**Original article**

# The effects of pelvic floor and transverse abdominal muscles' maximal voluntary contractions on pelvic floor ultrasound biometric parameters in women with stress urinary incontinence: preliminary results

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*Abstract. Aim:* To verify if bladder neck position, genital hiatus area and puborectalis muscle thickness change during pelvic floor and transverse abdominal muscles' maximal voluntary contractions, compared to rest position. *Methods:* A clinical, transversal and controlled study was carried out with 31 women with stress urinary incontinence (SUI) symptoms, scored through the International Consultation on Incontinence Questionnaire Urinary Incontinence - Short Form (ICIQ UI-SF). The participants were evaluated by *GE Voluson 730 Expert*® transperineal ultrasound. The ultrasound images were collected first at rest, then during pelvic floor muscles' (PFM) maximal voluntary contraction and finally during transverse abdominal muscle's (TAM) maximal voluntary contraction. Three biometric parameters were analyzed in each situation: bladder neck position, genital hiatus area and puborectal muscle thickness. The statistical analyses were performed using Kolmogorov-Smirnov, ANOVA for repeated measures and Tukey-Kramer tests, adopting a significance level of 5%. *Results:* All biometric parameter measurements significantly changed during PFM maximal voluntary contraction compared to rest position ($p<0.05$). During TAM maximal voluntary contraction, only the puborectalis muscle thickness measurement showed a significant statistical difference compared to rest position ($p<0.05$). *Conclusion:* PFM maximal voluntary contraction significantly changed all analyzed ultrasound biometric parameters' measurements compared to rest position. In contrast, during TAM maximal voluntary contraction only the puborectalis muscle thickness significantly increased compared to rest position, without presenting any significant effects on either bladder neck position or genital hiatus area measurements.

*Keywords:* Pelvic floor; Physiotherapy; Stress urinary incontinence; Ultrasonography.

## ABBREVIATIONS

| | |
|---|---|
| AC | Anal canal |
| B | Bladder |
| BN | Bladder neck |
| Cm | Centimeter |
| $Cm^2$ | Square Centimeter |
| ICIQ UI-SF | International Consultation on Incontinence Questionnaire Urinary Incontinence - Short Form |
| $Kg/m^2$ | Kilogram per square meter |
| MVC | Maximal voluntary contraction |
| M | Mean |
| MHz | Mega Hertz |
| PFM | Pelvic floor muscles |
| PFM MVC | Pelvic floor muscles' maximal voluntary contraction |
| POP | Pelvic organ prolapse |
| PS | Pubic symphysis |
| PBR | Puborectal muscle |
| SD | Standard deviation |
| SUI | Stress urinary incontinence |
| TAM | Transverse abdominal muscle |
| TAM MVC | Transverse abdominal muscle's maximal voluntary contraction |
| UUI | Urgency urinary incontinence |
| U | Urethra |
| UVJ | Urethrovesical junction |
| V | Vagina |

## INTRODUCTION

A new approach for pelvic floor muscle (PFM) dysfunctions' treatment, based on deep abdominal muscle training, particularly, the transverse abdominal muscle (TAM), has been used and discussed in several recent studies[1-6]. PFM are responsible for both urethral closure and its pressure increase during a maximal voluntary contraction, supporting the pelvic organs and avoiding their descent during intra-abdominal pressure increase[7].

Due to its anatomical position, the TAM does not present a direct effect on the continence mechanisms[8]. However, some authors have mentioned that during a TAM maximal voluntary contraction a PFM co-contraction occurs because of a synergistic activity between the PFM and TAM, which has already been observed in healthy and continent women[9-14].

Thus, we hypothesized that the TAM maximal voluntary contraction could influence the pelvic floor ultrasound biometric parameters. Consequently, the aim of this study was to verify if bladder neck position, genital hiatus area and puborectalis muscle thickness change during both pelvic floor and transverse abdominal muscles' maximal voluntary contraction compared to rest position, in women with predominantly stress urinary incontinence (SUI) symptoms.

## MATERIALS AND METHODS

### *Study design and participants*

A clinical, cross sectional and controlled study was conducted after its approval by the Research Ethics Committee (CAAE: 42456114.8.0000.5404).

Initially, 39 women were recruited in the study and then eight of them were excluded for not meeting the study's eligibility criteria, resulting in a final sample of 31 women (Figure 1). All participants gave their informed and written consent according to the Helsinki declaration, prior to the initial assessment.

