LATERAL AND ANTAGONISTIC ASYMMETRIES OF LUMBO-PELVIC-HIP COMPLEX
STABILIZING MUSCLES IN YOUNG POLISH WOMEN IN TENSIOMYOGRAPHY IMAGING

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Abstract

In terms of pelvic torsion muscle tissue seem to be underestimated. However, it is not clear what is the actual place of muscles in cause and effect chain of posture abnormality pathogenesis. Aim of the study was to characterize morpho-functionally specific group of superficial muscles, that are crucial in human bipedal stability, especially in terms of lateral and antagonistic asymmetries. Material was formed with a group of 34 women aged 22.7±2.8 years (19-29 yr), 166.2±5.6 cm (156-182 cm) of height, 58.4±4.9 kg (48-67 kg). Four of women were excluded because of incomplete data collection. 12 muscles were examined including: right and left Rectus abdominis, External oblique, Erector spinae, Gluteus maximus, Rectus femoris and Biceps femoris. Method selected for the study was tensiomyography with the use of TMG apparatus. Results showed lateral asymmetries in External oblique (p=0.01) and Gluteus maximus (p<0.001). Right abdominal muscle appeared to manifest shorter delay time. Gluteus muscle of this side revealed greater maximal displacement as well as longer contraction and summary contraction time. Antagonistic asymmetries in time parameters were found in both tested dyads (Rectus abdominis-Erector spinae and Rectus femoris-Biceps femoris). Rectus abdominis and Biceps femoris shoved higher values revealing more tonic character. In examined group, there are unidirectional functional asymmetries both in lateral and antagonistic muscle dyads. Those differences manifest in TMG procedure, therefore tensiomyography appeared to be a reasonable method for further physiotherapeutic studies and widening knowledge about lumbo-hip-pelvic complex stabilizing muscles.

Key words: posture, pelvis, stability

Introduction

Muscle system is considered to be a coherent structure of codependent elements. There is a great number of theories built to explain the complexity of relations between separate muscle groups and muscles itself. Majority of modern theses is based on specific functional chains of muscles and tendons (Richter et al., 2014). One of the most difficult issue in human dynamics is to understand what causes unfavorable changes and how to treat them. The holistic picture of muscle functionality was built on a great number of studies, starting from showing the simple mechanism of muscle tension (Huxley, 1969) and evolving to conceptions of automatic mechanisms of compensation in a range of motion or neutral zone in joint dysfunctions (Klineberg, 2017).

As the axial skeleton is known to be the most sensitive structure in terms of pathological changes in motion, the leading current in physiotherapy is concentrated on understanding mechanisms of its stability. It has been already shown, that both superficial and deep muscles of trunk play a great role in building stabilizing corset as they are all attached directly to elements of spine or ribs. Pelvis itself is a key point in posture creating model as it transfers load between spine and legs (Richardson et al., 2009; Richter et al., 2014). Stability of spine seems to be achieved basing on imprinted motion schemas of surrounding muscles activity that is modulated by automatic mechanisms of coupling feedback depending on proprioceptive reception (Richardson et al., 2009). Basic category of antigravity muscles brings a lot to understanding of the whole concept of human body stability (Souchard and Żak (Ed.), 2014). This classification has also its overtone in muscle histology and is strictly connected with physiological properties of separate muscles. It can be observed simply in concentration of different fibers that is responsible for giving more stabilizing or dynamic character to studied unit (Górski, 2006). The least understood, but at the same time, one of the most important aspect of human bipedal posture, is how the anatomy and function of lower extremities affect the axial skeleton through the pelvic girdle. Range of motion in hip joint give a wide mobility but at the same time creates a great potential for surrounding tissues to determine the range of neutral zone and the neutral position of femur (Souchard and Żak (Ed.), 2014). The major difficulty of studies of this
area is connected with relatively unavailable placement of M. iliopsoas, Gluteus medius and minimus muscles as well as deep muscles of front and dorsal face of pelvis (Richardson et al., 2009). Nevertheless, it has already been proven, how some of the superficial leg muscle functionally correlate with parameters of pelvis positioning. Some attach to pelvis in specific points creating force levers that increase or decrease degree of pelvic tilt (Richardson et al., 2009; Souchard and Zak (Ed.), 2014).

