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# A NON-INVASIVE PROCEDURE TO ESTABLISH THE PASSIVE AND ACTIVE BIOMECHANICAL PROPERTIES OF THE PUBOVISCERALIS MUSCLE: COMPARISONS BETWEEN ASYMPTOMATIC AND INCONTINENT WOMEN

## Hypothesis / aims of study

The female pelvic floor is a support structure that includes fascia, ligaments and muscles (PFM) of the urogenital region. It extends from the *symphysis pubis* to the coccyx, and comprises the *levator hiatus* for the passage of the urethra, vagina and rectum. The PFM include the *coccygeus*, *ileococcygeuos*, *pubococcygeus*, and *puborectalis* muscles, the latter two frequently referred together as the *puboviscerali*s muscle (PVM) [1]. The impairment of the pelvic floor muscles (PFM) is a major ingredient to develop urinary incontinence (IU) and/or pelvic organ prolapse (POP) (Schwertner-Tiepelmann et al., 2012).
These disorders may result from changes in the biomechanical properties of the supportive structures that occur from weakness or impairment of muscles or ligaments, or alterations in the stiffness of the pelvic fascia associated with the risk factors - age, hormonal changes, among others [2].
The related conditions have been studied through imaging techniques and experimental *in vitro* studies, evaluating biomechanical properties of the pelvic ligaments, vaginal tissue and *levator ani* (LA) muscle. To obtain these biomechanical properties, acquired tissue during surgery or from female cadaver has been tested using different techniques. However, these collected tissues are frequently afflicted in clinical environment, and consequently, the comparison to *in vivo* healthy tissues is difficult. Hence, these studies show the nonlinear mechanical behavior, but they do not reflect the natural conditions for *in vivo* muscle behavior in the pelvis. In this context, the computational analysis coupled with *in vivo* biomechanical properties may help to correctly reproduce the biomechanical behavior of the PFM.

## Study design, materials and methods

In this work, the computational models coupled with an inverse finite element analysis technique (FEA) was used to understand the passive and active behavior of the *puboviscerali*s muscle (PVM) during Valsalva maneuver and voluntary muscle contraction, respectively. Individual computational models of women asymptomatic and with stress urinary incontinence (SUI) were built based on magnetic resonance images, including the PVM and surrounding structures (Figure 1). To reproduce more accurately the nonlinear behavior of the PVM was used a quasi-incompressible transversely isotropic hyperelastic constitutive model [3] and posteriorly, the material parameters were estimated through inverse FEA.

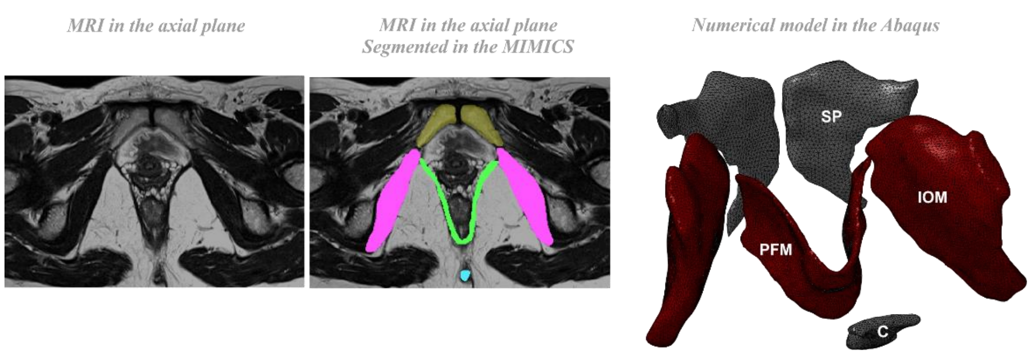


**Figure 1.** Magnetic Resonance images in the axial plane of a woman without pathology and finite element model. C - coccyx; IOM - internal obturator muscle; PFM - pelvic floor muscles; SP - symphysis pubis.

A set of women was asked to complete the International Consultation of Incontinence Questionnaire-Short Form (ICIQ-SF) – which is validated for the Portuguese language – to evaluate the presence and symptoms of UI. Demographic characteristics (age, body mass index (BMI) and parity) were also collected. For this work, the exclusion criteria included pregnancy and previous pelvic surgery. A convenient sample of eight women who gave informed consent was recruited. Four incontinent women (with SUI) and other 4 asymptomatic women were recruited at a regular urogynecology consultation.

## Results

Demographic characteristics of the asymptomatic and incontinent women are presented in Table 1. When comparing the two groups of women, no significant difference in age, BMI and parity were found.

**Table 1.** Demographic characteristics for the two groups.

| ***Variables*** | ***AW (n=4)*** | ***IW (n=4)*** | ***p-value*** |
|---|---|---|---|
| ***Age*** | 34.500±14.154 | 30.500±21.672 | 0.486 |
| ***BMI*** | 21.811±1.154 | 22.225±4.134 | 0.486 |
| ***Parity*** | 0.500±1.000 | 0.500±1.000 | 1.000 |

AW - asymptomatic women; IW - incontinent women.

The estimation of the material parameters evidenced a significant difference between two groups ($p<0.05$), with the values of asymptomatic women showing higher values (Table 2). The matrix parameters (*c* and *b*) and fiber parameters (*A* and α) were 84% and 28%, and 73% and 31% higher when compared with the ones of the incontinent women. The active material parameter ($T_0^M$) was approximately 75% higher than that of the incontinent women.

**Table 2.** Mean values of the material parameters for the passive and active behavior obtained for the two groups.

| ***Variables*** | ***AW (n=4)*** | ***IW (n=4)*** | ***p-value*** | ***variation (%)*** |
|---|---|---|---|---|
| ***c(MPa)*** | 0.058±0.074 | 0.009±0.002 | 0.029* | 84% |
| ***B*** | 1.695±0.415 | 1.226±0.057 | 0.019* | 28% |
| ***A(MPa)*** | 0.075±0.080 | 0.020±0.001 | 0.029* | 73% |
| ***A*** | 0.708±0.164 | 0.488±0.006 | 0.029* | 31% |
| $T_0^M$ ***(MPa)*** | 0.185±0.142 | 0.046±0.019 | 0.029* | 75% |

AW - asymptomatic women; IW - incontinent women.
*statistically significant.

Interpretation of results

The proposed methodology showed that the PVM of asymptomatic women are stiffer than that of women with incontinence. For these women, the lower passive parameters - as consequence of softer muscles - may be explained by a significant reduction of type III collagen, which is not due to a decreased production of collagen but due to increased degradation of new collagen. Additionally, previous studies also concluded that incontinent women have a decreased in active force and stiffness that can be associated with muscular weakness and also showed that these women have increased number of fibers but significantly narrower than that of the asymptomatic women.

Concluding message

In recent years, with the development of computer technologies, computer modelling tools have emerged, which deal with the application of mathematical models to analyse, understand and study the phenomenology of complex problems, and it has become an essential tool in the scientific environment due to its wide range of application fields - including medicine. The modelling of soft biological tissues has been facilitated due to substantial progresses in the fields of constitutive modelling and the finite element method (FEM). Hence, the computational models coupled with inverse FEA can represent mechanical phenomena such as the Valsalva maneuver and voluntary muscle contraction. In addition, they seem to be a promising possibility to determine the *in vivo* biomechanical properties of the PFM that characterize their mechanical behavior.
In conclusion, this methodology is completely non-invasive, using only MR images and it allows to compare asymptomatic women and incontinent women, which may contribute to the clinic.

References


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Disclosures


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