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Activation asymmetry of the lateral abdominal muscles in response to neurodevelopmental traction technique in children with pelvic asymmetry

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Abstract

Study aim: The aim of the study was to evaluate asymmetry of activation of lateral abdominal muscles (LAM) in response to neurodevelopmental traction technique in children with pelvic asymmetry.
Material and methods: Measurements of LAM activation asymmetry were performed during traction with the force of 5% body weight in two experimental conditions: 1) in neutral position, 2) in 20° posterior trunk inclination. Twenty-three healthy children with pelvic asymmetry participated in the study. To evaluate LAM activation asymmetry ultrasound technology was employed (two Mindray DP660 devices (Mindray, Shenzhen, China)). Activation asymmetry indices for each individual LAM were calculated.
Results: The magnitude of LAM activation asymmetry indexes formed a gradient, with the most profound transversus abdominis (TrA) showing the greatest asymmetry, and the most superficial obliquus externus – the smallest. The inter-muscle differences were most pronounced between the TrA and the two more superficial oblique muscles. There were no correlation between the magnitude of pelvic asymmetry and LAM activation asymmetry.
Conclusions: During the neurodevelopmental traction technique there is a difference in individual LAM activation symmetry, with deeper muscles showing greater asymmetry. The activation asymmetry of the LAM does not seem to be associated with the pelvic asymmetry. Results are similar to those recorded in earlier studies in samples where no pelvic asymmetry were subjected to analysis.

Key words: Developmental asymmetry – Ultrasound – Lateral abdominal muscles – Pelvis

Introduction

In the domain of modern physiotherapy structure and function of the core region muscles constitute issues of a significant interest [22, 37, 47]. In adults, these muscles are responsible for position and movement control of the trunk and the pelvis [24, 31, 33]. Expanded to three dimensions, precise neuromuscular control of the trunk becomes a crucial factor in core stability. Maintaining this stability is highly required in order to effectively perform any form of motor activity [27].

In adults, disturbed neuromuscular control of the core region frequently manifests itself in the form of low back pain [23] which may influence action of the brain functional networks [12, 13] and further jeopardize function of abdominal musculature, creating a vicious-circle mechanism. In such cases, numerous sources delineate the most useful therapeutic approaches (e.g. [8, 48, 49]). In children, low postural tone constitutes a common symptom of insufficient core control [20, 26, 40] in which the transversus abdominis muscle (TrA) seems to play an important role [18, 19]. It is also well known that besides low postural tone, postural asymmetry constitutes the other common sign of neuromuscular insufficiency during childhood [5, 6, 9, 51]. This includes symptoms of static pelvic asymmetry which also seems to be linked to the function of the TrA and other abdominal muscles [17, 29, 36].

In the aspect presented here, the problem of asymmetry was mainly explored by scientists interested in adult populations. The question as to whether the left and right core muscles show symmetry in healthy people has already

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been asked several times [32, 39, 41]. Aiming to find the answer, the core muscles were frequently subjected to observation, in particular the lateral abdominal muscles (LAM). In an attempt to increase the level of their activity various experimental tasks have been employed, e.g. the active straight leg raise [34, 46], rapid upper limb movement [1, 24], abdominal drawing-in manoeuvre [35, 38] or abdominal bracing exercise [39]. Using stimulation of these types, LAM responses were evaluated in healthy subjects demonstrating a moderate level of daily physical activity [32, 41, 44] or in patients with low back pain [10, 21]. Most authors agree that in healthy, adult subjects a symmetrical activation of LAM is the most typical [32, 41, 44].

In the developmental period of life, the pattern of LAM activation as well as symmetry of the activation have been subjected to investigation only by Gogola et al. [18, 19]. The neurodevelopmental traction technique was shown to be an efficient manoeuvre to increase activation level of the LAM [18] and claimed a useful approach aiming to improve 'postural stability'. The recorded responses were, however, different for each individual muscle. The superficial LAM responded more distinctly to the traction. In contrast, the TrA showed hardly any response or decreased its thickness.

