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Reliability of B-mode ultrasound imaging of the lateral abdominal muscles in healthy children during the active straight leg raise test

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Abstract

Background: To date, reliability of ultrasound imaging (USI) measures of the abdominal muscles in children during the active straight leg raise (ASLR) test has not been confirmed. The aim of this study is to assess the intra-rater reliability of USI in measuring of the thickness and percent thickness change of the external oblique (EO), internal oblique (IO) and transversus abdominis (TrA) on both sides of the body during the ASLR test.

Material/Methods: Thirty-two healthy children between 10-12 years old participated in the study. Three repeated USI measurements were recorded, in supine and resting positions and during the ASLR test. In supine position, measurements were collected at the end of normal expiration. In the case of ASLR, measurements were collected when the person undergoing examination touched the transverse delimiter with the distal part of the lower leg. A repeat session of the measurements was carried out 6 to 8 days later.

Results: The use of mean value of the three repeated measurements showed that $ICC_{3.3}$ fluctuated from 0.81 to 0.97 for OE, OI and TrA in resting position and during the ASLR test. In terms of percentage change of muscle thickness, the $ICC_{3.3}$ result obtained for TrA, OE and IO were 0.86, 0.83 and 0.78, respectively.

Conclusions: The USI evaluation of the lateral abdominal muscles thickness at rest has high reliability in children between 10-12 years old. The USI of the actual thickness and reflex activity of OE, OI and TrA during the ASLR test, based on three repeated measurements, is also reliable. It is recommended to perform three repeated measurements for children between 10-12 years old. There is still a need to seek solutions that will decrease the SDD value while evaluating the reflex activity of the lateral abdominal muscles during the ASLR test.

Keywords: reliability; ultrasound; children; abdominal wall

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INTRODUCTION

Lateral abdominal muscles consist of the transversus abdominis muscle (TrA), internal oblique (OI) and external oblique (EI). Each of these muscles has a specific function but, together with the dorsal muscles, they play a significant role in spine stabilization (Hodges, 1999). Their assessment in adult healthy people as well as in patients with spinal pain has been the object of interest for many researchers (Ferreira et al., 2004; Hides et al., 2008; Critchley et al., 2011; Ishida and Watanabe, 2013; Myśliwiec et al., 2014). In order to evaluate those muscles, the researchers have mainly used ultrasound imaging (USI) measures, which correlate with the results obtained by means of needle electromyography (Hodges et al., 2003; McMeeken et al., 2004) and magnetic resonance imaging (Hides et al., 2006). On the basis of two systematic reviews, it was unambiguously confirmed that the USI is a reliable method to assess the abdominal muscles in adults (Hebert et al., 2009; Koppenhaver et al., 2009b). In the case of children, there are considerably fewer studies concerning the reliability of USI. Studies carried out to date confirm that USI is a reliable tool to evaluate the lateral abdominal muscles in the resting recumbent, sitting and standing positions, during the abdominal drawing-in maneuver in the supine position in people between 10-16 years of age (Linek et al., 2014a; Linek et al., 2014c; Yang et al., 2014), as well as during the active straight leg raise (ASLR) test in the case of people between 13-16 years of age (Linek et al., 2014b).

ASLR test has been introduced to assess the ability to transfer loads through the pelvic girdle and to discriminate between healthy subjects and patients with lumbopelvic pain (Mens et al., 2001, 2002). In the only research in which changes within TrA and OI during ASLR test were compared, Teyhen et al., using USI as a basis, demonstrated differences in the TrA and OI activity in participants with unilateral lumbopelvic pain (Teyhen et al., 2009).

Taking into consideration that the changes in deep abdominal muscle activity during the ASLR test are connected with spinal pain, they may also be a marker of motor control disorders that may occur at various stages of children's and teenagers' development. For this reason, performing the USI test on abdominal muscles must be taken into consideration in this group. Currently, we know that carrying out three repeated measures during ALSR ensures high reliability of the lateral abdominal muscles USI in people over the age of 13 (Linek et al., 2014b), which is the period when a dynamic physical development takes place. In the studies referred to above, all the participants were fully conscious, and their age made it possible to ensure full cooperation with the person conducting the examination. All of this had an effect on the reliability level obtained for this age group (13-16 years old). In the younger age group, the examination may be more stressful, leading to greater variability in the activity of the abdominal muscles examined (greater stress and anxiety = different muscle tone). Marras et al. (2000) demonstrated that the muscles function differently in psychosocially stressful environments; the authors suggest that the stress factor is responsible for the change in muscular co-activation. For that reason, in this study, it was decided to examine the reliability of the USI of lateral abdominal muscles at rest and in the ASLR test in children aged 10 to 12.

