

DEPENDENCE OF MUSCULAR MASS IN THE ORIGIN OF INGUINAL HERNIA

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INTRODUCTION

We are interested in studying the genesis of a very common pathology: the human inguinal hernia. The way it appears is not definitively clear, but it is accepted that a combination of mechanical and biochemical alterations is the reason why this pathology occurs, and that muscular simulation plays an important role in this.

To study the dynamics of the region the oblique internal muscle has been simulated because this is the most important dynamic element, especially given its position in Hessert's triangle. The vertex of this triangle is the inguinal internal orifice; the triangle's side are the oblique internal muscle with the aponeurotic arch of the transverse muscle and the inguinal ligament; and the triangle's base is the aponeurotic edge of the straight muscle. We can consider the side of the inguinal as a fixed ligament and the side of the aponeurotic tissue as dynamically passive. The side of the oblique internal muscle is the dynamically active element in the triangle. This triangle is covered by the transversalis fascia, which is dynamically passive and the last element of protection before the appearance of hernias

METHODS

There are several studies on the simulation of the muscular movements but basically, the most popular model is that proposed by A. F. Huxley, known as the cross bridges theory [1]. The visco-elastic model proposed [2] uses the Hill-Maxwell mechanical model which is theoretically based in [1]. Thus a differential model can establish the control of the muscular contraction for every point.

The Hill-Maxwell model that we use to simulate the muscular unit consists of 3 elements, one contractile and two elastic. The contractile element EC is activated by a device $u(t)$, which represents the active force-generating capacity. The elastic element ES models the mechanical isometric response of muscle and EP accounts for the resistance to stretch. The formulation of the model took into account the strain of each element ($\varepsilon_c, \varepsilon_s$ and ε_p) and the associated stresses (σ_c, σ_s and σ_p), so that the lengths of each time moment t (l_c, l_s and l_p) can be calculated according to the initial lengths and strains per instant as $l_i = l_{i_0} (1 + \varepsilon_i)$ where $i = c, s, p$. Due to the structure of the Hill-Maxwell model, $\sigma_c = \sigma_p$ and the total stress is the sum of both ($\sigma = \sigma_c + \sigma_p$). The position of the muscle is obtained from the system:

$$\begin{cases} \dot{k}_c = -(|u| + |\dot{\varepsilon}_c|)k_c + k_{c_{\max}}|u|_+ \\ \dot{\sigma}_c = -(|u| + |\dot{\varepsilon}_c|)\sigma_c + k_{c_{\max}}\dot{\varepsilon}_c + \sigma_{c_{\max}}|u|_+ \\ \rho \ddot{y} + c \dot{y} - \text{div}(\underline{F} \cdot \underline{\sigma}) = 0 \\ \sigma_c = k_s(\varepsilon - \varepsilon_c) \end{cases}$$

where k_c is the stiffness of the contractile element, the points indicate derivatives regarding time and $\sigma_{c_{\max}}$ and $k_{c_{\max}}$ are empirically derived values. Moreover, the activation function $u(t)$ is represented by $u(t) = |u(t)|_+ - |u(t)|_-$ with:

$$\begin{cases} |u(t)|_+ = k_{ATP} \cdot I_{C_a(t) \geq \bar{C}} \\ |u(t)|_- = k_{RS} \cdot I_{\bar{C} \geq C_a(t) \geq 0} \end{cases}$$

where $C_a(t)$ is the concentration of calcium for each point of time, \bar{C} is the level that activates function, k_{ATP} and k_{RS} are two fixed values related

to properties of the sarcomeres, and finally, I_A is the indicatrix function.

RESULTS AND DISCUSSION

We submitted our model to muscular exposed contraction and then to several simulations from the state of reference, following the reference parameters in the literature. We measured the maximum strain in the fascia.

