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Experimental study

Asymmetry of activation of lateral abdominal muscles during the neurodevelopmental traction technique

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ABSTRACT

Objective: The aim of the study was to evaluate the symmetry and pattern of activation of lateral abdominal muscles (LAM) in response to neurodevelopmental traction technique.
Design and participants: Measurements of LAM thickness were performed in four experimental conditions: during traction with the force of 5% body weight (5% traction): 1) in neutral position, 2) in 20° posterior trunk inclination; during traction with the force of 15% body weight (15% traction): 3) in neutral position, 4) in 20° posterior trunk inclination. Thirty-seven healthy children participated in the study.
Interventions: Not applicable.
Main outcome measures: To evaluate LAM activation level ultrasound technology was employed (two Mindray DP660 devices (Mindray, Shenzhen, China) with 75L38EA linear probes). An experiment with repeated measurements of the dependent variables was conducted.
Results: Side-to-side LAM activation asymmetry showed relatively high magnitude, however, significant difference was found only in case of the obliquus externus (OE) during stronger traction *($P < 0.05$)*. The magnitude of LAM thickness change formed a gradient, with the most profound transversus abdominis (TrA) showing the smallest change, and the most superficial OE – the greatest. The inter-muscle differences were most pronounced between the OE and TrA *($P < 0.001$)*.
Conclusions: During the neurodevelopmental traction technique there is a difference in individual LAM activation level, with deeper muscles showing less intense activation. In statistical terms, the only signs of side-to-side asymmetry of LAM activation are visible in case of the OE, however, the magnitude of asymmetry is relatively high.
The results allow to identify patterns of activation of LAM in children showing typical development that will serve as a reference in future studies in children with neurological disorder.
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1. Introduction

In the domain of modern physiotherapy the popular and vivid issues are structure and function of the core region muscles (Bergmark, 1989; Cholewicki et al., 1997; O'Sullivan et al., 1997; Hodges, 1999; Tokuno et al., 2013). In adults, these muscles are responsible for position and movement control of the trunk above the pelvis (Aruin and Latash, 1995; Hodges et al., 1999; Marshall and Murphy, 2003; Lee et al., 2009). 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 (Kibler et al., 2006).

In adults, disturbed neuromuscular control of the core region frequently manifests itself in the form of low back pain (McGill, 2002; Hodges, 2003). In such cases, numerous sources delineate the most useful therapeutic approaches (e.g. Unsgaard-Tondel et al., 2010; Vasseljen and Fladmark, 2010). In children, low postural tone constitutes a common symptom of insufficient core control (Raine, 2006; Howle, 2002; Gogola et al., 2014). Here, the

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therapy focuses on optimizing 'postural stability' perceived as a basis for any anti-gravitational motor activity (Lynch-Ellerington, 1998). There is, however, no clear indication as to which muscles should be regarded as anti-gravitational. It is also well known that besides low postural tone, postural asymmetry constitutes the other common sign of neuromuscular insufficiency during childhood. Its symptoms may be found in such pathological states as developmental coordination disorder (Wilson et al., 2013), cerebral palsy (Einspieler et al., 2012), syndrome of contractures (Karski, 2011) and kinetic imbalance due to suboccipital strain (Brand et al., 2005).

In the aspect presented here, the problem of asymmetry was mainly explored by scientists interested in adult populations. The question of whether the left and right core muscles show symmetry in healthy people has already been asked several times. 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 (Teyhen et al., 2009; Mens et al., 2001) rapid upper limb movement (Allison and Brendan, 2008; Hodges et al., 1999), abdominal drawing-in manoeuvre (Park, 2013; Olivier et al., 2013) or abdominal bracing exercise (Park et al., 2014). Using stimulation of these types, LAM responses were evaluated in healthy subjects demonstrating a moderate level of daily physical activity (Mannion et al., 2008; Springer et al., 2006; Rankin et al., 2006) or in patients with low back pain (Ferreira et al., 2004; Hodges and Richardson, 1996; Hides et al., 2009). Some part of the research focused on LAM activation during asymmetric movement patterns in sports (Hides et al., 2008). Most authors agree that in healthy, adult subjects a symmetrical activation of LAM is the most typical (Rankin et al., 2006; Springer et al., 2006; Mannion et al., 2008).