Musculoskeletal system in humans, despite the conservativeness of bone structure, is highly susceptible to lateral symmetry disorders as the lateralization process, occurring in early ontogenesis, is needed for proper neural development (Coren and Bishop, 1993; Sastre, 2008). Asymmetries of this type may also have different genesis, but are common in population in wide variety of intensification (Chen et al., 2016; Liu et al., 2016). Pelvic torsion and scoliosis are typical pathologies based on lateral asymmetries or resulting in those. Congenital scoliosis appears relatively rarely and has its source in bone structure abnormalities. Acquired scoliosis may derive from physiological or neurological pathologies and be a direct symptom of systemic ailment. When observed in healthy subjects, scoliosis is usually considered to be a compensatory mechanism built automatically in response to primary disorder in pelvis positioning (Osipiuk, 2018). Despite all esthetic aspects of scoliosis, that in some extreme cases may have serious psychological implications (Payne et al., 1997), this type of disorder mainly affect functionally organs of chest (Koumbourlis, 2006) as well as the spine and its mobility and ability to transfer load (Richardson et al., 2009).

The second type of asymmetry relate to phenomenon of muscle antagonism. Muscles working in specific codependent groups create local balance affecting global stability. Classic dyad of two antagonists, consisting of flexor and extensor, abductor and adductor or opposite rotators units, is responsible for proper mobility of skeleton elements and joints protection (Górski, 2006). What creates disorder is a significant divergent between the dyad units manifested in strength or length dominance of one (Richardson et al., 2009). The main aim of least cost absorbing stability drives to compensatory mechanisms where the proprioception, again, plays a great role.

There are certain elements that contribute directly or indirectly to body motion system symmetry disorders. Despite the matter of idiopathic scoliosis, that still remains poorly understood (Sastre, 2008), majority of pathological changes is based on at least partly recognized mechanisms. As the construct of motoric system is built with specific tissues, all changes connected with motion dysfunction will appear in those, that belong to that scheme. However, muscle activity may also be changed by pathologies placed in different organs, as the mechanism of muscle guarding appears (Richardson et al., 2009; Szczeklik and Gajewski, 2018). The holistic physiology has also its own sign in connective tissue because of inseparability in terms of endocinial and neural functions (Sastre, 2008).

A functional change of increased tonic tension of spine extensors (Geisser et al., 2005) and simultaneous reduction of tension in Gluteus group (Leinonen et al., 2000) usually occurs in patients with low back pain. The same characteristics are observed in concave or convex back (Richter et al., 2014; Souchard and Zak (Ed.), 2014). The pathology of this phenomenon lays in inversion of primary function. As the Gluteus muscles are considered antigravity units, they should manifest typical tonic tension in standing position (Richardson et al., 2009; Richter et al., 2014). If one unit reveals tonic properties, antagonistic muscles usually have more phasic character (Górski, 2006). Stabilizing function, therefore, must be transmitted to different units, creating functional compensation that always contributes to pain or some tissues damage, because of abnormal usage.

Bone tissue, despite the injury aspect, is prone to deformation in two periods of life. Progressive ontogenesis is time, when physiological or functional aspects may affect permanently skeleton system (Duval-Beaupère et al., 1970). One of the most common symmetry abnormality originating in skeleton is leg length discrepancy. It can be true or functional, but always has a direct implication in body motion model usually resulting in scoliosis or osteoarthrosis (Woerman and Binder-Macleod, 1984). Some motion issues appear more frequently as people progress in age. Most of them have a degenerative character and can concern cartilage, bone, ligament or muscle tissue (Häkkinen et al., 1998; Laughton et al., 2003). Degeneration in joints affect surrounding muscles in specific way widening the neutral zone. It can be also seen in increased range of motion, but in significantly lower level (Richardson et al., 2009). Most of unilateral injuries result in compensational functional asymmetry if not followed up by rehabilitation. Minimization of energy expense is responsible for maintaining the motoric scheme from healing period later on.

There are several methods of human motor system examination including electromyography, dynamometry, ultrasonography and ground reaction force platforms. They are successfully used both in sports and physiotherapy. Although, there are some muscle characteristics that cannot be caught by them. To fulfill the muscle morpho-physiological imaging a new method has been used lately. Tensiomyography is a uninvasive method that allows for wide muscle properties detection. As its mechanism is based on a mechanic response to electric stimulation it gives a great opportunity for any physiological changes to manifest in measurement recording. Data, that can be obtained, relate to muscle fiber type composition, its tone and action characteristics (Macgregor et al., 2018).

