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BIOMECHANICAL POWER AND ENERGY ASSOCIATED WITH VOLUNTARY AND REFLEX PELVIC FLOOR CONTRACTIONS

<u>Hypothesis / aims of study</u>

Continence depends on the dynamic response of the lower urinary tract to maintain urethral closure. To this end the pelvic floor (PF) together with the urethral sphincter structures play an important guarding role in preventing leakage during stress (SUI). While appropriate PF training has the potential to minimize the incidence of incontinence; there are limited biomechanical standards to define the dynamic parameters of PF function. This deficiency is partly due to the lack of devices to directly enable such measurement in a way analogous to urodynamics. Using a novel biosensor, designed to measure the force and displacement of PF contraction in the anterior and posterior vagina, we computed the relative power and energy of voluntary and reflex cough contractions as potentially useful dynamic parameters.

<u>Study design, materials and methods</u>

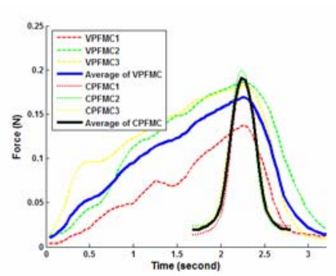
The vaginal biosensor is made of an applicator having retractable low inertia cantilevered force transducers, to measuring the force and associated displacement of PF contraction. Upon placement in the vagina the transducers are released to approximate the vaginal wall. Voluntary pelvic floor contraction and coughs are elicited from the subject while a PC collects data. Pilot studies were done on 9 women; mean age 64 yr with SUI. Data analysis: From these recordings the following waveform data analysis was undertaken: T_d : Duration of contraction, defined by the time interval between the start point (20% of the peak force, $0.2F_{peak}$) and the end point (20% of the peak force, $0.2F_{peak}$) of contraction. T_r : Rising Time, the force increased from 20% of the peak to peak. T_f : Falling Time, force decreased from the peak to 20% of the peak. The force in the anterior (F_a) and posterior direction (F_p) were compared. X, Y represents the anterior and the posterior direction respectively. F_a equals to F_p on the dotted line if the curve is above the dotted line, $F_p > F_a$. If the curve is below the dotted line, $F_p < F_a$.

Instantaneous Power Analysis (IP): During VPFMC and CPFMC, PFM did positive work and negative work to the probe by squeezing and releasing it through the vaginal wall in both the anterior direction and the posterior direction. Instantaneous power $P(t)$ can be calculated as follows: $P(t) = F(t) \cdot v(t) = F(t) \cdot \frac{dL(t)}{dt}$ (1) where, $F(t)$ is the force. $v(t)$ is the speed of the movement of the vaginal wall. $L(t)$ is the displacement. To analyze the characteristics of IP, the positive peak instantaneous power (P_{PP}) and negative peak instantaneous power (P_{NP}) of VPFMC and CPFMC are compared.

Energy Analysis: Because of the viscosity of the spring system on the probe, there was velocity-dependent energy loss when PFM squeeze and release the probe through the vaginal wall in both the anterior direction and the posterior direction during each contraction. Energy loss ΔW is calculated from: $\Delta W = \int_{t_1}^{t2} P(t)dt$ over duration t_1, t_2 of the contraction.

<u>Results</u>

The time course of the VPFMC relative to CPFC are typically illustrated by Figure 1, showing that in VPFMC, $T_r = 1.7867\text{s}$) is significantly longer than the falling time ($T_f = 0.52s$). (p=0.0023) while for CPFMC, the difference between the raising time ($T_r = 0.2533\text{s}$) and the falling time ($T_f = 0.28s$) is not statistically significant.



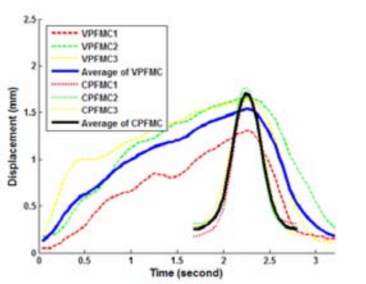
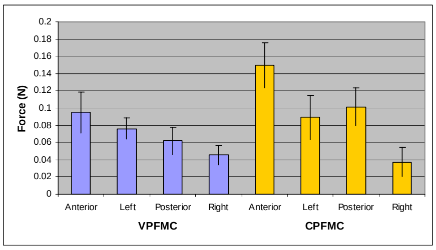


Figure 1(a) Figure 1(b)

Comparison of force (a) and displacement (b) trajectory during three VPFMC and CPFMC. In each case the average VPFMC and CPFMC are shown by the solid line.

Consideration of the force/displacement values obtained suggests that the middle vaginal wall produced more force and displacement in the posterior direction ($F_{mp} > F_{ma}$, $D_{mp} > D_{ma}$) during CPFMC, Figure 2a. By contrast, the middle vaginal wall produced more force and displacement in the anterior direction ($F_{ma} > F_{mp}$, $D_{ma} > D_{mp}$) during VPFMC, Figure 2b.



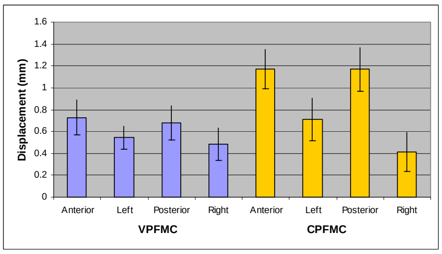
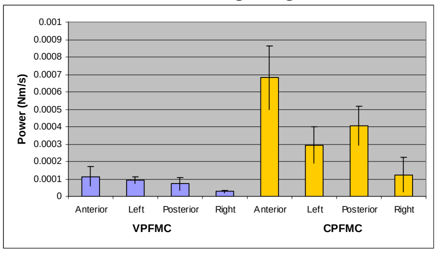


Figure 2: Comparison of the magnitude of force and displacement produced by volunary PF contraction and coughing relative to orientation of sensors.



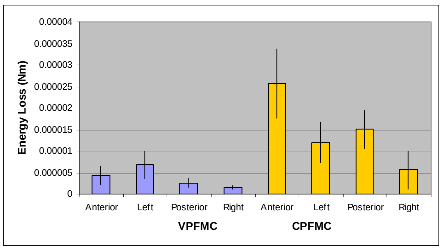


Figure 3: Comparison of defined Power and Energy Loss produced voluntary PF contraction and coughing relative to orientation of sensors.

The distribution of the Power and Energy loss of the contraction is given by Figure 3a and Figure 3b respectively. As shown, in Figure 3a, the total amount of power as well as energy produced by coughing is significantly higher in all aspects of the vaginal wall in comparison to the voluntary contraction.

Interpretation of results

The data suggest that the PF forces monitored within the vagina incorporates unique and distinct characteristics during reflex events such as coughing in comparison to voluntarily initiated contractions. These forces are anisotropic and suggest that force/displacement as well as the Power and Energy produced are at maximum in the anterior aspect of the vagina.

Concluding message

The present study provides a biomechanical analysis of the properties of the female pelvic floor and proposes new parameters that may enable better understanding of its function.

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