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Evaluation of the morphology of the lateral abdominal muscles in children aged 9 to 13 years with normal body posture: a pilot study

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Małgorzata Matyja[1], Justyna Ćwięląg[2], Aleksandra Sowa[3], Katarzyna Szewczyk[3]

[1]*Department of Physiotherapy of the Movement Disorders and Sports Medicine, Academy of Physical Education, Katowice, Poland*

[2]*Institute of Physiotherapy and Health Sciences, Academy of Physical Education, Katowice, Poland*

[3]*Graduate The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland*

Abstract:

The study presents the results of sonographic evaluation of the lateral abdominal muscles (LAM) in 36 children aged 9-13 with normal body posture. B-scanner MINDRAY DP-6600 Digital Ultrasonic Diagnostic Imaging System was used in the examination. The measurement was performed in five positions: resting lying, corrected lying, corrected sitting, resting standing, and corrected standing. The researchers were interested in answering questions concerning the thickness of individual lateral abdominal muscles, differences between boys and girls, differences between resting and corrected positions, and determination of the position in which LAM have the highest values.

Regardless of body position, the lowest thickness was found for the TrA muscle, whereas the highest one was recorded for OI muscle. In boys, most of the lateral abdominal muscles were thicker than in girls. The greatest thickness of all muscles was reported in the corrected sitting position. There was no uniform tendency in LAM thickness changes in the resting and corrected positions. In the corrected lying position, the muscles had greater thickness than in the standing resting position. In the corrected standing position, TrA muscle increased its thickness compared to the resting standing position, whereas the thickness of OI and OE muscles decreased. The literature review indicated that researchers who examined LAM also have not obtained homogeneous results in terms of an increase or decrease in the thickness of these muscles, either in different positions or during different activities.

Keywords: lateral abdominal muscles, children, ultrasonography, ultrasound scanning in different body positions

Corresponding author:

Małgorzata Matyja
Department of Physiotherapy of the Movement Disorders and Sports Medicine,
The Jerzy Kukuczka Academy of Physical Education, 40-065 Katowice,
Mikołowska 72A, Poland
m.matyja@awf.katowice.pl

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Introduction

Correct postural and motor control requires, among other things, sufficient activity of the muscles responsible for the stabilization of the lumbopelvic-hip complex. The Bergmark [1] distinguished three lateral abdominal muscles (LAM): the transverse abdominal muscle (musculus transversus abdominis, TrA), the internal oblique muscle (musculus obliquus internus abdominis, OI), and the external oblique muscle (musculus obliquus externus abdominis, OE) [2,3]. The deepest muscle is the transverse abdominal muscle, covered by the internal oblique muscle and the shallowest external oblique muscle [4,5]. The greatest role is attributed to the transverse abdominal muscle, which together with the posterior part of the internal oblique muscle, is part of a deep cylinder responsible for the stabilization of the upper body [2, 6].

Currently, ultrasonography seems to be the best method to assess the morphology of the lateral abdominal muscles. Furthermore, ultrasonography is a non-invasive and painless method. Ultrasound images are captured in real time and can reveal the structure and movement of muscles, tendons, and ligaments [7]. Previous research on the characteristics of the lateral abdominal muscles evaluated using ultrasonography has shown similarities to those obtained using magnetic resonance imaging or electromyography [8]. Most scientific research has been done in adults and focused mainly on the observation of the transverse abdominal muscle and the lumbar region of the multifidus muscle. This is due to the search for the aetiology of contemporary problems of back pain, which is supposed to be affected by the dysfunction within these muscles [9,10, 11, 12, 13]. Few studies concerning children have analysed the morphology of LAM in children with scoliosis [14,15] and in healthy children with normal body posture [16].

In light of the small number of reports on the functioning of LAM muscles in children, the aim of the present study was to assess the morphology of these muscles based on ultrasonography of students aged 9 to 13 years with normal body posture. The study was conducted in selected resting and corrected body positions.

In light of the presented study aim, the following research questions were asked: What is the thickness of individual LAM muscles in the resting and corrected positions? Are there differences in the thickness of LAM between boys and girls? Are there differences in the thickness of LAM between resting and corrected positions? What is the position for which the thickness of LAM reaches the highest values?

Material and Methods

Material

The study included students aged 9 to 13 years. They were students of the School Complex No. 3 in Jaworzno and Primary School No. 7 in Czeladź, Poland. The study was approved by the Bioethics Committee of the Academy of Physical Education in Katowice (Resolution No. 3/2017 of 05 Dec 2017).