The result of single measurement is a sequence of numeric data that refers directly to placement of the
sensor in time. What can be observed is a characteristic pattern of muscle contraction, that can be characterized by several phases defined as delay time (Td), contraction time (Tc), sustained contraction time (Ts) and half relaxation time (Tr) all expressed in milliseconds. Delay time refers to a period between electric stimulation and moment when muscle achieve 10% of maximal displacement. Contraction time comes directly after delay time and have its end in moment of achieving 90% of maximal displacement. Parameter that describes time lapse between two points, when greater than or equal to half of the maximal contraction is called sustained contraction time. Lastly, half relaxation time refers to time of relaxation after maximal contraction, between achieving 90% and 50% of maximal displacement. Maximal displacement (Dm), as a parameter, shows displacement of sensor, due to enlargement of muscle diameter, from 10% to maximal value. This measurement is expressed in millimeters.

A great correlation was proven between histological structure of muscle defined in different concentration of particular fiber types and TMG parameters. Higher percentage of type I (Slow Twitch) muscle fibers results in longer delay time and contraction time. What was also found was correlation between TMG time parameters and %MHC-I (percentage of type 1 myosin heavy chains) in muscles as well as diversified muscle composition varying from fast-twitch, near the graph, to slow-twitch, in depth of the muscle belly (Dahmane et al., 2005; Šimunič et al., 2011). This phenomena can be seen in TMG records of trials with different current intensity. Stronger electric impulses can penetrate tissue better, activating more muscle fibers in depth, giving more reliable results. Regardless to detailed morphology, TMG has been successfully used to asses muscle fatigue after a great variety of training, as the biochemistry of muscle strain affect its efficiency (Górski, 2006). Long lasting intense training gives its sign in contraction and relaxation time as well as in response time and muscle stiffness (García-Manso et al., 2011). Different strength training show diverse results in maximal radial displacement and contraction velocity (De Paula Simola et al., 2015). Each variable of training e.g. high load, frequency, time under tension etc. may result in adequate changes in parameters of muscle activity pattern (De Paula Simola et al., 2015), as it has a direct impact on muscle histology and physiology. It has been shown, by using TMG, that soccer players playing on different positions vary in dynamics of lower limb (Rey et al., 2012). Thanks to universal properties of this device, TMG is widely used in sports to control training intensity (Rusu et al., 2013) and detect neuromuscular risk factors of injury (Kim et al., 2015). Lately its qualities started to be appreciated also in the challenging fields of medicine and rehabilitation (Seijas et al., 2018; Chai and Bae, 2019).

Purpose of the study was to define morphophysiological characteristics of lumbo-pelvic-hip complex stabilizing muscles in young Polish women, obtained from TMG examination. It was aimed to analyze if there are statistically significant lateral and antagonistic asymmetries in studied muscles. Tensiomyography was also tested for efficiency in physiotherapeutic studies.

Methods
We examined 34 young women aged 22.7±2.8 yr (19-29 yr), 166.2±5.6 cm (156-182 cm) of height, 58.4±4.9 kg (48-67 kg) of body mass None of studied women was training sport professionally. Some women declared moderate to low level of physical activity. Mostly they practiced jogging or attempted cross fit or dancing classes. In some cases we obtained information about past physiotherapeutic treatment due to scoliosis but none of those women had a current visible posture defect. Cases (4) with uncomplete data were excluded from analyses.

Patients were examined, with informed consent, using TMGTM science for body evolution apparatus. Data were collected from 12 muscle units each time (right and left Rectus abdominis, External oblique, Erector spinae: Longissimus lumborum, Gluteus maximus, Rectus femoris and Biceps femoris: long head). Three most reliable parameters of TMG examination were taken to analyses. Those were: maximal displacement (Dm), delay time (Td) and contraction time (Tc). One additional parameter, named summary contraction time (Td+Tc), was created by adding both time parameters.

All variables were tested for normal distribution using the Shapiro-Wilk test. It determined usage of nonparametric tests for further operations.

To detect possible lateral or antagonistic asymmetries, the Wilcoxon signed-rang test was used. Test was chosen because of dependent character of variables. It also allows for passing over the intergroup variance aspect.

Results and discussion
Shapiro-Wilk showed a normal distribution in approximately 60 percent of variables. As almost 40 percent of variables appeared to have distribution statistically significantly different from normal, the nonparametric tests were chosen for muscle asymmetry detection. The only parameter that always showed a normal distribution was maximal displacement (Dm). Delay time (Td) differed from normal distribution in 10 of 12 measured muscles.
Erector spinae and Gluteus maximus. External oblique showed asymmetry in delay time and Gluteus maximus in all parameters except delay time. Delay time of the left abdominal muscle was shorter than the muscle of the opposite body side. Right Gluteus muscle showed larger maximal displacement and longer contraction time as well as summary contraction time.

