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Authors: Bartlomiej Burzynski, Piotr Gibala, Tomasz Jurys, Michalina Knapik, Agnieszka Mazur-Bialy, Piotr Bryniarski

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Ultrasound imaging of abdominal muscles activity among women with stress urinary incontinence: case-control study in Poland

[Short title: Abdominal muscles and incontinence]

Bartlomiej Burzynski[1], Piotr Gibala[2], Tomasz Jurys[3], Michalina Knapik[4], Agnieszka Mazur-Bialy[5], Piotr Bryniarski[6]

[1]*Department of Rehabilitation, Faculty of Health Sciences in Katowice, Medical University of Silesia in Katowice, Poland*

[2]*Chair and Department of Gynecology, Obstetrics and Gynecological Oncology, Faculty of Health Sciences in Katowice, Medical University of Silesia in Katowice, Poland*

[3]*Doctoral School, Faculty of Health Sciences in Katowice, Medical University of Silesia in Katowice, Poland*

[4]*Doctoral School, Department of Urology, Faculty of Medical Sciences in Zabrze, Medical University of Silesia in Katowice, Poland*

[5]*Department of Biomechanics and Kinesiology, Faculty of Health Science, Jagiellonian University Medical College, Cracow, Poland*

[6]*Department of Urology, Faculty of Medical Sciences in Zabrze, Medical University of Silesia in Katowice, Poland*

Corresponding author:

Tomasz Jurys

Doctoral School, Faculty of Health Sciences in Katowice, Medical University of Silesia in Katowice, Medykow 12, 40-752, Poland

e-mail: jurystomek3@gmail.com

ABSTRACT

Objectives: The aim of the present study is the assessment of thickness and percentage change in thickness of the *musculus obliquus externus abdominis* (OE), *musculus obliquus internus abdominis* (OI) and *musculus transversus abdominis* (TrA) among women suffering from stress urinary incontinence (SUI) in comparison with healthy controls.

Material and methods: The thickness and its percentage changes of the OE, OI and TrA among women with and without SUI were assessed. We observed the reactions of the abdominal muscles among 84 women by means of ultrasound imaging.

Results: The thickness of the OE was significantly greater in the SUI group during rest and tension of the lower part of the abdomen. Significant changes were found in the OI for the controls during isometric tension of the abdominal muscles, tension of the lower part of the abdomen, and ASLR (active straight leg raise) test of right leg. The thickness changes in the TrA were significant for the controls during isometric tension of the abdominal muscles.

Conclusions: Our results suggest interactions of the pelvic floor and the abdominal muscles during pelvic floor activity, differing in the women with SUI and controls.

Key words: stress urinary incontinence; pelvic floor muscles; ultrasound imaging; abdominal muscles

INTRODUCTION

Stress urinary incontinence (SUI) determines of involuntary loss of urine as a result of strenuous physical exertion activities, sneezing, coughing, or laughing [1–4]. There are many theories about the pathophysiology of stress urinary incontinence. Over the years, attention has been paid to the role of the urethra, pelvic floor muscles, and the innervation of the internal and external urethral sphincters. In each theory, an important role was played by the increase in intra-abdominal pressure generated by the abdominal muscles in certain situations, such as coughing, sneezing, and physical activity [5]. For this reason, the interactions between the abdominal and pelvic floor muscles have been the focus of studies by various specialists [6–10]. Among the available literature, the majority of studies concern the activity of the *musculus transversus abdominis* in the population of healthy women [11–13]. Most commonly, these studies employed electromyography in order to assess the correlation of the abdominal and pelvic floor muscles. Only the study by Arab et al. [15], in which women with and without SUI were examined by means of ultrasound imaging, compares changes in the thickness of not only the *musculus transversus abdominis* but also the *musculus obliquus internus abdominis*.

Objectives

The aim of the present study is the assessment of thickness and percentage change in thickness of the OE, OI, and TrA among women suffering from SUI in comparison with healthy controls. The authors of the present study evaluated the thickness of the chosen abdominal muscles during pelvic floor muscle tension and rest, during isometric tension of the abdominal muscles, during sucking-in of the lower part of stomach, and during the ASLR test. Additionally, the percentage change in the thickness of the target muscles during the imaging of the various activities is calculated. We focused on the reactions of the abdominal muscles to different activities by means of ultrasound imaging.

