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Gender Differences in Ultrasound Imaging of Lateral Abdominal Muscle Thickness and Trunk Mobility

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SUMMARY

Background. A number of gender differences are of great importance in the research interpretation, being a differentiating variable in many of them. The example is a varied structure of the musculoskeletal system. The objective of this study was to determine corelations between gender and thickness of the abdominal muscles as well as selected trunk mobility parameters.

Methods. The studied group consisted of 80 subjects: 42 women and 38 men aged 18-45. The inclusion criteria were: age 18-45, absence of pain of the spine and peripheral joints; Body Mass Index (BMI) $\leq$ 29.9; absence of neurological symptoms; absence of chronic diseases affecting the musculoskeletal system; absence of postoperative scars within the abdominal wall; not being pregnant. The research procedure consisted of an interview, morphological analysis with body composition assessment, measurement of abdominal muscle thickness by ultrasound imaging and mobility tests: Fingertip-to-Floor, Sit and Reach Test and lateral flexion of the spine. The ANOVA, the Pearson correlation coefficient (r) and Intraclass Correlation Coefficient (ICC3.1) were used.

Results. Statistically significant differences between the groups were demonstrated in the thickness of internal ($p = 0.0057$) and external oblique muscles ($p = 0.0079$) and in the total measurement TrA + IO + EO ($p = 0.0020$), indicating a greater mean thickness in the male group. The results from functional trunk mobility tests did not differ significantly between men and women ($p > 0.05$). There was a weak correlation between the selected morphological variables and the thickness of the abdominal muscles in both groups.

Conclusions. Gender differentiates the thickness of the muscles of the lateral abdominal wall. In the group of men there is a greater thickness of the internal and external oblique muscle, as well as the entire muscle complex. No relationship between sex and the thickness of the transverse abdominal muscle was demonstrated. There were no differences in the mobility of the trunk between women and men.

KEY WORDS

Gender; abdominal muscle thickness; mobility; ultrasonography; trunk movements.

INTRODUCTION

A number of gender differences are of great importance in the research interpretation, being a differentiating variable in many of them, especially in the area of sport, physical activity and public health. An example may be the different structure of the musculoskeletal system beetwen men and women expressed by dissimilarities in the overall somatic structure of the body *e.g.*, body weight, height, body composition and in the selected anthropometric measurements (1-5). Moreover, the endocrine system plays a significant role in this matter as well - especially sex hormones such as estrogens, testosterone, thyroid hormones, growth hormone and others. They determine the difference in muscle mass percentage, which affects greater strength and power generated by men later on (6-8). Both these parameters are elements of motor performance skills and strongly influence sport results achieved by women and men which causes a significant disproportion, especially visible and common in the early stages of children's and youth's sporting performance (9-11).

In addition to the difference in muscle mass, there is also a distinct proportion of bone and fat mass, which is respectively 15:36:30 (bone: muscle: fat) for women and 20:40:20 for men (12, 13). The bone and fat mass density is also regulated by sex hormones (including androgens in men and estrogens in women) (14, 15).

The mobility and stability of the trunk are part of the fundamental human motor skills, on the basis of which a proper motor function develops (16). That motor function is stimulated in the nervous system by the force of gravity (17). In the case of a child which develops new motor skills in the first year of life, differences resulting from gender are yet to be visible. Changes occurring at the level of basic motor skills begin to manifest later in life and are not yet fully known nor understood (18, 19).

The relation between mobility and stability is of high importance because the feasible range of motion increases as the stabilizing function of the trunk improves (20). Additionally, the stability of the trunk is the result of the interaction of multiple systems, ranging from neuromuscular control, control of the neutral zone of joints, their anatomical structure, flexibility and stiffness of the soft tissues (21-23).

The assessment of stability and mobility of a trunk as elements of the motor function is exceedingly challenging, because those two factors' outcomes must be expressed in a quantitative manner. Conversely, for clinicians and other practitioners concerning themselves with this matter, the qualitative assessment of the movement pattern is significantly more important, but also considerably more difficult to rank (16, 24, 25). Therefore, in this study, the thickness of abdominal muscles was measured by examining the variance in their mass, which has a direct effect on postural stability in case of deep muscle function and ability to generate strength and power in superficial muscles (20, 26, 27). Mobility was assessed as the range of motion in selected functional tests.

The aim of this study was to determine corelations beetwen gender and thickness of the abdominal muscles as well as selected trunk mobility parameters.