MATERIAL AND METHODS

Participants

Participants aged 10 to 12 who did not display any kind of faulty posture, especially scoliosis, during screening tests, entered the study. Additionally, the research project excluded those people who: a) had any surgical procedure in the areas of thorax, abdominal cavity, pelvic girdle or spine; b) suffered from chronic cardiopulmonary disease; b) had a disease/injury which was connected with a long-term (>14 days) hospitalization or immobility within 2 years preceding the study; c) experienced pain in the spinal area, pelvic girdle or lower extremities within the three months preceding the study; c) used medicines which could affect the functioning of nervous or muscular system within the year preceding the study. All the participants and/or their legal guardians gave a written consent to participate in the study. The study also received a positive opinion from the local bioethics committee.

Active Straight Leg Raise Test

The ASLR test was performed in a supine position on a typical examination couch. All the participants had the lower extremities positioned straight, feet 20 cm apart and the upper extremities placed along the torso. The applied methodology of the test was slightly different than the methods used by O`Sullivan et al. (2002) and Teyhen et al. (2009). In the cases referred to above, the participants were instructed to raise the lower extremity 5 cm above the ground, whereas in this study they were instructed to raise the lower extremity in such a way that a 30 degree angle of bend was obtained in the coxal articulation. In order to do that, we used a goniometer (Rippstein V-Plurimeter, Pirettes, Switzerland), by means of which the range of raising the lower extremities was measured and the transverse delimiter was adjusted to the requested height. The participants' task was to raise the lower extremity until it touched the transverse delimiter (Figure 1). Upon reaching the requested height, the participant was supposed to maintain the lower extremity in this position until he/she heard the instruction "drop it".

The change in the procedure can be explained by the fact that lifting the lower extremity to the level of 5 cm above the ground (the distance between the heel and examination couch) results in different range of flexion in the coxal articulation, which depends on the length of lower extremities. In this study, the purpose was to provide a standardized range of flexion in the coxal articulation, as all the examined muscles of the lateral abdominal wall are located in the pelvic area, which is functionally coupled with the coxal articulation.

Figure 1. Ultrasound scanning during the active straight leg raise test.

Ultrasound Imaging

The measurement of resting thickness of the lateral abdominal muscles was collected in supine position. The participant was asked to adopt a relaxed position of the body and maintain natural breath. The measurement was always collected at the end of normal expiration. In the case of the ASLR test, the measurement was collected when the participant had touched the transverse delimiter with the distal part of the shin, that is, when he/she obtained the 30 degree flexion in the coxal articulation. All measurements were always collected in an alternate manner; however, in the case of the ASLR test, they had always started from the right body side, raising the right lower extremity first. Each of the participants had to alternately raise the right and left lower extremity six times altogether. In this way, we obtained three measurements for each of the sides and both lifted extremities.

The entire procedure was performed by one physiotherapist (P. L.), who, prior to the current study, had had six months' experience in performing this type of measurements (only in adults). Additionally, he had completed a full series of training courses and received a certificate which entitles one to perform USI measures in rehabilitation.

This single-group repeated-measures design involved a baseline measurement session and a follow-up session 6 to 8 days later. The examinations were carried out at the school attended by the children who qualified for the study, in the nurse's office, which had been specially prepared for the purpose of the examination. Therefore, all subjects underwent the examination under the same conditions, using the same equipment. All assessments were carried out by the same researcher. A total of 36 images were taken of each participant (18 during the first session and 18 during the second session) to calculate intra-examiner reliability for all abdominal muscles.

Data Processing

All of the images taken during the examination were saved on a data storage device of the ultrasound scanner, and the measurements were read off directly after the examination with the use of original software provided with the USG scanner (no additional software was used for that purpose).

The gathered results of the OE, OI and TrA muscle thickness on the right and left body side at rest and during ALSR were the basis for calculating the percentage thickness change in the particular abdominal muscles, which is their reflex activity. For this reason, the following equation was used:

$$\frac{Thickness\ during\ ASLR - Thickness\ at\ rest}{Thickness\ at\ rest} x\ 100$$

$$= Reflex\ activity\ during\ ALSR\ [\%]$$

for each of the muscles separately.

Statistical Analysis

An intraclass correlation coefficient (ICC) was calculated to assess intra-rater reliability (ICC 3, k) of each muscle. Model 3, k was used for the intra-rater analysis because the specific rater was the only tester of interest (Shrout and Fleiss, 1979). In addition, the standard error of measurement ($SEM = SDx\sqrt{1 - ICC}$) and the smallest detectable differences ($SDD = 1.96\ x\ SEMx\sqrt{2}$) were calculated for each measurement. To investigate the effect of using the mean of multiple thickness measurements on reliability and measurement precision, the ICC$_s$ and standard error of measurements using the mean of the first 2 and 3 measures were compared with those using single measures. To compare the reliability with reliability of measurements of the adult and adolescent populations, we used the statistical approach based on the work by Koppenhaver et al. (2009a) and Linek et al. (2014b).