In comparison to other authors of studies, we aimed to assess more anterolateral abdominal wall muscles, in hopes of detailed evaluation of their functioning and observing differences between women with or without stress urinary incontinence. The need to conduct a similar study resulted from our clinical experience and observations since we found different patterns of abdominal wall muscles functioning during physiotherapy centered on improving pelvic floor muscles function among stress urinary incontinence women.

MATERIAL AND METHODS

The present study is an analysis of prospectively collected medical data on women undergoing treatment at Uromedicus Clinic, Zabrze (Poland) in the period from 1 July 2015 to 12 April 2016. Study group was consisted of women with grade 1 or grade 2 stress urinary incontinence in accordance with the Stamey classification [16]. Stress urinary incontinence was diagnosed by a urologist or gynecologist. Women who met the following criteria were excluded from the study: previous pelvic floor physiotherapy, chronic diseases (hypertension, diabetes, neurological disorders), urogynecological and lumbosacral spine surgeries (except caesarean section), hormonal treatment six month before the study, current lower urinary tract infection. The control group was consisted of women who attended medical centre to complete the preventive counselling visit during which SUI and other genitourinary system disorders were excluded by a urologist or gynecologist. The Bioethics Committee of the Academy of Physical Education in Katowice stated that all procedures were performed according to the medical experiment design and approved in Resolution No. 4/2011. Patients have given their informed consent for participation in the study.

For the purposes of the present research, assessment of the thickness of the OE, OI, and TrA among both the study group and the control group was carried out. Measurement of muscle thickness was performed during the following activities [17]:

- during rest position (the patient lying on her back and without muscle tension);
- during isometric tension of the abdominal muscles (the patient lying on her back and performing volitional tensing of the abdominal muscles with no change in their length);
- during sucking-in of the lower part of stomach (the patient lying on her back and performing volitional sucking-in of the navel towards the spine);
- during pelvic floor muscle volitional tension (the patient lying on her back and per performing pelvic floor muscle lifting in the direction of the head);
- during ASLR tests (the patient lying on her back and raising the straightened left lower leg, then the right leg, 20 cm from the vertical) [18]. This test allowed assessment of abdominal muscle reflex activity using ultrasound imaging.

Assessment of abdominal muscle thickness was performed by means of ultrasound imaging. A linear probe (60 mm width) and frequency of 7.5 MHz were applied. Detailed probe positioning is presented in the paper by Burzynski et al. [17], Hodges et al. [19], and Adams et al. [20]. Each measurement was carried out on the right side of abdomen, three times. The final value of muscle thickness was the average value of the three attempts. Patients were instructed in the technique of muscle tensing before each ultrasound trial in order to verify that patients could tense correctly. Ultrasound images were frozen and recorded at the end of exhalation in order to minimize the impact of breathing. The commands such as “tense” and “release”, “raise” and “release”, “suck in” and “release” were applied during assessment [11]. The application of the ultrasound probe and a specimen ultrasound image of examined muscles are shown in Figure 1 and Figure 2, respectively.

Based on measurements of muscle thickness, the authors of the present study chose to calculate the percentage changes in the thickness of the target muscles thickness during each assessed activity. The percentage muscle thickness changes were calculated as follows:

$$\% \text{ of muscle thickness change} = \frac{MTa - MTr}{MTr} \times 100$$

where: *MTa* = muscle thickness during volitional (isometric tension of abdominal muscles, sucking-in of the lower part of stomach, pelvic floor muscle tension) and reflexive (ASLR test) activity; *MTr* = muscle thickness during rest.

The medical data collected for the purpose of the present study was arranged in a Microsoft Office Excel 2007 spreadsheet. The STATISTICA Stat Soft program was used for statistical analysis. For the purpose of comparison of the study and control group, the Student's t-test for two independent samples was used. Across the entire statistical analysis, the level of statistical significance was $p < 0.05$.

RESULTS

After considering all inclusion and exclusion criteria, the final analysis included the data of 84 women who attended lower urinary tract physiotherapy. The study group consisted of 40 women suffering from SUI and the control group of 44 women with no symptoms of micturition disorders. Characteristics of the SUI and control group was presented in Table 1.

In the study group, the thickness of the OE was statistically significantly greater than that of the control group during two activities: 1. rest and 2. tension of the lower part of the abdomen. There were no statistically significant differences concerning the OE during the four other activities, although in each case the thickness values for the study group were higher than those for the control group. In the case of the OI and TrA, there were no significant differences between the study and control group (Tab. 2).