The inclusion criteria were:

- correct body posture assessed based on the point system; a score ≤ 5 points was considered as the correct posture [17],
- consent of parents or legal guardians to participate in the study,
- over 9 and under 13 years of age.

The above criteria were met by a total of 36 students, including 24 girls and 12 boys aged 9 to 13. The biometric data are presented in Table 1 [Tab. 1].

Method

Measurements of the thickness of the lateral abdominal muscles (OE, OI, and

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Table 1. Biometric data of the test group

Parameters	Girls			Boys		
	X	SD	Min-Max	X	SD	Min-Max
Age	11.83	1.20	Min- 9 Max-13	11.33	1.07	Min- 10 Max-13
Body weight [kg]	46.27	12.79	Min-32.9 Max-70.8	48.75	14.58	Min-30.4 Max -59.5
Height [m]	1.53	0.1	Min-1.34 Max-1.71	1.55	0.11	Min-1.32 Max-1.73
Quality of posture [points]	2.88	1.54	Min-0 Max-5	2.83	1.99	Min-0 Max-5

TrA) were performed in the final phase of expiration according to the methodology proposed by P. Linek [5].The right and left sides were evaluated separately. The measurement was carried out twice for each side and then the means were calculated. The ultrasonic wave reached a depth of 5.39cm. The wave frequency was 7.5 MHz. The head of the ultrasound device was positioned perpendicular to the body axis. It was applied on the anterior-lateral abdominal wall, between the iliac crest and the edge of the last muscle of the 12th rib.

The photographs were taken with a B-scanner device (MINDRAY DP-6600 Digital Ultrasonic Diagnostic Imaging System; Medical Corp., Redmond, WA, USA with a 60 mm video 75L38EA transducer 5.0/7.5/10 MHz). The photos were processed in Photoshop. An auxiliary horizontal line with perpendicular lines was drawn. The two middle lines (on the right and left) indicated the end of the fascia of the TrA muscle. From these lines, the distances of 12.5 mm were drawn in both directions to obtain two extreme lines on both sides that allowed for the evaluation of the thickness of LAM muscles (Fig.1).

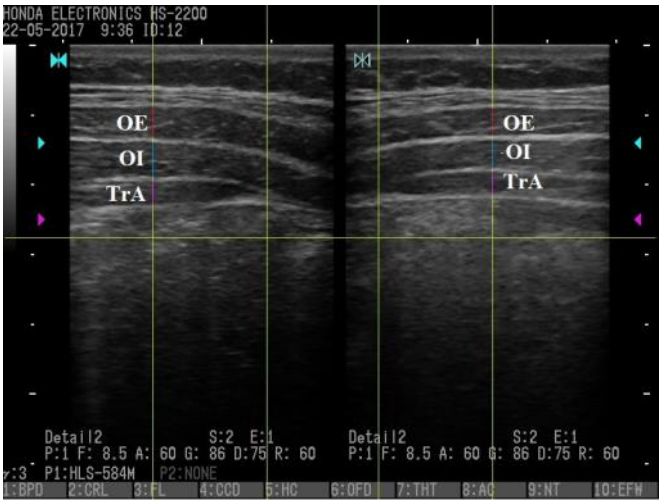

Figure 1. Sample USG image of the lateral abdominal muscles

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The measurement was performed in five positions (Fig. 2):

1. Resting lying position: lying supine, upper limbs along the body, lower limbs extended.
2. Lying position corrected: lying supine, upper limbs along the body, lower limbs extended, feet in dorsiflexion parallel to each other.
3. Corrected sitting position: straddle sitting with the upper limbs resting on the thighs, the spine in the upright position, lower limbs extended with the knee joints tangential to the ground, feet in dorsiflexion placed parallel to each other. The examination was conducted only in the corrected position. Examination of the muscles of the lateral abdominal muscles in the resting sitting position was infeasible for technical reasons.
4. Resting standing position: the habitual posture taken by the study participant, with upper limbs along the body, and lower limbs kept at hip width and evenly loaded.
5. Corrected standing position: the child leaning against the wall, head and heels in contact with the wall, feet parallel to each other, upper limbs crossed on the chest, hands resting on shoulder joints.