RESULTS

Participants

14 girls and 18 boys aged 10 to 12 took part in the research. The full characteristics of the research material are presented in Table 1.

Table 1. Demographic data of study subjects (N=32)

Characteristic	
Age, y	11.3 ± 0.70
Sex	43.7 % girls
Height (cm)	151.1 ± 7.32
Mass (kg)	41.1 ± 6.7
Rohrer index*	1.19 ± 0.14

* = [Body mass/body height)^3] x 100, where body mass is in grams and body height is in centimeters

Reliability

The mean value of repeated measurements of OE, OI and TrA muscle thickness at rest decreases SEM on average by 22%, whereas the third additional measure decreases SEM by 40% compared to the first one. A similar situation happens with the lateral abdominal muscle thickness during the ASLR test, in which case the mean value of the three repeated measurements decreases SEM by 36.5% compared to the first measurement (Table 2). For that reason, the reliability evaluation was performed for three repeated measurements.

Regardless of the condition of specific lateral abdominal muscles (resting or contracted during the ASLR test), the mean value of their thickness in the three repeated measurements ($ICC_{3,3}$) was characterized by a high reliability within the limits of 0.81-0.97. The analysis of muscle reflex activity showed a significantly lower result for ICC, which was on average 0.86, 0.83 and 0.78 for TrA, OE and OI, respectively. SDD for the three repeated measurements was on average 24.5, 24.3 and 19.1% for OE, OI and TrA, respectively. The detailed results of ICC and SDD for the specific muscles on both sides of the body are presented in table 3.

DISCUSSION

This study is the first study in which it was decided to assess the reliability of USI of the lateral abdominal muscles on both sides of the body during the ASLR test in children aged 10 to 12. We also carried out the rest thickness evaluation of all analyzed muscles. The performed examination demonstrated that the thickness of OE, OI and TrA is characterized by a very good result of $ICC_{3,3}$ above 0.80. These types of results are coherent with other examinations performed on children and adult populations (McMeeken et al., 2004; Koppenhaver et al., 2009a; Teyhen et al., 2009; Linek et al., 2014c). Similar results were also obtained in relation to the real values of abdominal muscle thickness during the ASLR test. In the study of Linek et al. (2014b), the examination involved teenagers aged 13 to 16, and the obtained results of $ICC_{3.3}$ were on a level of 0.95 for OE, OI and TrA.

Table 2. Difference in standard error of measurements* using the mean of 2 and 3 measures compared with that of a single measure

	Intraexaminer					
	Right leg raised			Left leg raised		
Muscle / State	Single measure	Mean of two measures	Mean of three measures	Single measure	Mean of two measures	Mean of three measures
EO – right side						
Rest	0.41	0.31	0.26			
Contracted (ASLR)	0.56	0.36	0.30	0.89	0.82	0.68
IO – right side						
Rest	0.65	0.56	0.43			
Contracted (ASLR)	0.81	0.55	0.48	0.76	0.64	0.50
TrA – right side						
Rest	0.38	0.27	0.19			
Contracted (ASLR)	0.58	0.37	0.32	0.40	0.32	0.26
EO – left side						
Rest	0.56	0.39	0.27			
Contracted (ASLR)	0.62	0.58	0.41	0.47	0.39	0.30
IO – left side						
Rest	0.45	0.36	0.29			
Contracted (ASLR)	0.73	0.72	0.56	0.73	0.59	0.49
TrA – left side						
Rest	0.36	0.27	0.21			
Contracted (ASLR)	0.55	0.39	0.33	0.46	0.37	0.28

EO – external obliques abdominis; IO – internal obliques abdominis; TrA – transversus abdominis; *in millimetres

Table 3. Intraexaminer reliability using a mean of 3 measures

Muscle State	Right leg raised†		Left leg raised†	
	$ICC_{3.3}$	SDD*	$ICC_{3.3}$	SDD*
OE – right side				
Rest	0.95	0.72		
Contracted (ASLR)	0.93	0.85	0.81	1.90
% change	0.75	22.5	0.81	26.6
OI – right side				
Rest	0.94	1.18		
Contracted (ASLR)	0.93	1.35	0.94	1.38
% change	0.72	21.9	0.78	22.5
TrA – right side				
Rest	0.97	0.53		
Contracted (ASLR)	0.92	0.88	0.93	0.72
% change	0.81	19.5	0.90	19.0
OE – left side				
Rest	0.96	0.74		
Contracted (ASLR)	0.92	1.21	0.94	0.84
% change	0.87	25.7	0.89	23.5
OI – left side				
Rest	0.96	0.81		
Contracted (ASLR)	0.89	1.55	0.92	1.36
% change†	0.77	27.5	0.79	25.5
TrA – left side				
Rest	0.95	0.59		
Contracted (ASLR)	0.85	0.92	0.88	0.79
% change†	0.87	19.2	0.88	18.9