Analysis of the percentage changes in the thickness of the OE did not present any statistically significant differences between study and control groups during each assessed activity. However, in the case of the OI, there were statistically significant differences between the study and control groups during isometric tension of the abdominal muscles, tension of the lower part of the abdomen, and ASLR test of right leg, where higher percentage changes were found for the control group. Analysis of the percentage muscle thickness changes in the TrA showed statistically significant difference between study and control groups only during isometric tension of the abdominal muscles, again with a higher result for the control group (Tab. 3).

DISCUSSION

The reliability, validity and safety of ultrasound imaging as a means of assessment of abdominal muscle thickness, for example in order to evaluate muscle activity, has been borne out by several past clinical studies [21–24]. **Moreover, the ultrasound imaging is still the part of the "gold standard" in the gynaecological imaging options** [25].

The results of the present study indicate differences in the thickness values of selected abdominal muscles, and in their percentage changes in reaction to different activities, between women with and without SUI symptoms. The changes in muscle thickness of the OE, OI, and TrA during volitional pelvic floor muscle tension indicate existing co-activation of the abdominal muscles with the pelvic floor muscles. Sapsford et al. [11] make the same claim in their paper, in which the reaction of the abdominal muscles to maximum volitional pelvic floor muscle tension among healthy women was observed. A similar conclusion was presented by Madill et al., showing that during pelvic floor muscle tension the most active muscles are the *musculus transversus abdominis, musculus obliquus internus abdominis, musculus obliquus externus abdominis,* and the lower part of the *musculus rectus abdominis* [12].

In the present study, there were no statistically significant differences observed in the *musculus transversus abdominis* thickness values during each assessed activity, though the average muscle thickness among healthy women was higher than in the group of women with SUI symptoms — a similar finding to the results of the study by Madokoro et al. [22]. Analysis of the percentage changes in *musculus transversus abdominis* thickness in the present study shows that, among women suffering from SUI, these changes were significantly lower than in the control group, which again corresponds to the findings of the Madokoro et al. [22]. The study by Tajiri et al. [14] indicates that changes consisting in the reduction of the thickness of the *musculus transversus abdominis* are a significant risk factor in urinary incontinence. However, the results of the present study and of the study by Madokoro et al. do not support such a correlation [14, 22].

The other muscle for which a statistically significant percentage change in thickness was observed is the *musculus obliquus internus abdominis*. Its percentage changes were lower in the group of women with SUI symptoms during all assessed activities except for the ASLR test of the left leg. Results for isometric tension of the abdominal muscles, tension of the lower part of the abdomen, and the ASLR test of the right leg were all statistically significant. Assessment of the *musculus obliquus internus abdominis* in a study by Arab et al. [15] likewise found that changes in muscle thickness among healthy women were greater, but their results were not — unlike in the present study — statistically significant [15].

In the present study, the analysis of thickness of the *musculus obliquus externus abdominis* shows that, among women suffering from SUI, the muscle was thicker during each assessed activity, and that the results during rest and tension of the lower part of the abdomen were statistically significant. On the other hand, analysis of the percentage change of the *musculus obliquus externus abdominis* shows no significant differences between the study and control groups during each activity. The only study concerning the *musculus obliquus externus abdominis* which the authors of the present study have been able to compare to theirs, by Figueiredo et al. [26], also indicates that there is no strong correlation between muscle thickness changes and urinary incontinence.

Based on the foregoing, the authors tend to draw attention to further need for conducting research assessing the correlation between individual abdominal wall muscles with pelvic floor muscles. Perhaps it will allow the development of that kind of strategy of female SUI management, which will be focused on only on the pelvic floor muscle's function, but also on abdominal wall muscles functioning. Currently, several authors observed and described certain pelvic floor and abdominal wall muscle associations. However, due to significant differences in their methodology, there is difficult to develop detailed standards including therapy of abdominal wall muscles among female SUI patients.

The present authors acknowledge some limitations in this study. The first concerns the relatively low number of participants, which, if increased, might reveal new significant differences and / or strengthen the current findings. A similar effect could be achieved by inclusion in the study of women suffering from grade 3 SUI. Moreover, in the present study, the thickness of the *musculus rectus abdominis* was not assessed. It would be worthwhile to extend the study to include measurement of the activity of the *musculus rectus abdominis*, thereby achieving evaluation of all the anterolateral abdominal wall muscles.