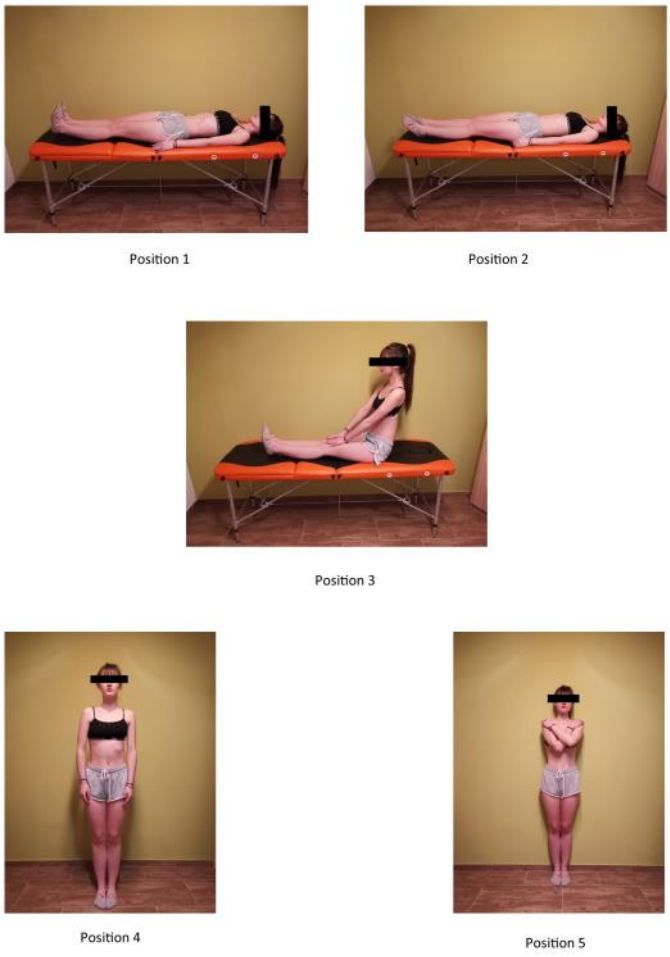

Figure 2. Graphical presentation of the positions used in the examination

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Statistical analysis

Two pieces of software were used in the study for descriptive statistics and statistical analysis. The measurement results were collected in an Excel spreadsheet. Excel was used to analyse the age, weight, and number of points scored by children during the examinations using the T. Kasperczyk's methodology. Statistical analysis was carried out using STATISTICA v.13 (StatSoft). The Student's t-test was used to assess the statistical significance of the presented test results. A level of significance was set at $p \leq 0.05$.

Results

Statistical analysis showed no statistically significant differences in thickness between the right and left muscles. The only exception was the OI muscles in the resting lying position in both genders. They showed statistically significant differences between the right and left sides. In most cases, the values of p ranged from -0.29 to 0.99. Therefore, the thickness of individual muscles was averaged and further analysis was conducted without separating the right and left sides. Table 2 shows the values of the thickness of individual muscles with the division into boys and girls.

Table 2. Thickness of the LAM in the examined students with respect to gender

Position	TRA [mm]		OE [mm]		OI [mm]	
	Boys	Girls	Boys	Girls	Boys	Girls
Resting ly-ing	3.28	2.91*	3.71	3.6*	5.03	4.51
Corrected lying	3.54	2.85*	3.98	3.51*	6.78	5.44
Corrected sitting	4.2	3.9	5.68	5.17	7.79	7.12
Resting standing	3.4	3.35	4.66*	4.06*	5.87*	6.03*
Corrected standing	3.45	3.39	3.74*	3.57*	5.48*	5.59*

*Legend: *muscles which have a lower thickness in the corrected position compared to the resting position*

The data presented in Table 2 show that the highest thickness in all positions in both sexes was found for the internal oblique muscle (OI). The lowest values were recorded for the transverse abdominal muscle (TrA). Furthermore, all examined muscles had the highest values in the corrected sitting position.

It is slightly surprising that the LAM muscles often have a smaller thickness in corrected compared to resting positions [marked * in Tab. 2].

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These results [Tab. 4] are statistically significant only for OI (p=0.01) in lying and standing positions.

Table 3 shows the difference in muscle thickness between the resting and corrected positions. Boys had greater muscle thickness than girls in most positions. The exception was the OI muscle - in the resting and corrected standing positions. Statistically significant differences were found only for OI (p=0.04) and TrA (p=0.05) in the corrected lying position [Tab. 3].

Table 3. Student's t-test assessment of the differences in muscle thickness between boys and girls in resting and corrected positions

Position	TrA (p)	OE (p)	OI (p)
Resting lying, boys vs girls	0.25	0.79	0.36
Corrected lying, boys vs girls	0.05*	0.26	0.04*
Corrected sitting, boys vs girls	0.39	0.35	0.38
Resting standing, boys vs girls	0.82	0.21	0.79
Corrected standing, boys vs girls	0.85	0.66	0.83

Legend: * statistically significant differences at p≤0.05*

Table 4 shows the differences in muscle thickness between:

1. the same resting and corrected positions (e.g. resting lying - corrected lying; resting standing - corrected standing);
2. different resting and corrected positions (e.g. resting lying - resting standing, resting lying - corrected standing).