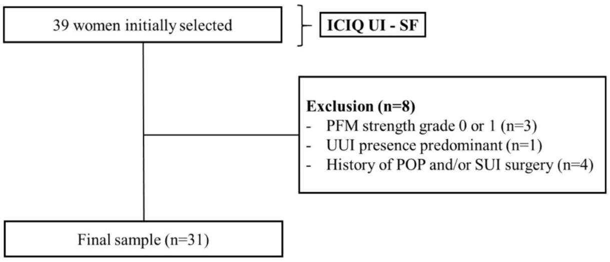


Figure 1. – Study population.
ICIQ UI – SF = International Consultation on Incontinence Questionnaire Urinary Incontinence – Short Form; PFM = pelvic floor muscles; UUI = urgency urinary incontinence; SUI = stress urinary incontinence; POP = pelvic organ prolapse.

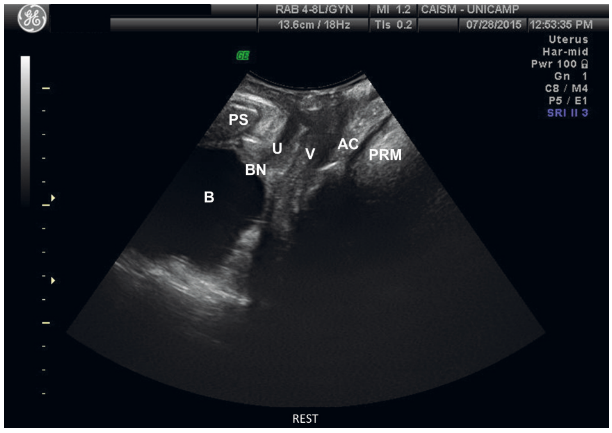


Figure 2. – Sequential representation of the structures observed in the pelvic floor muscles' ultrasound image. PS = Pubic symphysis; U = Urethra; BN = Bladder neck; B = Bladder; V = Vagina; AC = Anal canal; PRM = Puborectalis muscle.
(*Source:* Researcher's data)

*Inclusion and exclusion criteria*

We included 18 year or older women, who had reported predominantly SUI symptoms that were identified by means of an internationally validated questionnaire: International Consultation on Incontinence Questionnaire - Urinary Incontinence Short Form (ICIQ-UI SF), translated into Portuguese by Tamanini et al.[15]. We excluded women who had current urinary tract infection, myopathy, neurological abnormalities, diseases with a collagen alteration, cognitive and physical disorders that would hinder their participation in the evaluation, both SUI or/and pelvic organ prolapse surgery history, any pelvic organ prolapse exceeding the vaginal opening, PFM strength grade either zero or one according to the *Modified Oxford Grading Scale*[9] inability to contract the TAM and previously performed pelvic floor and/or transverse abdominal training supervised by health professionals.

*Outcome measurements*

First, one of the researchers investigated the participants' personal, demographic and clinical data, verifying whether they were eligible to participate in the research. A second researcher, a physical therapist specialized in woman health and in female PFM assessment, carried out the physical examination. This same examiner was trained by a physician, specialist in gynecological ultrasound and member of the research group, in order to carry out the ultrasound exams.

In the beginning, the participants' ability to perform a correct PFM contraction was verified by digital palpation. We also verified their ability to perform correct TAM contractions using ultrasound. To do this, the linear SP 6-12 MHz transducer was positioned at the point where the abdominal lateral wall is intercepted by the umbilical line, asking the participant to contract the lower abdominal part without performing any articular movements or any other muscle contractions[8,17]. Contractions were standardized in order to be carried out during the expiratory phase, correcting both inspiratory apnea or Valsalva maneuver situations.

*3D / 4D Transperineal ultrasound GE Voluson 730 Expert (GE Medical Systems Kretz-Technik GmbH and Co. OHG, Zipf, Austria)* ultrasound device and the *RAB4-8L / obstetric* convex transducer were used to obtain the 3D / 4D ultrasound images, where the image acquisition angle was set at 85º.

With the participant in supine position, with her knees bent, hips and feet flat on the table, the researcher placed the transducer, covered by a condom and gel, in contact with her vaginal introitus and between the major labia, without making too much pressure. The transducer axis was positioned on the mid-sagittal plane, allowing the sequential views of the following structures: the pubic symphysis, urethra, bladder neck, bladder, vagina, anal canal and, posteriorly, the puborectalis muscle, in Figure 2.