CONCLUSIONS

Results of the present study indicate the pelvic floor muscle tension has an impact on abdominal muscles (*musculus obliquus externus abdominis, musculus obliquus internus abdominis* and *musculus transversus abdominis*). Also, there are the differences in the activity of the abdominal muscles (*musculus obliquus externus abdominis, musculus obliquus internus abdominis* and *musculus transversus abdominis*) between women with SUI and healthy controls. Based on the results of the present study, the authors suggest the physiotherapy for women with stress urinary incontinence should be focused not only on the pelvic floor muscles, but also on the abdomens.

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__Conflict of interest__

All authors declare no conflict of interest.

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Table 1. Characteristics of the study and control group

Group	Age [years]	Body mass [kg]	Height [cm]	BMI [kg/m^2]
SUI [$\bar{x}$ ± SD]	45.2 ± 7.8	68.6 ± 10.5	164.7 ± 5.2	25.2 ± 3.4
Control [$\bar{x}$ ± SD]	41.7 ± 7.7	63.4 ± 7.2	165.2 ± 4.4	23.2 ± 2.7

BMI — body mass index; SUI — stress urinary incontinence, $\bar{x}$ — mean, SD — standard deviation

Table 2. Thickness values of assessed muscles during different activities in the study and control groups

Muscle	Group	Muscle thickness during activity [mm]					
		Rest	Isometric tension of abdominal muscles	Lower part of abdomen tension	Pelvic floor muscle volitional tension	ASLR test — right leg	ASLR test — left leg
OE	SUI [$\bar{x}$ ± SD]	5.37 ± 1.01	4.95 ± 1.24	5.41 ± 1.12	5.31 ± 1.25	4.76 ± 1.00	5.33 ± 1.37
	Control [$\bar{x}$ ± SD]	4.86 ± 0.83	4.55 ± 0.98	4.88 ± 1.04	5.00 ± 1.25	4.52 ± 1.04	4.88 ± 1.22
	p-value	0.014*	0.103	0.029*	0.269	0.277	0.125
OI	SUI [$\bar{x}$ ± SD]	7.50 ± 1.47	8.62 ± 2.03	8.16 ± 1.87	8.08 ± 2.12	7.18 ± 1.76	7.11 ± 1.64
	Control [$\bar{x}$ ± SD]	7.26 ± 1.53	9.11 ± 2.43	8.63 ± 1.63	8.02 ± 1.77	7.48 ± 1.60	6.88 ± 1.30
	p-value	0.464	0.317	0.228	0.893	0.429	0.413
TrA	SUI [$\bar{x}$ ± SD]	3.77 ± 0.97	4.97 ± 1.63	5.60 ± 1.38	5.08 ± 1.32	4.11 ± 1.10	3.98 ± 1.04
	Control [$\bar{x}$ ± SD]	3.64 ± 0.81	5.63 ± 1.73	5.72 ± 1.63	5.23 ± 1.86	3.98 ± 1.12	3.81 ± 0.98
	p-value	0.517	0.077	0.718	0.680	0.588	0.430

*statistically significant result (student's t-test, $p < 0.05$); ASLR — active straight leg raise test; OE — musculus obliquus externus; OI — musculus obliquus internus; SD — standard deviation; SUI — stress urinary incontinence; TrA — musculus transversus abdominis; $\bar{x}$ — mean

Table 3. Percentage change of muscle thickness during different activities in the study and control groups

Muscle	**Group**	Muscle thickness change [%]				
		Isometric tension of abdominal muscles	Lower part of abdomen tension	Pelvic floor muscle volitional tension	ASLR test — right leg	ASLR test — left leg
OE	SUI [$\bar{x}$ ± SD]	−6.70 ± 18.74	3.08 ± 19.56	−0.28 ± 17.15	−10.17 ± 15.95	−2.08 ± 14.50
	Control [$\bar{x}$ ± SD]	−5.41 ± 15.01	1.89 ± 19.07	2.07 ± 22.55	−5.81 ± 17.54	1.45 ± 19.67
	p-value	0.730	0.780	0.590	0.240	0.353
OI	SUI [$\bar{x}$ ± SD]	15.97 ± 23.86	9.62 ± 17.41	8.14 ± 18.71	−4.44 ± 13.73	−4.37 ± 15.00
	Control [$\bar{x}$ ± SD]	28.46 ± 32.65	21.93 ± 23.43	12.96 ± 23.31	4.79 ± 17.45	−3.61 ± 11.80
	p-value	0.047*	0.007*	0.297	0.009*	0.799
TrA	SUI [$\bar{x}$ ± SD]	36.05 ± 36.83	56.08 ± 42.85	40.54 ± 35.93	11.13 ± 23.18	8.13 ± 22.32
	Control [$\bar{x}$ ± SD]	57.32 ± 42.26	58.96 ± 33.95	43.46 ± 30.04	10.33 ± 19.83	5.17 ± 19.83
	p-value	0.016*	0.735	0.688	0.864	0.526

