mechanical characteristics

Representation shall be reported to a deltoid-adapted reference system, but which takes into account the reference system to which the human body is replayed. The axes of the reference system shall be considered as follows (Fig. 1):

1. the Ox axis is rear-to-back;
2. the Oy axis is directed from right to left;
3. the Oz axis is routed upwards, from the bottom up, to the orthostatic positioned subject.

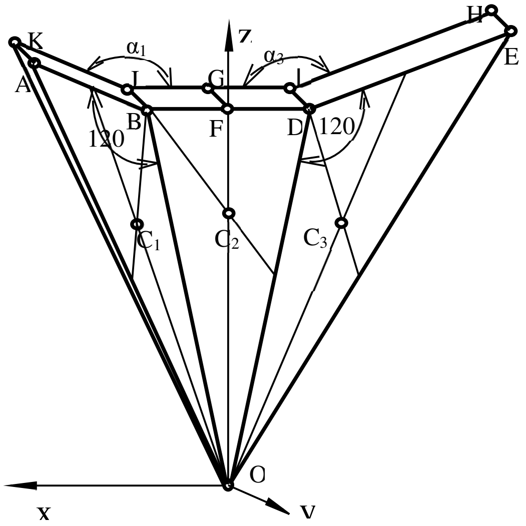

Fig. 1. The left deltoid of a human subject. Index1, refers to in the anterior deltoid, the 2nd is for the medial deltoid, and index 3 is of the posterior deltoid.

The mechanical model of the left deltoid, schematically represented in Figure 1, has a real correlation in two female subjects, who have been given dimensional measurements. The dimensional values of the two subjects are centralized in Table 1 and are rendered according to the notations of Figure 1.

Table 1.

Measured dimensions of the left deltoid

Name	Item	U.M.	Value
Subject 1	OF	Cm	15,7
	Ab	Cm	4,33
	DE	Cm	10,0
	α_1	Degrees	57
	α_2	Degrees	72
Subject 2	OF	Cm	16,0
	Ab	Cm	4,66
	DE	Cm	10,0
	α_1	Degrees	57
	α_2	Degrees	72

The coordinates of the points specific to the material system shall be related to the reference system shown in Figure 1.

Table 2.

Coordonates of the Subject 1 points

Point	x [mm]	y [mm]	z [mm]
O	**0.**	**0.**	**0.**
G	**0.**	**0.**	**157.**
F	**0.**	**20.**	**157.**
B	**35.**	**20.**	**157.**
D	**- 35.**	**20.**	**157.**
I	**- 35.**	**0.**	**157.**
J	**35**	**0.**	**157.**
A	**23.6**	**-23.3**	**174.563**
K	**23.6**	**- 43.3**	**174.563**
H	**-30.96**	**-72.48**	**201.03**
E	**- 30.96**	**-52.48**	**201.03**

Table 3.

Coordonates of the Subject 2 points

Punctul	x [mm]	y [mm]	z [mm]
O	**0.**	**0.**	**0.**
G	**0.**	**0.**	**160.**
F	**0.**	**20.**	**160.**
B	**32.5**	**20.**	**160.**
D	**- 32.5**	**20.**	**160.**
I	**32.5**	**0.**	**160.**
J	**- 32.5**	**0.**	**160.**
A	**25.397**	**-26.6**	**178.96**
K	**25.397**	**-46.6**	**178.96**
H	**- 30.96**	**-72.48**	**202.66**
E	**- 30.96**	**-52.48**	**202.66**

2.2. Masses geometry of left deltoid

The muscle of the left deltoid represented in Figure 1 is evaluated for each subject the volume and mass of each component part.

Table 4.

Masses geometry of subject 1

Muscle	Anterior	Medial	Posterior
Volume [cm^3]	14.28	219.	270.98
Mass [kg]	0.01428	0.219	0.271

Table 5.