A first image, at rest, was recorded and stored into the device. Then, and always in this order, the participant was asked to conduct a PFM maximal voluntary contraction, followed by a TAM maximal voluntary contraction. Each maneuver was maintained for about 10 seconds in order that it would be possible to capture the 3D / 4D ultrasound real-time image.

*Data processing and analysis*

The ultrasound images were initially stored into the device, and then transferred to a notebook, to be able to analyze them afterwards through *4D View software* (*GE Healthcare Medical System*). In each image, three parameters were analyzed:

– *Urethrovesical junction's (UVJ) position:* Measured from the bladder neck to the lower margin of the pubic symphysis, after drawing a reference line, on the pubic symphysis axis (x axis) and another line, perpendicular to this at the intersection of the posterior inferior margin of the pubic symphysis (y axis)[18];

– *Genital hiatus area:* Bounded by the puborectal muscle's dorsal part and pubic symphysis[19];

– *Puborectalis muscle thickness*: The thickness of the puborectalis was measured each side (left and right), near the rectum, at 3 and 9 o'clock positions[20].

The UVJ positioning was analyzed on the mid-sagittal plane, while the genital hiatus area and the puborectalis muscle thickness were analyzed after 3D / 4D-volume design, on the axial plane at the minimum hiatal dimension level, shown between the pubic symphysis hyperechogenic front edge and the rear part of the rectum[19].

*Statistical analysis*

Data normality was analyzed using the Kolmogorov-Smirnov test. ANOVA for repeated measures test was used for investigate the biometric parameters' differences among the three proposed situations, followed by Tukey-Kramer post-test to investigate these parameters' differences between the rest and maximal voluntary contractions' situations.

The statistical analysis was carried out using GraphPad INSTAT 3.0 software, adopting a 5% significance level.

## RESULTS

The group was considered homogeneous for demographic and clinical variables. Most participants were white (74.2%), married (64.5%), completed primary school (48.4%) and had no labor activity (61.3%). The participants' average age was 51.6 (± 8.2) years and their body mass index was 24.6 (± 5.5) kg / $m^2$. Their ICIQ-UI SF questionnaire's mean score was 15 (± 3.6) points and PFM average strength grade was equal to 2.5 (± 0.7) according to the *Modified Oxford Scale*.

All analyzed ultrasound parameters presented significantly different measurements between rest and PFM maximal voluntary contraction situation. Only the puborectal muscle thickness showed a statistically significant difference in the measurements between rest and the TAM maximal voluntary contraction (Table 1).

## DISCUSSION

Arnold Kegel, a gynecologist, was the first to introduce the isolated PFM contraction exercises to treat urogynecological dysfunctions, including female urinary incontinence. Currently, globalized body interventions focusing on the abdominopelvic enclosure muscles[1-6] are being associated with Kegel's exercises, in order to strengthen PFM and improve the urogynecologic symptoms.

Considering studies on the co-activation between PFM and TAM[9-14], some authors[3,5] suggest that training TAM contractions must be encouraged before activities that promote intra-abdominal pressure increase and for women who do not present PFM awareness and perception. Currently, there seems to be a growing number of physiotherapists who are replacing PFM contractions by TAM contractions, as a treatment of female PFM dysfunctions[8]. However, there has not been any consensus yet on the effectiveness of trainings that use, exclusively, TAM contractions in order to increase PFM strength and treat urinary incontinence[21].

There is evidence that the PFM co-contraction occurs from the TAM contraction in continent women[9,11,12], but in incontinent women, this co-contraction seems to have been lost or changed[17,22,23].

Recent studies[24] have used ultrasound to evaluate the PFM contraction effect on the abdominal muscles, verifying that the TAM presents an increased thickness as a response to PFM contraction. However, this study has not evaluated the pelvic floor biometric parameters, to verify how they would respond during TAM contractions.

The effect of TAM maximal voluntary contraction on both PFM and the anatomical structures involving urinary continence mechanisms is not clear yet. Some authors argue that the thickness of TAM directly correlates with the PFM electromyographic activity[24] and that an isolated contraction of the TAM causes the elevation of the bladder neck in women without pelvic floor dysfunction[13]. On the other hand, other authors[8] believe that the PFM contraction obtained from a TAM contraction is significantly smaller and does not generate any significant changes in the genital hiatus area when compared to a direct PFM contraction, in women with pelvic organ prolapse.