*statistically significant result (student's t-test, $p < 0.05$); ASLR — active straight leg raise test; OE — musculus obliquus externus; OI — musculus obliquus internus; SD — standard deviation; SUI — stress urinary incontinence; TrA — musculus transversus abdominis; $\bar{x}$ — mean

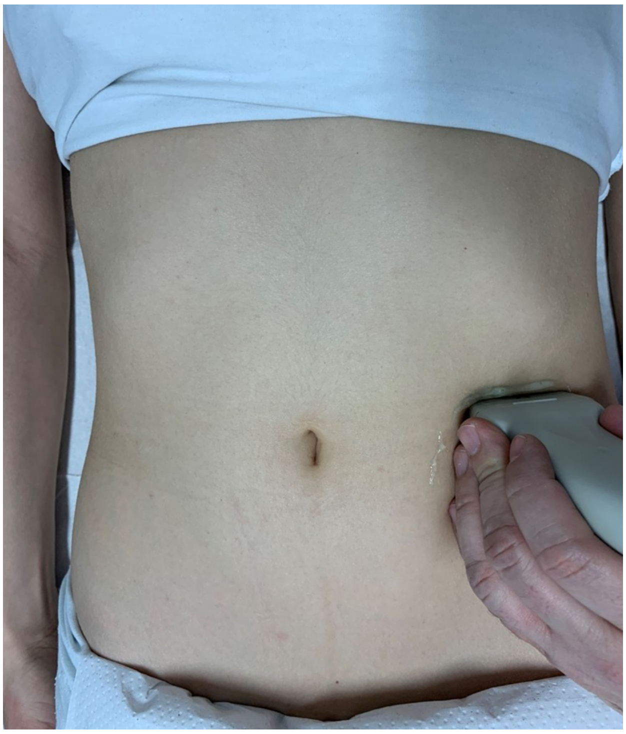

Figure 1. Point of application of ultrasound transducer (source: own material)

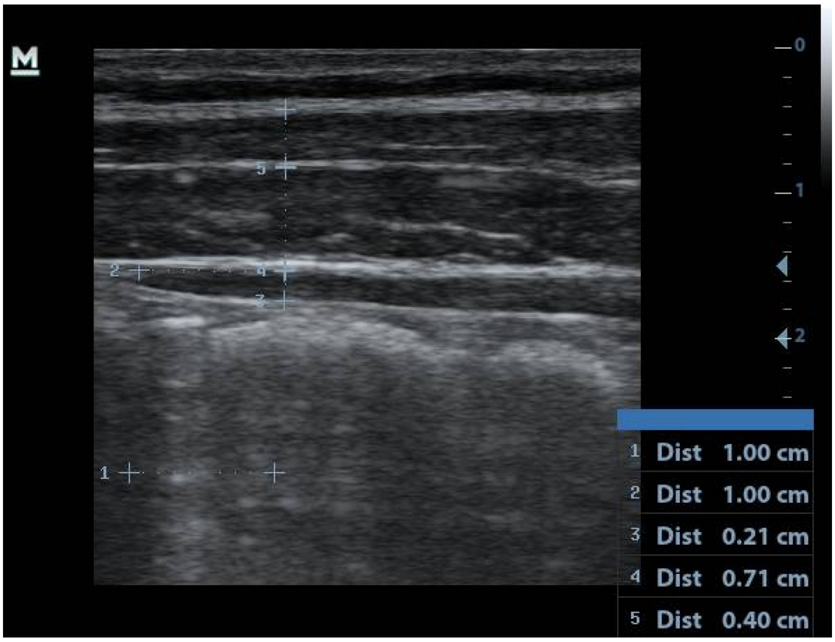

Figure 2. Ultrasound image for muscle thickness assessment; (**1**) reference distance of 1 cm (**2**) distance from the origin of musculus transversus abdominis to the point of thickness measurement of each muscle (individually variable) (**3**) thickness measurement of musculus transversus abdominis (**4**) thickness measurement of musculus obliquus internus (**5**) thickness measurement of musculus externus (source: own material)