Comparison of the TrA, OE, and OI muscles in the corrected standing position to the resting standing position revealed that only the TrA muscle increased its thickness in both boys and girls [Tab. 3] in the corrected standing position compared to the resting standing position. Other OE and OI muscles have a lower thickness in the corrected standing position compared to the resting standing position [Tab. 2]. These results are statistically significant in both genders only for the OI muscle (p=0.01) [Tab. 4] in favour of the resting lying and standing positions.

It is worth noting that the thickness of most muscles reaches the highest values in the corrected sitting position [Tab. 2]. Comparison of the corrected sitting with other positions revealed that all results were statistically significant in girls. However, statistical significance in boys was found in six cases [Tab. 4].

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Table 4. Differences in the thickness of the lateral abdominal muscles between assessed positions evaluated by the Student's t-test

Position	TrADz (p)	OE Dz (p)	OI DZ (p)	TrACh (p)	OE Ch (p)	OI Ch (p)
Resting lying vs corrected lying	0.77	0.78	0.01*	0.57	0.62	0.01*
Resting standing vs corrected standing	0.84	0.15	0.00*	0.91	0.07	0.00*
Resting lying vs resting standing	0.06	0.16	0.00*	0.73	0.11	0.00*
Resting lying vs corrected standing	0.04~	0.94	0.01*	0.68	0.94	0.01*
Corrected lying vs resting standing	0.03~	0.10	0.16	0.75	0.10	0.16
Corrected lying vs corrected standing	0.02~	0.86	0.70	0.84	0.86	0.70
Corrected sitting vs resting lying	0.00^	0.00^	0.00^	0.07	0.00^	0.01^
Corrected sitting vs corrected lying	0.00^	0.00^	0.00^	0.20	0.00^	0.32
Corrected sitting vs resting standing	0.02^	0.01^	0.04^	0.08	0.06	0.03^
Corrected sitting vs corrected standing	0.03^	0.00^	0.00^	0.11	0.00^	0.01^

*Legend: 1. ~ statistically significant differences between the resting/corrected lying position and the resting/corrected standing position 2. * statistically significant differences between resting and corrected positions 3. ^ statistically significant differences between the corrected sitting position and other positions*

The results presented in Table 3 show that statistically significant differences in LAM thickness between the remaining resting and corrected standing and lying positions occurred in seven cases. It is worth emphasizing that these differences between the resting and corrected positions and the corrected sitting are statistically significant in 18 cases.

It is also remarkable that there was not a single position in boys where a statistically significant difference in the thickness of the TrA muscle occurred between the resting and corrected positions [Tab. 4]. Furthermore, the OE muscle [Tab. 4] changed its thickness statistically significantly only when individual positions were compared to the corrected sitting. There were also statistically significant differences in the thickness of TrA between the resting and corrected standing position in girls and OI in both sexes [Tab. 4].

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Discussion

The sonographic analysis of the morphology of the lateral abdominal muscles has found many supporters over the years [14-27]. Ultrasound examinations have been performed in many positions, both resting and dynamic, for example, with the lower limb being lifted in the active straight leg raise (ASLR) test or the abdominal drawing in manoeuvre (ADIM) test [15,23,24]. Comparison of the findings obtained in this paper with those presented in other publications reveals both consistent and contradictory results.

The results obtained for muscle thickness are consistent with those of most authors. These results can be referred to both children and adults, as no differences in LAM thickness were found between individuals of different ages [27,28]. Most researchers have measured the thickness of LAM in the resting position. A. F. Mannion et al. [26] examined women and men (57 persons, between 30 and 50 years of age) and found that the thickest of the examined muscles was OI and the thinnest was TrA, both in the resting lying position and during the ADIM manoeuvre. P. Linek et al. [25] examined LAM thickness in students (71 people aged between 10 and 16 years) in the resting position and found a similar relationship (OI>OE>TrA). In the same study, P. Linek et al. [25] also found that during the ADIM manoeuvre, the order of muscles changed slightly: the internal oblique muscle remained the thickest lateral abdominal muscle, but the thinnest was the external oblique.