MATERIALS AND METHODS

Characteristics of the subjects

The studied group consisted of 80 subjects: 42 women and 38 men, who consituted respectively 52.5% and 47.5% of all respondents. The inclusion criteria were the following: age 18-45, absence of pain of the spine and peripheral joints; Body Mass Index (BMI) ≤ 29.9; absence of neurological symptoms; absence of chronic diseases affecting the musculoskeletal system; absence of postoperative scars within the abdominal wall; not being pregnant.

The exclusion criteria included presence of back pain and/or with accompanying neurological symptoms; abdominal wall surgery; diagnosis of a chronic disease; in the group of women - pregnancy; missing at least one training session or measurement procedure; current pharmacotherapy (including analgesics during the study); resignation at any stage of the study. The variables describing the study group are presented in **table I**. There were no statistically significant differences in the level of physical activity between the groups, assessed with the IPAQ questionnaire ($p = 0.6143$). Moreover, none of the women mentioned having children in the interview.

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the Bioethics Committee of the Medical University of Silesia, Katowice, Poland (Resolution No KNW/ 0022/KB46-7/18). Each of the subjects gave their written consent to participate in the research.

Methods

The research procedure consisted of the interview which was the initial qualification, morphological analysis including body composition assessment, assessment of abdominal muscle thickness and basic mobility tests. The obtained results were recorded in the research questionnaire. The study was preceded by the pilot examination for the sake of refinement and validation of the measurement procedures and elimination of potential errors.

Table I. Statistics of age and morphological parameters.

Variable	Sex	N	X	Min	Max	CI - 95%	CI 95%	SD	p*
Age (years)	Women	42	23.71	19.00	37.00	22.64	24.79	3.44	0.0837
	Men	38	27.03	19.00	45.00	24.99	29.07	6.21	
Height (cm)	Women	42	167.95	158.00	179.00	166.26	169.65	5.44	0.0000
	Men	38	180.42	165.00	195.00	178.19	182.65	6.79	
Body mass (kg)	Women	42	59.71	46.80	72.70	57.76	61.67	6.28	0.0000
	Men	38	79.46	59.80	102.80	76.42	82.49	9.24	
BMI (kg/m2)	Women	42	21.21	17.20	27.00	20.48	21.94	2.35	0.0000
	Men	38	24.37	20.40	28.20	23.66	25.08	2.17	
Fat mass (%)	Women	42	26.54	17.20	37.00	25.06	28.03	4.76	0.0000
	Men	38	18.56	8.80	25.80	17.36	19.76	3.64	
Fat free mass (kg)	Women	42	43.65	37.70	51.50	42.67	44.63	3.13	0.2390
	Men	38	63.37	16.20	80.00	60.08	66.66	10.02	

*Analysis of variance ANOVA.

Participatnts who met the inclusion criteria were informed about changing into sports clothes (t-shirt and shorts) and were directed to warm-up activities, including riding a spinning bike with a load of 70 watts (W) and a duration of 5 minutes (min) and an elliptical bike afterwards (power: 80W, cadence of 70 RPM, 5 min). The tests were performed without shoes.

Morphological analysis

Body composition analysis was performed using the Tanita scale (Tanita BC-418, Tanita Corp., Tokyo, Japan). A bioelectric resistance method was used to assess the following parameters: body weight (kg), BMI (kg/m^2), body fat mass (%), fat free mass (kg). Height (cm) was measured using Wall-Mounted Height Rod (Tanita HR-200, Tanita Corp., Tokyo, Japan). The measurement was performed in accordance with the manufacturer's instructions. Due to the dress code, all participants were set to -0.5 kg body weight before the measurement.

International Physical Activity Questionnaire

The IPAQ short questionnaire is a tool designed primarily for population surveillance of physical activity among adults. The specific types of activity are assessed as walking, moderate-intensity activities and vigorous-intensity activities (28). The respondent answered on his own and the questions concerned 7 days before the assesment.

Assessment of abdominal muscle thickness

The thickness of abdominal muscles was measured utilizing ultrasound system (Edan DUS 60, Edan Instruments, Shenzhen, China) (USG) with a linear probe of 10 MHz frequency, B-mode. The study was conducted and performed by a certified researcher with 3 years of experience in the field of musculoskeletal system ultrasound examinations and based on the methology elaborated by Niewiadomy *et al*. (29).