Previous results indicate that, indeed, application of the traction technique influences the level of LAM activity in healthy children. However, it is still not known whether activation asymmetry of the LAM may be linked to symptoms of structural asymmetry within the lower portion of the trunk, e.g. static pelvic asymmetry. In this context, the aim of the current study was to answer the following questions: 1) Is there a difference between individual LAM activation asymmetry indices during the neurodevelopmental traction technique in children with pelvic asymmetry?; 2) Is there a correlation between the magnitude of the activation asymmetry indices of the LAM and pelvic asymmetry?

Material and methods

Subjects

Forty-one children together with their parents agreed to participate. The children were tested against the selection criteria. The inclusion criteria were: age between 11 and 13 years (before the puberty spurt); ability to comply with verbal commands; typical, undisturbed neuro-motor development, static pelvic asymmetry of at least 4.0º as measured used the approach described in detail below. The exclusion criteria were: history or current diagnoses of any serious orthopaedic or neurologic conditions (e.g. fractures, congenital deformations, cerebral palsy, etc.); history of any surgical interventions; history of serious musculoskeletal pain and dysfunction (of more than 2-week duration, requiring medical/physiotherapeutic assistance), or any recent (1 month prior to the experiment) musculoskeletal pain and dysfunction; minor maladies on the day of measurement (cold, headache, excessive fatigue, etc.); obesity precluding ultrasound measurement of LAM thickness (body mass index higher than 22 kg/m^2). Ten children did not meet the inclusion criterion of pelvic asymmetry of 4.0º. Five children were excluded due to a history of fractures, one due to a history of surgical interventions within the abdominal area and two due to recent ankle joint injury. Twenty-three children (13 girls) who qualified for the study (mean age 12.15 ± 0.73 years; body mass 41.87 ± 7.82 kg; body height 154.12 ± 6.23 cm) received detailed information on the objectives and procedures. There were no dropouts present. In the case of all included children written informed consent was obtained from their parents. The study was approved by the institutional Biomedical Research Ethics Committee (approval number 4/2019, 11 April 2019).

Design

The experimental study was conducted with repeated measurements of the dependent variables. Measurements of LAM activation asymmetry were performed during traction with the force of 5% body weight (5% traction) in two experimental conditions: 1) in neutral position of the trunk, 2) in 20° posterior trunk inclination.

Measurements

Evaluation of the pelvic asymmetry was performed directly using the method developed previously by Gnat et al. [14, 15]. This direct method consists of measurement of the angle of inclination of the line joining the two anterior superior iliac spines in relation to the horizontal line. An angle equal to 0º indicates symmetrical arrangement of the pelvis. A hand inclinometer (Palpation Meter US Patent 5 327 907, Performance Attainment Associates, St. Paul, USA) with a precision of ±1º was used. The subject was positioned upright with both feet placed close together, and sight fixated on one point at eye level. After the relevant anatomical landmarks had been found (without observing the scale of the inclinometer) the researcher gave the command 'ready' and the second person read the reading of the device. This procedure was repeated three times and mean value of these three measurements was taken into further consideration. The measurement procedure showed acceptable intra-rater reliability with intraclass correlation coefficients of 0.831 [15], standard error of measurement of 0.51º and smallest detectable difference of 1.81º. Basing on recommendations by Gnat and Biały [11] the cut-off value for inclusion criteria was set at 4.0º (doubled minimal detectable difference).

To evaluate LAM activation and activation asymmetry various approaches are used [3, 4] including the indirect ultrasound methods. In this particular study the ultrasound technology was employed, too (two Mindray DP660 devices (Mindray, Shenzhen, China) with 75L38EA probes), using Gnat's et al. [16] methodology. B-mode images showing three layers of LAM (obliquus externus (OE), obliquus internus (OI), transversus abdominis (TrA) were bilaterally recorded in the two experimental conditions and subjected to further analysis. The analysed parameter was the asymmetry index of the LAM thickness change (a measure of LAM activation asymmetry) during 5% traction. Previous research showed that these measurements present an acceptable level of reliability [16]. According to the authors, in case of abdominal muscles (especially OI and TrA) the asymmetry index correlate with electromyographic signals at low levels of maximal voluntary contractions (in our study one cannot expect high activations levels during moderate posterior trunk inclination angle; see below) [25], which may be used as valid indicators of LAM activation. Onsets of LAM activation can be detected equally precise by means of electromyography and ultrasounds [50]. Other studies point out the usefulness of ultrasounds to measure contractile parameters of various skeletal muscles [2, 42, 43], too. At last, based on literature data and our former experience, our aim was to employ ultrasounds as the most non-invasive and the less cumbersome alternative to EMG, despite its indirect character and imperfect validity. We did this only after reaching the highest possible levels of measurement reliability.