Dong-Ki Kim et al. [15], who examined a group of healthy people and patients with scoliosis (65 people, between 11 and 28 years of age) established the OI>OE>TrA relationship in the group of healthy individuals. Rankin G. et al. [27] examined 123 people (55 men and 68 women aged between 21 and 72 years) found the same relationship (OI>OE>TrA) as A.F. Mannion [26], P. Linek [25], and Dong-Ki Kim [15]. This is largely in line with the results presented in this paper. It should be added, however, that higher TrA thickness compared to OI was also reported in a study of soldiers published by Hoppes C.W. et al. [20].

Furthermore, in the present study, an identical relationship (OI>OE>TrA) was observed in the corrected lying, corrected sitting, resting standing and corrected standing positions.

The data were not processed in the form of a separate assessment for the right and left sides as the differences between the two sides proved to be statistically insignificant for the vast majority of muscles. Similar results were presented by A.F. Mannion et al. [26] for a group of 57 healthy individuals aged 22-62 years at rest and during typical exercises that activated LAM muscles. No significant differences were found between the left and right sides of LAM. However, there were also studies showing differences between the sides. Linek et al. [25] indicated that on the right side, the OE and OI muscles were thicker than on the left side. Gray J. et al. [18] reported that asymmetry of LAM activity occurs in athletes practising asymmetric sports (e.g. cricket). It should be added that the dominant side had always smaller LAM thickness values.

Boys reported greater thickness than girls in most muscles except for the OI muscle in the resting and corrected standing positions. Statistically significant differences were found only for OI ($p=0.04$) and TrA ($p=0.05$) in the corrected lying position. This result is consistent with the findings of Rankin G. et al. [27], who examined 123 people, including 55 men and 68 women. However, these researchers carried out the examinations only in the resting position. Also Tahan N. et al. [29] demonstrated that male subjects had much thicker abdominal muscles (TrA, OI, OE) than their female peers. The study was conducted on 156 healthy people aged

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18 to 44 years. No studies were found to demonstrate the differences in LAM thickness between boys and girls of comparable age to those examined in our study.

Stetts DM. et al. [30] studied LAM (TrA, OI, OE) at rest and during the abdominal drawing in manoeuvre (ADIM) in 12 healthy older adults. In their study, TrA almost doubled in size, while the thickness of OI and OE remained relatively constant during ADIM. Furthermore, there was no significant difference between the thickness of the left and right TrA and OI at rest or during ADIM.

Mew R. [31] conducted the examinations of the LAM in 28 healthy individuals at rest and during lower abdominal hollowing (LAH) in the standing position and lying position with flexed lower limbs (crook lying). The thickness of all LAMs in the standing position was found to be increased compared to the lying position. Greater changes in thickness during LAH in the standing position were observed for TrA, while OE and OI showed greater changes during LAH in the lying position. TrA showed a much greater increase in thickness during LAH in the standing position compared to the lying position. In our study, the TrA muscle in both boys and girls was also thicker in the resting standing position compared to resting lying. In most studies, the LAM muscles increased their thickness during activity, but Gray et al. was already quoted [18].

Two phenomena not described by other authors were reported in the present study. One was the situation when OE and OI muscles had a lower thickness in the corrected standing position compared to the resting standing position [Tab. 2]. These results are statistically significant in both genders for the OI muscle ($p=0.01$). Unfortunately, there are no comparable studies and it is difficult to interpret this phenomenon. It seems that in more active positions, the muscles should show greater thickness. Another specific phenomenon is the statistically significant differences in the thickness of most LAMs in the corrected straddle sitting position compared to other positions. This phenomenon may seem understandable as pelvic control in the straddle sitting position is difficult and requires considerable mobilization and integration of the stabilizing muscles.

The present study has some limitations. Children aged 9 to 13 years are not at the same developmental stage since some are in the prepubertal period and some are probably already in puberty. However, the assessment of the characteristics of puberty would require the participation of a physician. Furthermore, for technical reasons, we did not perform the LAM examinations in the resting sitting position although the LAM activity in this position could be interesting compared to the corrected sitting position.

In conclusion, the TrA muscle in children aged 9 to 13 years had the smallest thickness, whereas the thickness of OI was the greatest, regardless of the examined body positions. In boys, most of the LAM muscles had greater thickness than in girls. Statistically significant differences were found only for OI ($p=0.04$) and TrA ($p=0.05$) in the corrected lying position. There was no uniform tendency in changes in LAM thickness. In the corrected lying position, the muscles are thicker than in the resting position. In the corrected standing position, TrA muscle increased its thickness whereas the thickness of OI and OE decreased. All the muscles studied had the greatest thickness in the corrected straddle sitting position. It is advisable to develop exercises that activate the lateral abdominal muscles in the corrected sitting position.

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