EO – external obliques abdominis; IO – internal obliques abdominis; TrA – tranversus abdominis; ICC – intraclass correlation coefficient; SDD – the smallest detectable differences; *Values in millimeters except % change;† – does not apply to resting thickness values

In the studies concerning adults, the researchers analyzed only OI and TrA and obtained the results of $ICC_{3.2}$ = 0.96 and $ICC_{2.3}$ = 0.88, respectively (Koppenhaver et al., 2009a; Teyhen et al., 2009). In the current study, the value of $ICC_{3.3}$ for the muscle thickness during the ASLR test was 0.90, 0.92 and 0.90 for OE, OI and TrA, respectively. As may be observed, regardless of the age of the examined participants, the results of reliability of USI during evaluation of the thickness of lateral abdominal muscles in the ASLR test are comparable.

However, in contrast to the study of Koppenhaver et al. (2009a) and similarly to the study of Linek et al. (2014b), the current study showed a 40% decrease of SEM only for the three repeated measurements, whereas in the study of Koppenhaver et al. (2009a), this effect was already achieved with the mean value of two measurements. Therefore, the current study confirms that in the case of children and teenagers, it is required to perform three repeated measurements in order to decrease SEM while evaluating the USI of lateral abdominal muscle thickness. However, it needs to be taken into consideration that the cause of the indicated differences (apart from the participants' age) may also be the different methodology used in carrying out the ASLR test and/or the different interval in performing the second series of measurements in the study of Koppenhaver et al. (2009a).

In case of muscle reflex activity during the ASLR test, generally lower values of $ICC_{3.3}$ were obtained for all the muscles of lateral abdominal wall. However, these results cannot be surprising, as the reflex activity during the ASLR test is achieved by two separate measurements, these being thickness at rest and thickness during ASLR. Taking into consideration that both measurements are connected with some error, then some sort of error cumulation in the measurement must be present during calculation of the muscle activity. To our knowledge, only three studies to date have analyzed the reliability of percentage change of muscle thickness (reflex activity) during the ASLR test (Koppenhaver et al., 2009a; Teyhen et al., 2009; Linek et al., 2014b). In the studies performed on adults, ICC of TrA and OI was over 0.87 while in the case of teenagers aged 13-16, it fluctuated from the value of 0.81 to 0.91 for TrA, from 0.65 to 0.79 for OI and from 0.72 to 0.89 for OE (Koppenhaver et al., 2009a; Teyhen et al., 2009; Linek et al., 2014b). In the current study, the $ICC_{3.3}$ for the percentage change of thickness was from 0.75 to 0.89 for OE, from 0.72 to 0.79 for OI and from 0.81 to 0.90 for TrA. Thus, the obtained values were similar between participants in their second decade of life.

From a research point of view, the SDD value seems to be more significant than the actual ICC value. SDD makes it in fact possible to indicate the minimum difference between groups in order for it to be approved as actual. In the study of Koppenhaver et al. (2009a), the analysis of two repeated measurements enabled definition of the SDD value for TrA at the level of 24.2%, whereas Linek et al. (2014b) obtained the SDD value for TrA at the level of 20% but with the use of three repeated measurements. In the current study, the SDD value obtained for TrA was 19.2%, also with the use of three repeated measurements. In case of the remaining lateral abdominal muscles in participants aged 13 to 16, the SDD was 25.3% and 24.2% for OI and OE respectively (Linek et al., 2014b). Similar results were achieved in the current study, in which the analysed group comprised participants aged 10 to 12 years.

It needs to be taken into account that the current study referred to the analysis of only healthy participants aged 10-12 years, who did not experience any pain ailments or problems with the body posture (e.g., scoliosis). The examination was performed within the school premises, which could significantly affect the child's behavior during the examination. It may be assumed that performing this type of examination in an unfamiliar environment (community health centre, hospital, etc.) will affect the child's behavior and consequently the reliability of USI of the examined muscles. The current research involved only intra-rater reliability, and so the next research projects should evaluate the degree of reliability that will be obtained between researchers in different time intervals.

CONCLUSION

The ultrasound evaluation of the lateral abdominal muscles thickness at rest is characterized by a high reliability in the case of children aged 10 to 12 years. In this age group, the USI reliability of the actual thickness and reflex activity of OE, OI and TrA during the ASLR test is at a similar level to that of participants aged 13 to 16 years. For this reason, it is recommended to perform three repeated measurements for this age group as well. There is still a need to seek solutions that will decrease the SDD value and at the same time increase ICC, while evaluating the reflex activity of the lateral abdominal muscles during the ASLR test.

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