Procedure

The experimental procedure was developed based on the work of Gogola et al. [18]. Briefly, the neurodevelopmental traction technique is performed while sitting and consists of two components: a traction force applied to the trunk through the head and a posterior trunk inclination. These components were imitated in a standardised manner. Traction with the desired force was applied to the head with the use of a pulley system and a Glisson loop. To achieve posterior trunk inclination the subjects were seated on a stool mounted on a movable platform. Initially, the subjects were positioned directly under the pulley with their trunks in a neutral position. Subsequently, the platform was moved forward (the pulley remained stationary on the ceiling), which produced posterior inclination of the trunk. This was stopped when the range of inclination reached 20° (controlled with the use of a Rippstein plurimeter secured on the subject's sternum) (see Figure 1).

The desired levels of traction force (5% of the bodyweight) as well as the optimal range of posterior trunk inclination (20°) were established prior to the experiment in the pilot study. In this study the level of intra-rater reliability of our raters was evaluated too. In the neutral trunk position the intraclass correlation coefficients (model (3,3)) for the OE, OI and TrA equalled 0.95, 0.93 and 0.82, respectively. In the inclined trunk position they were 0.96, 0.95 and 0.91, respectively. Standard errors of measurement were smaller than 0.4 mm.

After verification of the inclusion (including the measurement of pelvic asymmetry) and exclusion criteria was

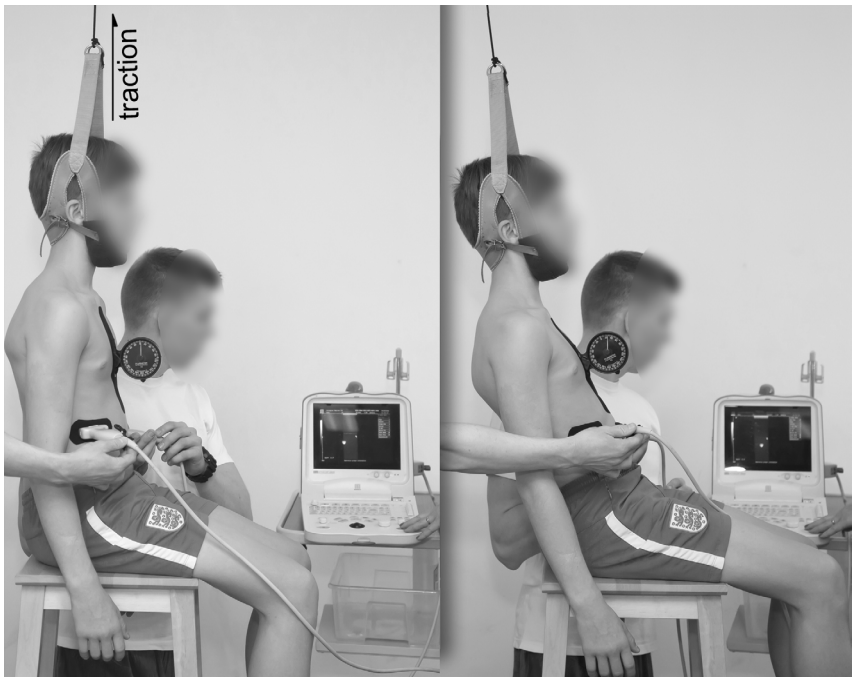


Figure 1. Subjects positioned with their trunks in a neutral position and 5% traction (left); next in 20° posterior inclination of the trunk and 5% traction (right) during recording of the ultrasound images

complete, the measurements of LAM activation asymmetry started. The 5% body weight traction through the head was applied first. Then, the image of the right and left LAM were recorded: 1) in the neutral trunk position, and 2) after moving the platform anteriorly, in 20° posterior trunk inclination. After this, the platform and the trunk returned to the neutral position. Traction force was released. The cycle: 5% traction – neutral trunk position (image registration) – 20° inclined trunk position (image registration) – neutral trunk position – traction release; was repeated six times. We did not try to introduce any random or pseudorandom order of body positions in order to reproduce clinical procedures typically employed in the field of physiotherapy.