The preliminary results of our study showed that the bladder neck position, genital hiatus area and puborectalis muscle thickness showed a significant difference between rest and PFM maximal voluntary contraction. In contrast, during the TAM maximal voluntary contraction, only the puborectalis muscle thickness presented a significant difference when compared to its value at rest. The other evaluated ultrasound parameters (bladder neck position and genital hiatus area), in spite of having changes during the TAM maximal voluntary contraction, did not result in significant changes when compared to their values at rest.

Based on these results, we can assume that puborectalis muscle thickness increasing during the TAM maximal voluntary contraction reinforces the theory that there is a synergic and functional relationship between the PFM and TAM[9-12].

In contrast, the TAM maximal voluntary contraction was not able to generate an effective PFM co-contraction so that it could significantly reduce the genital hiatus area and elevate the UVJ positioning, corroborating with the study of Bø et al[8].

This is a considerably important factor, since the genital hiatus area reduction can serve as a parameter to assess the efficacy of a PFM contraction once that this reduction occurs due to the shortening of their muscle fibers[19]. Similarly, the TAM maximal voluntary contraction was also not effective in raising the UVJ positioning, which is an important process for maintaining urinary continence[13]. Other authors[23,25] reported that incontinent women have a likely uncoordinated action between PFM and TAM, which generates an increase in intra-abdominal pressure and consequent urinary loss.

These preliminary results, indicated that is necessary to continue the research to clarify whether TAM voluntary contraction has an effect on the bladder neck position and genital hiatus area in women with SUI, which allows promoting evidence-based clinical practice.

As limitations of this study, we can mention the contraction time required for capturing the image and form the 3D / 4D volume in real time. Ten seconds, becomes too long, considering that incontinent women usually have low PFM

Table 1. PFM ultrasound biometric parameters during pelvic floor and transverse abdominal muscles' maximal voluntary contractions, compared to rest position.

| | Rest M (SD) | PFM MVCM (SD) | TAM MVC M (SD) | Comparison of all situations² | Comparison of each situation with rest² |
|---|---|---|---|---|---|
| **Urethrovesical junction position** (cm) | 2.7 (0.3) | 3.0 (0.4) | 2.8 (0.3) | **p=0.0001*** | Rest x PFM MVC **p<0.001***Rest x TAM MVC p>0.05 |
| **Genital hiatus area** ($cm^2$) | 13.8 (3.2) | 10.5 (2.5) | 12.7 (3.4) | **p<0.0001*** | Rest x PFM MVC **p<0.001***Rest x TAM MVC p>0.05 |
| **Puborectalis muscle thickness** (cm) | 0.7 (0.2) | 0.9 (0.1) | 0.8 (0.2) | **p<0.0001*** | Rest x PFM MVC **p<0.001***Rest x TAM MVC p**<0,05**** |

Data presented as mean (M) and standard deviation (SD). PFM MVC = Pelvic floor muscles' maximal voluntary contraction; TAM MVC = Transverse abdominal muscle's maximal voluntary contraction; PFM = Pelvic floor muscles; TAM = Transverse abdominal muscle; cm = centimeter; $cm^2$ = square centimeter. ¹ANOVA for repeated measures. ²Tukey-Kramer post test. *p<0.001. **p<0.05.

sustaining capacity. Faced with this issue, all the collections that would be incompatible should be excluded, although we have not had any such cases so far.

PFM and TAM assessments were not simultaneously performed as well, due to the used method's limitation. However, prior to evaluation, we confirmed the correct contraction of the TAM through ultrasound. Thus, we are sure that all participants were able to perform the appropriate contraction for both assessed muscles.

We stress the need for new studies that compare the effect of TAM contraction on both continent and incontinent women's pelvic floor biometric parameters. Furthermore, we suggest conducting randomized clinical trials evaluating the TAM contraction effect on the PFM biometric parameters in women with SUI, after conducting a TAM training protocol.

In conclusion, we verified that the PFM maximal voluntary contraction significantly changed all analyzed ultrasound parameters, compared with its measurements at rest. In contrast, during TAM maximal voluntary contraction, only the puborectalis muscle thickness increased significantly, compared to its size at rest, without presenting any significant effects on the bladder neck position and genital hiatus area.

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