Masses geometry of subject 2

Mucle	Anterior	Medial	Posterior
Volume [cm^3]	15.64	214.4	282.56
Mass [kg]	0.01564	0.2144	0.28256

2.3. Mases center of the left deltoid muscle

Each muscle belonging to the deltoid system in terms of assessing the position of the center of the masses can be considered a straight pyramid for the medial deltoid and a sloping pyramid for the other two deltoids.

Table 6.

Mass center of the subject 1 deltoids

Muscle	x_{Ci} [mm]	y_{Ci} [mm]	z_{Ci} [mm]
Anterior (i=1)	**6.027**	**-57.4**	**99.42**
Medial (i=2)	**0.**	**13. (3)**	**105.**
Posterior (i=3)	**-19.44**	**- 45.52**	**108.77**

Table 7.

Mass center of the subject 2 deltoids

Muscle	x_{Ci} [mm]	y_{Ci} [mm]	z_{Ci} [mm]
Anterior (i=1)	**6.1425**	**-58.5**	**101.325**
Medial (i=2)	**0.**	**13.3**	**106.**
Posterior (i=3)	**- 19.81**	**- 46.39**	**110.85**

3. MECHANICAL CHARACTERISTICS OBTAINING

From the literature [Net 01] it is considered that the determination of the mechanical characteristics of the segments of the human body, which characterize the elasticity and damping of each component part, can be obtained relatively easily if geometric bodies of ellipsoidal shape are considered, as in Figure 2.

Fig. 2. Body ellipsoidal segment adapted to the left deltoid, with semiaxes: b – on the body direction x; c – on the body direction y; a – on the body direction z,

Table 8.

Ellipsoidal semiaxes of the left deltoid corresponding to Subject 1.

Muscle	a [cm]	b [cm]	c [cm]
Anterior	**17.5**	**4.33**	**2.0**
Medial	**15.7**	**7.0**	**2.0**
Posterior	**18.84**	**10.0**	**2.0**

Table 3.9.

Ellipsoidal semiaxes of the left deltoid corresponding to Subject 2.

Muscle	a [cm]	b [cm]	c [cm]
Anterior	**17.172**	**4.66**	**2.0**
Medial	**16.0**	**6.7**	**2.0**
Posterior	**19.2**	**10.0**	**2.0**

3.1. Calculation of elasticity constants

It has been experimentally proven that for the elasticity constant, it is directly proportional to the longitudinal dimension of the segment in the direction considered and depends on the other two dimensions of the segmental ellipsoid. It is directly proportional to the "E" elasticity modulus of the material system. It is rated at E = 7.5kN/m^2, corresponding to muscle tissue. It also depends on an experimentally proven integrative factor, which is marked with I and has a value of 3.66.

1. the elasticity constant on the z direction is calculated with the:

$$k_Z = \frac{\Pi \quad E \quad a \quad b}{c \quad I} \qquad (1),$$

which applied to both subjects leads to the setting of values for the deltoid muscles of each subject, which is shown in Table 10.

Table 10.

Deltoid elasticity constant in the Oz direction of the adopted reference system

Muscle	Anterior	Medial	Posterior
Elasticity constant k_Z	[N/m]	[N/m]	[N/m]
Subject 1	2457.843	3535.717	6061.229
Subject 2	2574.462	3448.852	6183.613

2. the elasticity constant on the y direction is calculated with the:

$$k_Y = \frac{\Pi \quad E \quad b \quad c}{a \quad I} \qquad (2)$$

gives to the table 11.

Table 11.

Deltoid elasticity constant in the Oy direction of the adopted reference system

Muscle	Anterior	Medial	Posterior
Elasticity constant k_Y	[N/m]	[N/m]	[N/m]
Subject 1	31.841215	57.377049	68.30601
Subject 2	34.922459	53.888319	67.02527

3. the elasticity constant on the x direction is calculated with the:

$$k_X = \frac{\Pi \quad E \quad c \quad a}{b \quad l} \qquad (3),$$

and the results are:

Table 12.