Data processing

After completing the procedure we gathered 6 images of the left and 6 images of the right LAM for experimental conditions 1 (neutral trunk position) and 2 (inclined trunk position). Thickness of each individual LAM during each condition was measured as described in detail by Gnat et al. [16] and Gogola et al. [18] (see Figure 2). Raw real-time ultrasound image of the lateral abdominal muscles was edited in Photoshop software. After the brightness and contrast of the image were adjusted, the layers of fascia intersecting the abdominal muscles were selected and shaded in white, final image showing 3 layers of lateral abdominal muscles (OE – obliquus externus abdominis, OI – obliquus internus abdominis, TrA – transversus abdominis) and subcutaneous tissue (ST). As an example, TrA thickness was measured along the three black lines drawn in 1/4, 1/2 and 3/4 of the length on the edited image. The mean value of these 3 measurements was subjected to further analysis as the outcome of the one particular, single image. Thickness of the two remaining muscles was measured accordingly. Mean thickness measured on all 6 images for any given side of the body and any given experimental condition was subjected to analysis.

After calculation of mean values, the percent thickness change of each individual LAM were calculated between experimental conditions 1 (neutral trunk position) and 2 (inclined trunk position) according to the formula:

$$TC = (TN - TI) \times 100\%/TN$$

where: TC – thickness change; TN – thickness in neutral trunk position; TI – thickness in inclined trunk position.

In the next step, the asymmetry index between left and right sides of the body was calculated for each individual LAM according to the formula below. This operation returned a single number describing activation asymmetry of each individual LAM, namely the asymmetry index.

$$AI = |(TCl - TCr)| \times 100\%/|(TCl + TCr)|$$

where: AI – asymmetry index; TCl – thickness change recorded for the left LAM; TCr – thickness change recorded for the right LAM.

Statistical analysis

Data analyses were performed using Statistica software (version 13; StatSoft, Inc.). Distribution of the

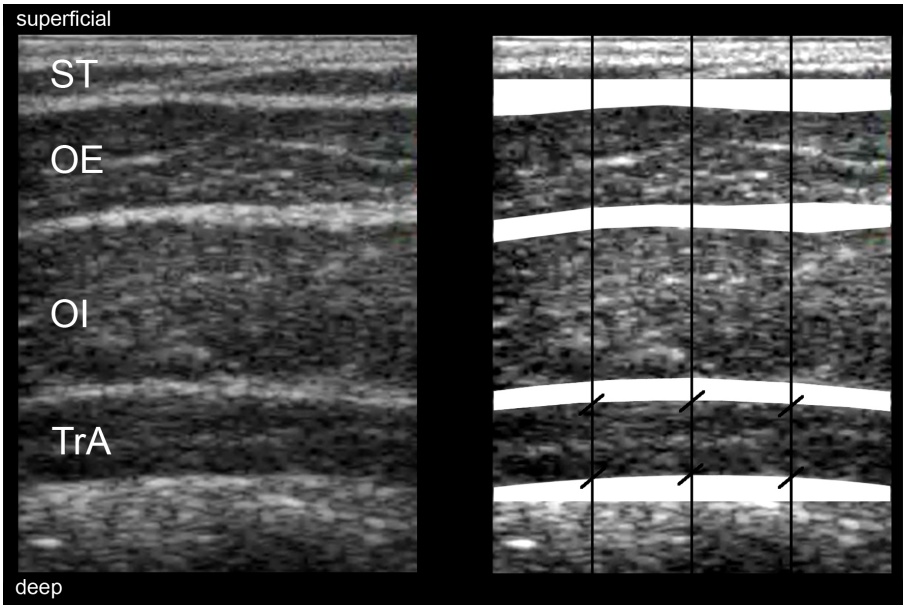


Figure 2. Left: raw real-time ultrasound image of the lateral abdominal muscles; right: an image after editing in Photoshop software. OE – obliquus externus abdominis, OI – obliquus internus abdominis, TrA – transversus abdominis, ST – subcutaneous tissue