<table>
<thead>
<tr>
<th>Variables</th>
<th>X</th>
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<tr>
<td>Td [ms]</td>
<td>32.21</td>
<td>30.29</td>
<td>23.03</td>
<td>47.31</td>
<td>24.68</td>
<td>23.83</td>
<td>18.68</td>
<td>37.88</td>
<td>48.00</td>
<td>3.79</td>
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<td>Tc [ms]</td>
<td>37.68</td>
<td>33.96</td>
<td>22.73</td>
<td>64.27</td>
<td>23.85</td>
<td>21.44</td>
<td>10.52</td>
<td>46.39</td>
<td>36.00</td>
<td>4.04</td>
<td>0.001</td>
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<tr>
<td>Td+Tc [ms]</td>
<td>69.89</td>
<td>64.25</td>
<td>48.46</td>
<td>101.19</td>
<td>48.53</td>
<td>45.26</td>
<td>35.58</td>
<td>77.69</td>
<td>22.00</td>
<td>4.33</td>
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| Left      |   |     |     |     |   |     |     |     |   |   |   |
| Td [ms]   | 31.88 | 30.44 | 22.41 | 55.43 | 25.37 | 24.26 | 14.77 | 40.89 | 68.00 | 3.38 | 0.001 |
| Tc [ms]   | 37.26 | 38.57 | 23.28 | 59.41 | 20.46 | 14.26 | 45.68 | 32.00 | 4.12 | 0.001 |
| Td+Tc [ms] | 69.14 | 69.01 | 47.13 | 94.24 | 44.41 | 44.71 | 32.00 | 71.34 | 35.00 | 4.06 | 0.001 |

Most muscles did not reveal statistically significant lateral asymmetries (Table 1). The only two muscles, that appeared to differ laterally were External oblique and Gluteus maximus. External oblique showed asymmetry in delay time and Gluteus maximus in all parameters except delay time. Delay time of the left abdominal muscle was shorter than the muscle of the opposite body side. Right Gluteus muscle showed larger maximal displacement and longer contraction time as well as summary contraction time.

<table>
<thead>
<tr>
<th>Variables</th>
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<tr>
<td>Biceps femoris</td>
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<td>Td [ms]</td>
<td>27.54</td>
<td>27.36</td>
<td>20.95</td>
<td>38.15</td>
<td>33.11</td>
<td>31.52</td>
<td>25.62</td>
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<tr>
<td>Tc [ms]</td>
<td>28.12</td>
<td>28.75</td>
<td>12.63</td>
<td>44.00</td>
<td>42.32</td>
<td>41.32</td>
<td>23.15</td>
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<tr>
<td>Td+Tc [ms]</td>
<td>55.66</td>
<td>56.10</td>
<td>33.58</td>
<td>70.68</td>
<td>75.42</td>
<td>72.84</td>
<td>49.19</td>
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| Left      |   |     |     |     |   |   |   |
| Td [ms]   | 28.24 | 28.54 | 21.83 | 41.17 | 32.58 | 31.18 | 25.51 | 48.42 | 66.00 | 3.42 | 0.001 |
| Tc [ms]   | 29.57 | 28.26 | 19.06 | 43.53 | 44.24 | 48.46 | 18.81 | 75.64 | 47.00 | 3.82 | 0.001 |
| Td+Tc [ms] | 57.81 | 56.80 | 40.89 | 84.70 | 76.82 | 79.64 | 45.25 | 102.78 | 35.00 | 4.06 | 0.001 |

Time parameters (Td, Tc) in examined muscle pairs showed antagonistic asymmetries with high (p<0.001) statistical significance (Table 2). Erector spinae and Rectus femoris revealed shorter delay time, contraction time and summary contraction time than their antagonists.

The aim of the study was to characterize in terms of functional and morphological asymmetries a specific muscle group in young adult women. Those muscles are crucial for human bipedal stability. The reason behind this purpose was to better understand the...
physiological mechanisms that manifest in pelvis rotation. This phenomena is common in population and occurs, depending on sources, with intensity of few to few dozen percent (Bień et al., 1996; Bibrowicz, 1995; Prętkiewicz-Abacjew, 1997; Saulicz, 1996, 1998; Skolimowski, 1993). Currently pelvic abnormalities are observed in as high as 60-90% of primary school students (Słoń; 2015; Słoń and Strupińska-Thor, 2018). Even though the rotation may be one of the natural consequences of lateralization (Güntürkün and Ocklenburg, 2017; Lanshammar and Ribomb, 2011), its extreme cases result in highly destructive posture abnormalities. Muscle tissue is the easiest to influence in whole motoric system. Consequently, there is a great potential in understanding its role in controlling pelvic position.