Deltoid elasticity constant in the Ox direction of the adopted reference system

Muscle	**Anterior**	**Medial**	**Posterior**
Elasticity constant k_X	[N/m]	[N/m]	[N/m]
Subject 1	520.10371	288.62997	242.44918
Subject 2	474.21442	307.31587	247.08195

3.2. Depreciation constants of the left deltoid

The damping constants of each segment depend on the coefficient of viscosity of the blood and the dimensions of the segment on the direction considered. The viscosity of the blood depends on the concentration of the hematoids, which increase the resistance to blood flow [Osc 13]. Blood viscosity decreases when the rate of flow increases, a property that defines blood as non-Newtonian fluid. It is pseudoplastic because it is a non-homogeneous fluid and it is a suspension. After experimental and scientifically in-depth studies, it can be considered that for the segmental study of the body, the depreciation constants on each segment are calculated with the relationship:

$$c = \frac{12\mu}{\pi} \bullet \frac{A^2 \quad l}{D_m . e^3} \qquad (4)$$

In relation (4) the meaning of the notation is:

c – depreciation constant in the direction considered [Ns/m];

μ – blood viscosity coefficient, $\mu = 0.003$ Ns/$m^{2;}$

A – segment area [cm^2];

D_m – the average diameter of the segment [cm];

l – the average length of the segment [cm];

e – eccentricity of the missing corresponding to a segment [cm].

The area of an ellipsoidal segment is determined by the formula Knud Thomsen [Net 03], in which the ellipsoid semiaxes are specified, as follows:

$$\boldsymbol{A = 4\pi.} \left[\frac{(a.b)^{1.6075} + (a.c)^{1.6075} + (b.c)^{1.6}}{3}\right]^{1/1.6075} \qquad (5)$$

3.3. Representative sizes of the calculation of depreciation constants

The depreciation constant of a body segment, according to the relationship (4) requires specified some dimensional sizes, resulting from measurements (in this case), which are presented tabularly for each subject.

Table 13.

Representative sizes of the deltoid of Subject 1

Muscle	**l_v [cm]**	**D_v[cm]**	**e_v4%D_v[cm]**	**l_o [cm]**	**D_o[cm]**	**e_o4%D_o[cm]**
Anterior	**17.5**	**4.33**	**0.1732**	**4.33**	**17.5**	**0.7**
Medial	**15.7**	**7.0**	**0.28**	**7.0**	**15.7**	**0.628**
Posterior	**18.84**	**10.0**	**0.4**	**10.0**	**18.84**	**0.7536**

Table 14.

Representative sizes of the deltoid of Subject 2

Muscle	**l_v [cm]**	**D_v[cm]**	**e_v4%D_v[cm]**	**l_o [cm]**	**D_o[cm]**	**e_o4%D_o[cm]**
Anterior	**17.172**	**4.66**	**0.1864**	**4.66**	**17.172**	**0.68688**
Medial	**16.0**	**6.7**	**0.268**	**6.7**	**16.0**	**0.64**
Posterior	**19.2**	**10.0**	**0.4**	**10.0**	**19.2**	**0.768**

3.4. Segmentational areas of the deltoid

The segmentation areas of the left deltoid of the two subjects investigated are calculated using the ellipsoid semiaxes, using the relationship (5), and the results obtained are centralized tabularly

Table 15.

Segmentation areas of the left deltoid

Muscle	**Anterior**	**Medial**	**Posterior**
Aria	**[cm^2]**	**[cm^2]**	**[cm^2]**
Subject 1	**570.96715**	**768.37689**	**1269.4096**
Subject 2	**594.4904**	**752.9406**	**1293.0708**

3.5. Segmentation depreciation constants

With the so calculated data, the formula (4) is used, with which the vertical damping constants are calculated, for which the adapted formula is (6), respectively the horizontal depreciation constants, for which the corresponding formula is (7).

$$c_v = \frac{12\mu}{\pi} \bullet \frac{A^2 \; l_v}{D_{mv}.e_v^3} \tag{6}$$

$$c_o = \frac{12\mu}{\pi} \bullet \frac{A^2 \; l_o}{D_{mo}.e_o^3} \tag{7}$$

Centralize the results for the two subjects investigated and centralize the data obtained int ables 16 for vertical direction and 17 for a direction perpendicular to the anterior. They were noted with c_v as damping constant in vertical direction and with c_a damping constant in the horizontal plane.