The interpretation included thickness of three abdominal muscles: transverse abdominal muscle (TrA), internal oblique muscle (IO) and external oblique muscle (EO). Moreover, the results were also analyzed with a particular consideration of the total thickness of all three muscles (TrA + IO + EO) from the lower edge of TrA to the upper edge of EO and not including the intermuscular septums. The measurement was noted with an accuracy of 0.01 mm and was repeated five times.

Fingertip-to-Floor Test

In the Fingertip-to-Floor Test, the subjects started in a free standing position on the platform specially designed for this test so that the spinal flexion range could be evaluated in the maximum trunk forward bend with legs remaining straight - bending the knees was not allowed (30, 31). The placement of hands on a centimeter scale in their final position provided a score ranging from - 30 cm to + 30 cm, which means that the higher the value, the greater the mobility range. Placing a 5 centimeters (cm) high original FMS platform (Functional Movement System, Inc., Chatham**,** USA) under the feet was a modification of the test. The changes were applied in two ways: by placing the platform under the subject's heel and under the forefoot to influence the tension of the posterior myofascial chain. The measurement, being repeated three times, was noted with an accuracy of 1 cm.

Sit and Reach Test

The Sit and Reach Test assessed the maximum forward flexion of the trunk in a sitting position with the knees extended, feet together and soles of the feet placed against the edge of the box (32). This test was also performed using the dedicated platform (the same as in the Fingertip to floor test) and continued until three results were obtained. The calculations were noted with an accuracy of 1 cm.

Lateral flexion of the spine

The lateral flexion of spine was tested and evaluated with the subject sitting on the edge of the chair with the feet hip-width apart. The plane of motion was marked by a pole placed on participant's shoulders. Measurements were made with a digital inclinometer (Saunders Group Inc., Chaska, USA) placed in the center of the pole. The subject alternately executed the movement of lateral flexion in both directions (31). The movement was repeated three times with an accuracy of 1°.

Statictical analysis

Statistical analysis was performed on the basis of the Statistica 13.3 (TIBCO Software Inc., CA., USA) program. The Kolmogorov-Smirnov test (K-S) with Lileforse's correction was used to assess the normality of the distribution. Gathered quantitative variables are presented in the form of position measures with arithmetical mean (x), and measures of variability with standard deviation (SD). Additionally, the minimum (min) and maximum (max) values and Confidence Intervals (CI) are given. The Analysis of Variance Test ANOVA was used to calculate the level of intergroup differences for quantitative variables with the estimation of the F-value, while to assess the relationship between the variables, the Pearson correlation coefficient (r) was computed. For the tests, an Intraclass Correlation Coefficient was calculated for one researcher (ICC3.1). Statistical significance level was determined as $p < 0.05$. Moreover, the test power was calculated for individualy analyzed variables in relation to the number of variables. In all cases, the power of the test was valid for the null hypothesis.

RESULTS

Both abdominal muscle thickness measurements and the outcomes of mobility tests are summarized in **tables II** and **III**. Statistically significant differences between the groups were demonstrated in the thickness of IO ($p = 0.0057$), EO ($p = 0.0079$) and in the total measurement of TrA + IO + EO ($p = 0.0020$). The mean values of muscle thickness in male group were greater than in women and equaled 10.19 mm ± 2.8 for IO; 9.1 mm ± 3.6 for EO and 22.47 mm ± 5.7 for TrA + IO + EO. However in female group, the mean thickness was 8.77 mm ± 1.6 for IO, 7.44 ± 1.6 for EO and 19.16 mm ± 3 for total measurement of TrA + IO + EO.

Table II. Abdominal muscle thickness measured by ultrasound, divided by gender.

Variable	Sex	N	X	Min	Max	CI - 95%	CI 95%	SD	p*
TrA (mm)	Women	42	2.96	1.48	4.44	2.73	3.18	0.72	0.2452 F-1.37
	Men	38	3.17	1.76	5.52	2.87	3.47	0.92	
IO (mm)	Women	42	8.77	5.19	11.64	8.28	9.25	1.56	0.0057 F-8.1
	Men	38	10.19	6.52	17.68	9.27	11.11	2.80	
EO (mm)	Women	42	7.44	3.72	12.12	6.93	7.94	1.61	0.0079 F-7.4
	Men	38	9.11	4.76	21.34	7.92	10.29	3.60	
TrA + IO + EO (without muscle septum) (mm)	Women	42	19.16	12.17	24.34	18.21	20.11	3.05	0.0020 F-10.8
	Men	38	22.47	14.04	35.42	20.59	24.34	5.69	

*Analysis of variance ANOVA.