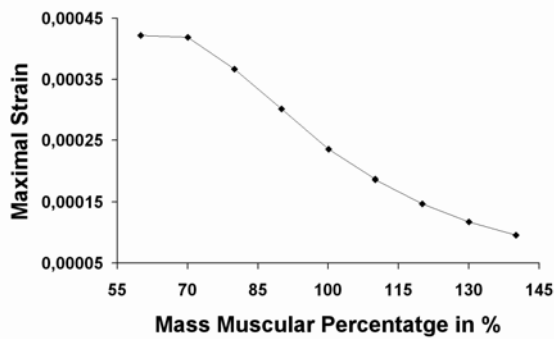


Figure 1: The vertical axis shows the maximum strain in the fascia. The horizontal axis shows the variation for the muscular mass in percentages.

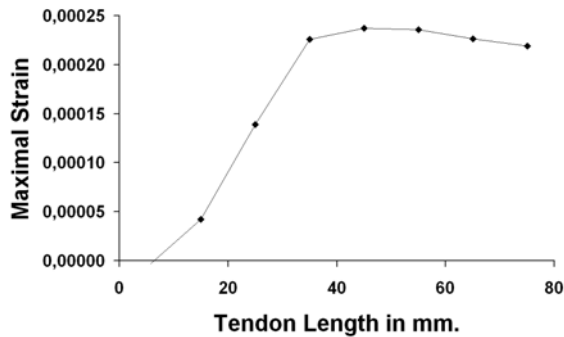


Figure 2: The vertical axis shows the maximum strain on the fascia. The horizontal axis shows the length of the tendinous tissue in mm.

In our study, we have varied the muscular mass in the direction orthogonal to the fibre. In this way we have varied the volume but not the length. The average muscular mass in our initial model was 100%, and we increased and decreased this mass by 40% in accordance with [3]. After subjecting the resulting models to muscular contraction, we measured the maximum strain on the fascia transversalis at the time of maximum contraction (Fig. 1).

Munhequete [3] showed that the average length of the lower fibres of the internal oblique muscle from the pubic tubercle is about 60 mm. (Fig. 3). In some

cases the tendon can reach 90 mm and cover the whole triangle. In other cases it can be just 10 mm long.

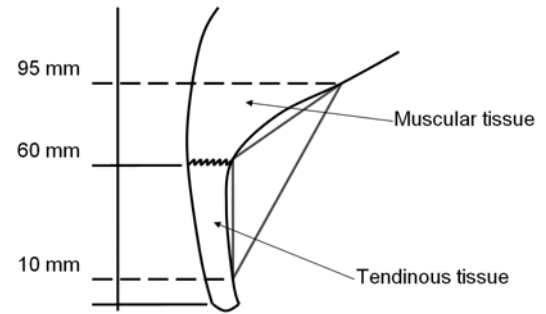


Figure 3: Scheme of the length of the tendinous tissue in the internal oblique muscle.

CONCLUSIONS

First, we demonstrate that Keith's conjectures are correct, that is, the risk of inguinal hernia diminishes when the volume of the muscular mass increases. This is shown by the maximum strain that can be placed on the fascia transversalis.

Second, our model confirms the results obtained by Ajmani [4], which establish a direct dependence between the likelihood of suffering a hernia and the distance between the origin of the muscular fibres and the tubercle of the pubis. Ajmani states that individuals in whom this distance is greater are more likely to suffer from hernias, and this is corroborated by our model (Fig. 2).

REFERENCES

- 1.Huxley AF. *J. Physiol.* **243**, 1-43, 1974
- 2.Bestel J. *Modèle différentiel de la contraction musculaire contrôlée. Application au système cardiovasculaire.* Ph.D. dissertation, Université Paris IX Dauphine, France, 2000
- 3.Munhequete E. "Estudio de las estructuras anatómicas relacionadas con la formación de hernias inguinales". PhD dissertation, Universitat Autònoma de Barcelona, Spain, 2003..
- 4.Ajmani ML. et al. *Anat. Anz.* **153**, 245-248, 1983.

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