variables were evaluated using the Shapiro-Wilk test. Due to significant deviations from normal distributions for OI and TrA asymmetry indexes non-parametric statistics were used. Differences of the calculated asymmetry indexes were assessed: between individual LAM – using Kruskal-Wallis analysis with its own post hoc test for multiple comparisons. Correlations were assessed using the Spearman correlation coefficient. The critical *P* level was set at 0.05.

Results

The mean pelvic asymmetry of 5.78 ± 1.21° was recorded in the included group of participants.

Descriptive statistics for LAM activation asymmetry indexes are presented in the Table 1. The asymmetry indexes showed a characteristic gradient with the TrA being the most asymmetric and the OE the least. The inter-muscle difference was significant between OE and TrA ($P < 0.001$) as well as between OI and TrA ($P < 0.03$, see Table 1). The mentioned gradient is clearly noticeable in Figure 3.

The highest correlation coefficient of $R = 0.25$ (weak, positive, non-significant correlation; $P > 0.05$) was recorded between the magnitude of pelvic asymmetry and activation asymmetry index of the TrA. The remaining coefficients (for OE and OI) were smaller and, similarly, non-significant.

Table 1. Descriptive statistics (%) for the lateral abdominal muscles activation asymmetry indexes during traction of 5% bodyweight. Presented are *P* levels of differences between the individual lateral abdominal muscles (post hoc test for Kruskal-Wallis ANOVA)

Muscle	Mean (SD) min–max
OE	35.69 ± 18.63 3.11–79.15
OI	45.27 ± 22.19) 2.56–115.11
TrA	60.10 ± 55.19) 1.21–198.88
P OE vs. OI	NS
P OE vs. TrA	<0.001
P OI vs. TrA	<0.03

OE – obliquus externus abdominis, OI – obliquus internus abdominis, TrA – transversus abdominis.

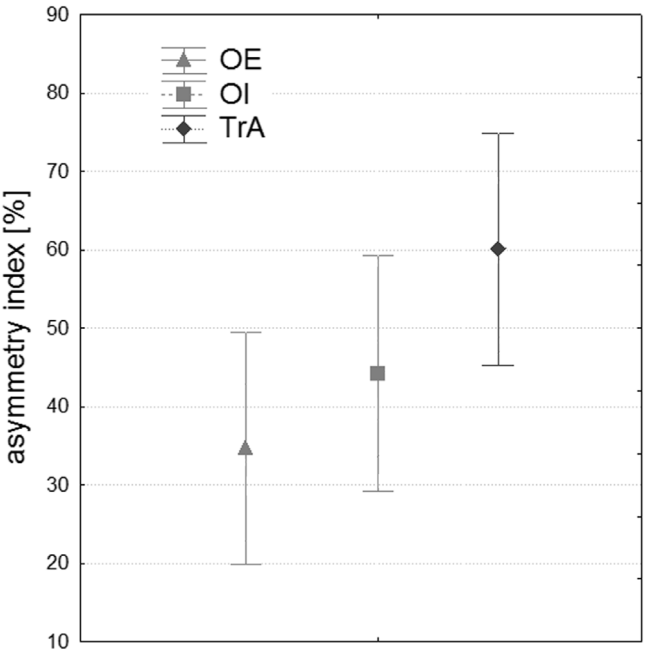


Figure 3. Mean values (whiskers indicate 95% confidence intervals) of lateral abdominal muscles asymmetry indexes during traction with the force of 5% body weight. OE – obliquus externus abdominis, OI – obliquus internus abdominis, TrA – transversus abdominis

Discussion

In frames of the presented study we investigated in children showing symptoms of pelvic asymmetry (and otherwise showing normal development) the LAM activation asymmetry during axial traction through the head in neutral and inclined trunk positions. These two elements – traction and trunk inclination – are the two components of the neurodevelopmental traction technique.