In the developmental period of life, neither the pattern of LAM activation nor the symmetry of the activation have been subjected to investigation. Based on the assumption that within the framework of neurodevelopmental therapy an increase in core muscles activity, including LAM, is beneficial in order to improve 'postural stability', we recently provided a piece of evidence (Gogola et al., 2016). With the use of ultrasounds, we investigated the responses of the three LAM (obliquus externus (OE), obliquus internus (OI) and transversus abdominis (TrA)) to the application of the neurodevelopmental traction technique. The results revealed the expected response; however, the response was different for each individual muscle. The superficial LAM responded more distinctly to the traction. The OE and OI significantly increased their thickness. In contrast, the TrA showed hardly any response or it decreased its thickness. This was in contrast with the evidence obtained in adults (Hides et al., 2010; Moseley et al., 2003; Tsao and Hodges, 2008) in whom increases in TrA thickness were usually demonstrated.

Our previous results indicate that, indeed, application of the traction technique influences the level of LAM activity. However, it is still not known whether it may be helpful in attempts to reduce symptoms of LAM activation asymmetry perceived as a sign of disturbed core region neuromuscular control in children. In this context, the aim of the current study was to answer the following questions: 1) is there a difference in individual LAM activation level during the neurodevelopmental traction technique using the head as the key point?; 2) is there a difference between the activation level of the left and right LAM?; 3) is there a difference in the magnitude of activation asymmetry between individual LAM?; 4) does force of the applied traction influence LAM activation level and its asymmetry? Only healthy children were involved because our intention was to observe muscular reactions without any interference from a dysfunctional nervous system.

2. Subjects and methods

2.1. Subjects

Forty-three 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 neuromotor development. 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^3). Three children were excluded due to a history of fractures, two due to a history of surgical interventions within the abdominal area and one due to recent undiagnosed pain within the left ankle and knee. Thirty-seven children (22 girls) who qualified for the study (mean age 12.00 (±0.82) years, body mass 43.68 (±8.22) kg and height 151.46 (±7.76) cm) received detailed information on the objectives and procedures. No dropouts were recorded during the procedure. 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.

2.2. Design

The experimental study was conducted with repeated measurements of the dependent variables. Measurements of LAM thickness (indicating LAM activation level) were performed in four experimental conditions: during traction with the force of 5% body weight (5% traction): 1) in neutral position, 2) in 20° posterior trunk inclination; during traction with the force of 15% body weight (15% traction): 3) in neutral position, 4) in 20° posterior trunk inclination.

2.3. Outcome measures

To evaluate LAM activation level ultrasound technology was employed (two Mindray DP660 devices (Mindray, Shenzhen, China) with 75L38EA linear probes) in accordance to the methodology presented in detail by Gnat et al. (2012). B-mode images showing three layers of LAM (OE, OI, TrA) were bilaterally recorded in four experimental conditions and subjected to further analysis. The analysed parameters were: percent thickness change of the individual LAM between neutral and inclined trunk positions (a measure of LAM activation level) as well as asymmetry index of the thickness change (a measure of LAM activation asymmetry), both during 5% traction and 15% traction. Previous research showed that these measurements present an acceptable level of reliability (Gnat et al., 2012) and are valid indicators of LAM activation based on their strong correlation with electromyographic signal from LAM (Vasseljen et al., 2009).

2.4. Procedure

Detailed description of the experimental procedure is presented elsewhere (Gogola et al., 2016). Briefly, the neurodevelopmental traction technique is performed while sitting and consists of two components: a traction force applied to the trunk through the head

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