Although the normal distribution testing was taken to determine selection of tests for further examination, there are several facts that came as a result of this operation. A great difference in conservativeness of several parameters can be mentioned. Normal distribution of maximal displacement was observed in all muscles. It can be explained by anatomical character of this parameter, that depends strictly on volume and stiffness of muscle unit of particular examined individual. The opposite tendency, observed in delay time lays in physiological background. As the neurotransmission has its typical velocity depending on fiber type, obtained measurements may take on specific range of values. Typical velocity of muscle electric conduction vary between 1.5 and 6 m/s what gives 1.7-6.7 ms per one centimeter of distance. Muscle contraction time of specific muscle fibers types take on following values: slow-twitch fibers 54±13 ms, fast-twitch resistant fibers 47±7 ms, fast-twitch fatigable fibers 49±8 ms (Górski, 2006). Delay time and contraction time showed a tendency to oscillate near single value that vary depending on examined muscle between 20 and 45 ms giving summary contraction time in range of 40-90 ms. Those summary values fit into literature norms for different fiber types suggesting initially studied units characteristics. Time variables that showed a normal distribution may be ones that slightly vary in main function individually.

Two muscle revealed lateral asymmetries. In both units differences were unidirectional and showed higher values on the right side of the body. Right External oblique revealed higher delay time (p=0.01). This finding suggest more tonic character of this unit. This parameter diversity may be a consequence of a presence of scoliosis diagnosed and treated in past in some of studied women (Dong-Kia et al., 2018; Linek et al., 2018). Analogic tendency was observed in Gluteus maximus which showed longer contraction time and summary contraction time on the right side (p≤0.001). Higher value of maximal displacement in right Gluteus muscle (p<0.001) was also found. This parameter could be mistakenly taken as an indicator of the opposite character of this unit as greater muscle volume may suggest higher concentration of fast-twitch fibers. More probable interpretation seem to be connected with increased length of studied unit. As pelvic rotation occurs in only one direction (frontal inclination of right side resulting in lowering of right iliac spine) elongation of Gluteus maximus on the right side may be naturally connected with differentiation in bone structure. There were no statistically significant asymmetries found in extremity muscles, regardless of what can be observed in athlete groups. Hamstring muscle strength differences were observed among others in rugby training women. (Hill, 2011). As tensimyography is a method usually used for sport related purposes, lateral asymmetries, as well as antagonistic asymmetries may be compared only with athlete material. Functional asymmetries are present in all population (Hides et al., 2010), however, comparison may be distorted because of high lateral specialization of professional sportsmen/women (Fukuda et al., 2018).

Statistically significant differences were observed in all time parameters in both muscle dyads. Maximal displacement was not compared in these tests because of strong dependency of this parameter in matter of unit morphology. Rectus abdominis revealed longer time parameters suggesting higher concentration of slow-twitch fibers than in its antagonist. Spinal muscles of this region are usually considered to be more prone to increased muscle tension and shrinkage. Erector spinae is usually found to activate a lot before the rest of trunk muscles in upper extremities movement studies (Eriksson Crommert et al., 2015). It shows a strong stabilizing function of this unit. However, results revealed even more tonic character of Rectus abdominis. This may suggest crucial role of neuronal control in trunk muscle stabilizing function. In lower extremity more tonic character was demonstrated in Biceps femoris. This finding is coincident with literature. Knee flexors and extensors are frequently examined in sport sciences because of their high importance in sport performance and injury prevention. Cięszczyk et al. described this muscle dyad in study of muscle strength. Their examination revealed grater muscle strength in the group of extensors in athlete group as well as in non-training group. What is more, in cited study control group appeared to have slightly greater differences than experimental group of basketball players. This tendency may or may not have further consequences. The role of muscle imbalance as a risk factor of injury is not clear. Research results vary even though most studies concern a specific sport group of soccer players (Murphy et al., 2003).

**Conclusion**

Lateral asymmetry was found in External oblique and Gluteus maximus. Right abdominal muscle revealed more tonic character. This delay time differences could have a source in scoliosis treated in past in some participants. Right Gluteus muscle
showed larger maximal displacement as well as higher time parameters. This unit appeared to have more tonic character and probably to be longer, due to typical pelvic asymmetry. There was no statistically significant asymmetry in lower extremity muscle, that would manifest typical leg lateralization. In antagonistic dyads more tonic character was found in Rectus abdominis and Biceps femoris. Erector spinae appeared to have lower time parameters than abdominal muscle despite its typical role in trunk stability. Tensiomyography, as a noninvasive method of studying muscles isometric contraction, appeared to be a reasonable choice for widening knowledge about human stability mechanisms.

References


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