Our results indicate the amount of LAM activation asymmetry, as indicated by the asymmetry indexes, was relatively high. It ranged between 36 and 60%. It seems that such an amount of asymmetry cannot pass unnoticed. We may claim that our results are quite in line with those obtained previously by colleagues [18, 19] using exactly the same methodology. In comparison with other authors, we found the most similar approach presented by Kim et al. [28]. These authors assessed LAM activity during sudden, unexpected postural perturbation to the trunk in healthy adults and found activation asymmetry indexes of 37%, 17% and 10% for TrA, OI, and OE, respectively. We also recorded a similar gradient of activation asymmetry indexes (TrA – the biggest, OE – the smallest), however our indexes were much larger than these found by Kim et al. [28] most probably due to differences in asymmetry indexes calculation. Signs of a greater symmetry of

LAM activation in healthy adults may also be found in the study by Rankin et al. [41]. The authors found near perfect symmetry for all abdominal muscles (all muscles exhibited less than 1.5% difference between sides). Similarly, Teyhen et al. [45], who assessed the symmetry of LAM thickness changes at rest and during the active straight leg raise manoeuvre claimed that recorded changes are symmetrical. Mannion et al. [32], who measured LAM thickness changes during abdominal drawing-in exercises, found no significant differences between left and right sides of the body. It seems therefore, that it is justified to suggest that children with pelvic asymmetry, similarly to children in whom pelvic asymmetry was not assessed [18, 19], may present more asymmetrical activation of LAM than healthy adult subjects. It is worth noting, that in accordance to Gogola's et al. [18] clinical recommendations, we engaged 5% traction which is supposed to evoke more symmetrical LAM activation than stronger tractions. Even though, the recorded asymmetry of LAM activation was greater than in other studies.

Basing on the above-mentioned findings we may count the more asymmetrical LAM activation in children as a feature that potentially are different in children and adults. If true, these characteristic may be treated as a vector of the maturation process of the core stability mechanisms. Taking this one step further, they may be regarded as indicators of dysfunctional states. Building postural tone is often called the cephalo-caudal process [7, 30]. Perhaps, at least in the core region, it is also a process directed from superficial towards deeper muscular layers and from asymmetrical activation towards more symmetrical activation.

We also provided the evidence that the magnitude of LAM activation asymmetry is not correlated with the magnitude of positional asymmetry within the lower portion of the trunk, in this case – the static pelvic asymmetry. This finding cannot be compared with findings from other studies since, to our best knowledge, no authors investigated such correlation so far. Our observations stand in opposition to claims of the others, suggesting that symptoms of structural or functional skeletal asymmetry (including the pelvic asymmetry) may well be linked to the function of the TrA and other abdominal muscles [17, 29, 36]. Although valid explanations are provided by the authors, our results do not support those claims. It seems safer to regard them speculations more than facts.

We would also like to acknowledge the high reliability indices of our measurements, which emphasize their credibility as well as the limitations of the study. Among the limitations our target group may be questioned. We cannot be sure that groups recruited by Gogola et al. [18, 19] did not include some children with static pelvic asymmetry. This fact creates bias for comparisons with results of these authors. Besides of this we explained that the age of our participants, 11–13 years, provided higher compliance with verbal commands. Moreover, our measurement of LAM activation was of the indirect nature, via ultrasounds. This decision was based on our former experiences and literature data showing acceptable correlation between ultrasound and electromyographic signals forma LAM. However, acknowledgement is needs that validity of such measurement may be lower in case of OE muscle [25]. In this point it is also difficult to judge what clinical consequences of the discovered asymmetry of the LAM could be or how large the minimal clinically important difference of the asymmetry is. Obtained results prompt us to conduct further research of younger population and populations with more severe postural faults.

Conclusions

1. During the neurodevelopmental traction technique there is a difference in individual LAM activation asymmetry, with deeper muscles showing greater asymmetry.
2. In statistical terms, the LAM activation asymmetry differs between the OE and TrA, as well as OI and TrA.
3. There is no significant correlation between the magnitude of LAM activation asymmetry and pelvic asymmetry.

Conflict of interest: Authors state no conflict of interest.

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