Table 16.

Vertical deltoid damping constant

Muscle	**Anterior**	**Medial**	**Posterior**
Damping constant c_v	[Ns/m]	[Ns/m]	[Ns/m]
Subject 1	2907.39	6916.28	6154.92
Subject 2	2305.1438	8064.1128	5750.27

Table 17.

Horizontal deltoid damping constant

Muscle	**Anterior**	**Medial**	**Posterior**
Damping constan c_o	[Ns/m]	[Ns/m]	[Ns/m]
Subject 1	26.962	121.86	229.12
Sujiect 2	33.9298	103.826	220.38

4. CONCLUSIONS

The solution of the subject relating to the mechanical characteristics of the left deltoid of the body followed three distinct directions:

1. The graphic representation of the deltoid was made schematic, in order to make it easier to perform the calculations, for which has been adopted a reference system according to the reporting of the human body.
2. The coordinates of the points, the volume, the mass, the position of the center of the masses of each muscle followed the established laws of mechanics.
3. The calculation of elasticity constants and depreciation constants was made considering each muscle an ellipsoid, for which mathematical or experimental formulas existing in literature were used.

4.1. Conclusions relating to the constants of elasticity of the left deltoid

From the results of the calculations presented in the subchapters presented for elasticity behavior can be listed some concluding aspects of the two subjects investigated as regards the behavior of the left deltoid of the body.

1. The two subjects have comparable elasticity characteristics (coefficients) (of the same order of size) because they have close dimensions, and the relationships presented do not take into the appearance of the subjects' age.
2. In the vertical direction both subjects have the constant of elatity of the order of tens of thousands.

3. On the horizontal direction that comes out of the muscle (Oy), both subjects have the constant lasticity of the order of tens, which is correct given that a plucked muscle breaks slightly compared to a stretched one.
4. On the horizontal direction, the tangent of the muscle (Ox) the constant elasticity has the value of the order of hundreds for both subjects.
5. The values resulting from the calculations are comparable to the values in the literature relating to the behavior of the muscles subject to the demands.
6. The left deltoid muscle does not differ from other body muscles in terms of elasticity.

4.2. Conclusions relating to the amortization constants of the left deltoid

From the point of view of the depreciation constancy calculated in this paper, the following aspects are highlighted:

1. The horizontal damping constant is two orders of magnitude smaller than the vertical direction depreciation constant.
2. Depreciation constants are comparable in size for the two subjects in both vertical and horizontal directions.
3. Depreciation constants do not depend on the age of the subjects, but only on the size of the deltoid muscles.
4. Depreciation constants do not depend on the age of the subjects, but only on the size of the deltoid muscles.
5. The medial deltoid has the highest damping constant both vertically and horizontally for both subjects under investigation.
6. Depreciation constants resulting from calculations fall in the same order of magnitude as the depreciation constants existing in the literature.

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STUDIUL VIBRATIILOR LIBERE CU ACTIUNE ASUPRA SISTEMULUI MUSCULAR AL ORGANISMULUI UMAN. PARTEA I: CARACTERISTICI MECANICE ALE DELTOIDULUI STANG

Rezumat: *Lucrarea prezinta modul de calcul si de interpretare in determinarea caracteristicilor mecanice ale deltoidului stang al organismului uman. Lucrarea este pregatitoare pentru studierea actiunii vibratiilor libere asupra deltoidului stang*

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