Table III. Test results: Fingertip-to-Floor, Fingertip-to-Floor (heel), Fingertip-to-Floor (inverted heel), Sit and Reach, lateral flexion to the right and to the left, divided by gender.

Variable	Sex	N	x	Min	Max	CI - 95%	CI 95%	SD	p*
Fingertip-to-Floor Test (cm)	Women	42	1.89	- 22.33	19.00	- 1.11	4.89	9.63	0.3476
	Men	38	4.05	- 18.33	24.00	0.49	7.61	10.85	
Fingertip-to-Floor (heel), (cm)	Women	42	-0.33	- 24.00	15.33	- 3.07	2.40	8.78	0.5919
	Men	38	0.82	- 20.33	19.33	- 2.61	4.26	10.45	
Fingertip-to-Floor (inverted heel) (cm)	Women	42	-2.22	- 24.00	15.00	- 5.24	0.80	9.70	0.3503
	Men	38	0.02	- 21.00	23.33	- 3.80	3.83	11.61	
Sit and Reach Test (cm)	Women	42	5.06	- 16.00	20.33	2.19	7.94	9.22	0.4771
	Men	38	6.65	- 14.33	24.00	3.15	10.14	10.63	
Lateral flexion to the right (degrees)	Women	42	55.48	33.33	75.67	52.33	58.64	10.14	0.8000
	Men	38	56.11	31.00	90.00	52.15	60.07	12.05	
Lateral flexion to the left (degrees)	Women	42	53.93	31.33	74.00	50.63	57.23	10.59	0.6197
	Men	38	55.17	37.00	89.33	51.34	58.99	11.64	

*Analysis of variance ANOVA.

The mean values of TrA thickness and the Fingertip-to-Floor, Sit and Reach and lateral spinal flexion tests did not differ significantly between men and women.

By analyzing the influence of the remaining morphological variables on the thickness of abdominal muscles, statistically significant weak correlations were obtained in the group of women between: muscle mass and IO (r = - 0.308, p = 0.047); fat mass and TrA (r = - 0.3305, p = 0.033). However, in the group of men significant correlations were found between: body weight and IO (r = - 0.3743, p = 0.021) as well as TrA + IO + EO (r = - 0.3899, p = 0.016); between BMI and IO (r = - 0.3495, p = 0.031) as well as TrA + IO + EO (r = - 0.3279, p = 0.045); between fat mass and IO (r = - 0.3316, p = 0.042); as well as between fat free mass and EO (r = - 0.6492, p = 0.000) and TrA + IO + EO (r = - 0.4688, p = 0.003).

The correlation between muscle thickness and mobility tests was only shown in the group of women between the thickness of TrA and lateral spinal flexion: to the right (r = 0.3492, p = 0.023); to the left (r = 0.3181, p = 0.040). This correlation also proved weak.

All the tests used in the study have shown excellent reliability: ICC3.1 = 0.98 for abdominal muscles thickness, ICC3.1 = 0.99 for Fingertip-to-Floor Test, ICC3.1 = 0.98 for The Sit and Reach Test and ICC3.1 = 0.97 for measurement of Lateral flexion of the spine in the frontal plane.

DISCUSSION

The best known differences in body composition and proportions of men and women according to common knowledge were confirmed in this study such as height, body mass, BMI and fat free mass - higher in the group of men, and fat mass higher in woman. Furthermore, an ultrasound was used to measure the thickness of the abdominal muscles, which is a common method for assessing morphological changes of muscles. The high reliability of this tool at the ICC level of 0.98, also confirmed by other authors, should also be noted (29, 33-35). In the group of men, greater thickness of the internal (on average by 1.42 mm) and external oblique abdominal muscles (on average by 1.67 mm) was obtained, as well as in total measurement of the muscle complex of the lateral abdominal wall (on average by 3.31 mm) compared to the group of women. Assessing by their proportion, regardless of gender, the thickest muscles of the complex is the internal oblique muscle. In both groups, the internal oblique muscle constituted slightly more than 45% of the entire complex thickness. This relationship has been confirmed in other studies (34-36).

Interestingly, no statistically significant differences were found at the level of the transverse abdominal muscle, which is main active stabilizer of the lumbar spine. This can be explained by a deliberate selecion of the subjects, which accounted for healthy, young and professionally active people with no chronic low back pain. Hence, no atrophic changes in the abdominal muscles resulting from impaired motor function, weakened stabilization of the lumbo-pelvic-hip complex or other degenerative deviations in the spine or intervertebral disc were to be expected. In addition, the transverse abdominal muscle is a local muscle composed in the most part of tonic, slow-twitch muscle fibers (ST). In the study by Linek *et al*. (37), thickness of that muscle was assessed by additionally optimizing the measurement with normalization of body weight according to described algorithm. As in our own study, no differences in its thickness relative to sex were found. On the contrary, the external oblique muscle consists predominantly of fast-twitch phasic fibers, and this type of muscle has different characteristics. The study by Jee *et al*. (38) estimated the influence of both sex and the aging process on the mechanical functions of the vastus lateralis muscle by examining its single fiber. It has been demonstrated that the mechanical and functional properties of the muscle, including its power, the fibers' shortening velocity and the maximum force of contraction is influenced by gender to a greater extent than the aging process. These discrepancies were also apparent in the muscle's cross section. Successively, Krivickas *et al*. (39) showed that the quality of single muscle fibers in older women and men is the same, so it cannot explain the differences in the strength, power and function of the entire muscle. It appeares that it is the tonic or phasic composition of muscle fibers and the muscle function they determine that are of greatest importance, and not the sex differences themselves. The transverse abdominal muscle as a trunk stabilizer shows no difference in thickness between men and women, but several differences are observed in the global muscles that are responsible for one's performance; including strength, speed or power.

There are studies that indicate differences in the thickness of the TrA muscle in men and women, but in our judgement, their limitation lies in the methodology - the use of convex probe instead of linear probe, which significantly affects the objectivization of measurements (40) as well as conducting research on a small number of subjects (41).

In our study, no statistically significant differences were found in the mobility of the trunk in the frontal and sagittal planes. The men obtained higher mean scores on each test. Many authors have used the Fingertip-to-Floor and Sit and Reach tests in various ways to evaluate mobility. For instance, Kuszewski *et al.* (42) in their study focused on the assessment of mobility in two groups - physically active and inactive people, of which the first group had better mobility results. A similar study was conducted by Knapik *et al.* (43), in which, using the Fingertip-to-Floor, Sit and Reach tests and lateral flexion of the spine tests, better results were also obtained in the group of physically active people. Gender was not taken into account as a differentiating variable in this research. In the study by Minarro *et al.* (44) the range of the spinal flexion was approached by measuring the thoracic and lumbar angles during performing numerous variants of the Sit and Reach and Fingertip-to-Floor tests. Interestingly, in all tests, the group of men acquired higher values of the thoracic angle than the group of women. The authors also point out the exceptional consistency of these trials, which have been used unchangingly for 50 years. Nevertheless, Jackson and Langford (45), while analyzing male and female Sit and Reach test results, discovered that women, in turn, obtained better results. As in this study, they used a centimeter scale. Finally Youdas *et al*. (46) in Sit and Reach test noticed a greater range of flexion of the hip joints also in the group of women compared to men.

An analysis of the research conducted so far shows that failure of the abdominal muscles, which act as local stabilizers, may result in compensation in the form of shortening of the hamstring muscle group, and thus a reduction in mobility (44-49). However, in this study it was not possible to establish a relationship between the thickness of abdominal muscles and the results of selected mobility tests, which is probably related to the lack of dysfunctional symptoms of the lumbar spine in the group of respondents taken into account in other publications.

In summary, the methodology used in this publication is the mobility tests and measurements of the abdominal muscle thickness utilizing an ultrasound is reliable and often used by reaserchers. Differences in the basic morphological parameters characterizing the studied group and in the thickness of abdominal muscles have been demonstrated.

In our opinion, the lack of differences between sex in the transverse abdominal muscle allows for the interpretation of its results without division into sex. It is different in the case of internal and external oblique muscles, where this division should be taken into account. It should be assessed whether other deep muscles, apart from the transverse abdominal muscle, are differentiated by gender. This requires further research into the mechanism of central stabilization.

Some limitations were highlighted in the study.The lack of divergence between men and women in the results of the mobility tests may be related to the selection criteria for the comprised group - which was a limitation to the results. The subjects were young, healthy people with a correct body weight and standard physical and professional activity. Their BMI value was a condition for obtaining high reliability of ultrasound measurements.

CONCLUSIONS

Gender differentiates the thickness of the muscles of the lateral abdominal wall. In the group of men there is a greater thickness of the internal and external oblique muscle, as well as the entire TrA + OI + OE muscle complex.

No relationship between sex and the thickness of the transverse abdominal muscle was demonstrated.

There were no differences in the mobility of the trunk between women and men.

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None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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