

Abdominal muscles activity during abdominal bracing and posterior pelvic tilt in women after natural birth and after caesarean delivery

NATALIA KUCIEL^{1*}, JUSTYNA MAZUREK¹, KAROLINA BIERNAT¹, ŁUKASZ PAWIK², EDYTA SUTKOWSKA¹

¹ Department and Division of Medical Rehabilitation, Wrocław Medical University, Wrocław, Poland.

² Department of Physiotherapy in Orthopaedic and Traumatologic Surgery, University School of Physical Education, Wrocław, Poland.

Purpose: Exercises after pregnancy can reduce the severity and risk of postnatal locomotor system disorders and muscular dysfunctions. The aim of the study was to evaluate electromyographic activity of abdominal muscles in women who gave birth naturally and via a caesarean section, and to compare it to a group of women who have never given birth. *Methods:* 27 women were included into the study after completing the personal questionnaire and functional examination. The surface electromyography during abdominal bracing and posterior pelvic tilt was used to test rectus abdominis muscles and internus oblique/ transversus abdominis muscles bilaterally. After normalization test, patients were asked to perform abdominal bracing and posterior pelvic tilt exercises. *Results:* Activity of rectus abdominis muscle is higher in posterior pelvic tilt compared to abdominal bracing. It should be noted that the internus oblique/transversus abdominis muscle activity in both exercises is similar. *Conclusions:* In women after natural birth and after a cesarean section who experienced no locomotor system symptoms, no statistically significant differences in abdominal muscle activity in both exercises were observed. In each group being studied, posterior pelvic tilt activated rectus abdominis muscles to a greater extent than just bracing.

Key words: motor control, exercise performance, physical activity, caesarean section

1. Introduction

Physical activity and regular exercising during the perinatal and postnatal periods are very important for women, but, so far, little time has been devoted to this issue [23]. Exercising offers physical and psychological positive effects and improves quality of life in postpartum period [8], [11]. It promotes faster return to pre-pregnancy body weight, regulates cell metabolism, reduces the risk of postpartum depression and improves cardiopulmonary function [12]. Furthermore, a suitable training regimen can reduce the severity and risk of postnatal locomotor system disorders and muscular dysfunctions, such as lower back pain, diastasis recti or pelvic floor disorders (e.g., stress urinary incontinence) [11]. For women after natural birth with no complications, aerobic exercises are recommended

as early as 6 weeks after delivery, while abdominal muscle activation is recommended during the first few days following delivery. The situation is different for women after caesarean section (C-section) due to a cut in the abdominal wall and the postoperative wound. In their case, abdominal muscle exercises can only be performed at a later period [8]. C-section is one of the most common surgical procedures performed on the abdominal cavity. Currently, it is estimated that approx. 40% deliveries are done via a C-section [19]. A C-section affects the activity of the abdominal muscles by weakening them and lowering their tonic activity and stabilizing function. For this reason, it is recommended to postpone abdominal muscle exercises, as these muscles need more time to regenerate after this type of delivery [10]. At present, there are few studies which deal with physical activity and exercises recommended for women after a C-section

* Corresponding author: Natalia Kuciel, Department and Division of Medical Rehabilitation, Wrocław Medical University, ul. Borowska 213, 50-556 Wrocław, Poland. Phone: 660 897 427, e-mail: nataliakuciel@interia.pl

Received: July 30th, 2020

Accepted for publication: November 18th, 2020

(this applies to both women after an uncomplicated C-section and women who suffer complications, such as diastasis recti or lower back pain) [1], [5]. So far, researchers have focused on the immediate postoperative period, where the effects of TENS and verticalization-supporting exercises on return to functioning were studied [5]. Researchers were also interested in pelvic floor muscles (PFM) after both types of delivery in the context of stress urinary incontinence, although this area also lacks sufficient information and reference to activity of these muscles in women after delivery who do not experience pelvic floor problems [1]. However, the most frequently discussed issue is that of diastasis recti abdominis (DRI), although studies which would define the characteristics of activity of all abdominal muscle groups as well as individual linea alba exercises and differences between them depending on the type of delivery have not been found [26].

The aim of this study was to evaluate electromyographic activity of abdominal muscles in women who gave birth naturally and via a C-section, and to compare it to a group of women who have never given birth. Determination of abdominal muscle activity in women who suffer no musculoskeletal pain is necessary for comparison of that activity to symptomatic groups after natural birth or a C-section. So far, there have been no studies which would determine the characteristics of activity of these muscles during the period of 6–12 months after birth.

2. Materials and methods

Type of the study

A cross-sectional study design was used to compare the muscles activity level in 3 groups of women: 6–12 months after natural delivery, C-section and control group (nulliparous women).

Participants of the study

The study comprised 11 women after natural birth, 8 women after a C-section and 8 women who have never given birth (control group). Patients were recruited via the Internet, with the help of a social media website, where invitation to participate in the study was posted in closed groups which deal with postnatal topics. Volunteers underwent the examination during morning hours at the University Clinical Hospital in Wrocław, in a gymnasium belonging to structures of the Department and Division of Medical Rehabilitation of the Wrocław Medical University. After being informed

about the examination procedure, the patients gave their written consent to participate in the study and to have their personal data processed. Inclusion criteria for the group of women after natural birth were: no lumbosacral or abdominal pain, first pregnancy and uncomplicated delivery with no additional procedures, i.e., no forceps or vacuum extraction, negative spine, hip joint and knee joint mobility tests, negative physical examination tests (Posterior Pelvic Pain Provocation, Long Dorsal Ligament test, Gaenslen's test, modified Trendelenburg test). Criteria for the group of women after a C-section: no lumbosacral, pelvic or abdominal pain, first pregnancy and delivery, planned C-section without complications, negative physical examination tests as mentioned above.

Inclusion criteria for the control group were: no lumbosacral, pelvic or abdominal pain, no previous pregnancies and deliveries, negative physical examination tests.

Exclusion criteria for all groups: no consent to participate, lumbosacral, pelvic or abdominal pain, 2 or more pregnancies, unexpected C-section, natural birth with additional procedures, positive physical examination tests, problems with proper performance of the motor task.

The study was carried out in accordance with the Helsinki Declaration and before its commencement was approved by the Bioethics Commission of the Wrocław Medical University (Bioethics Commission Opinion no. KB – 321/2018).

Questionnaire

The participants have filled in a personal questionnaire which included information concerning socio-demographic and clinical data: age, mode of delivery, type of work performed as well as information concerning the occurrence of lumbosacral pain and incontinence problems. The person who examined the patients measured their height, weight and BMI, and supplemented the relevant data in the questionnaire.

Function tests used for physical examination

Function tests were performed by the person who took the measurements in order to exclude pain and limitations in terms of mobility of the spine, hip joints or knee joints (Table 1). Performed tests included: spine mobility tests in the sagittal, frontal and rotation planes in a standing position, passive hip joint mobility tests in the aforementioned planes, passive knee joint mobility test (flexion/extension), Posterior Pelvic Pain Provocation, pain provocation in the iliolumbar ligament area, Trendelenburg test and Gaenslen's test.

Table 1. Tests used for physical examination

Test	Performance
Spine mobility test in the sagittal, frontal and rotation planes	Standing position, feet at hip level, hands close to the body. Performance: flexion and extension of the trunk; lateral flexion left and right; rotation left and right [31]
Hip joint mobility test	Supine position: passive test of flexion, internal and external rotation as well as abduction and adduction of the hip. Prone position: passive test of hip extension [31]
Knee joint mobility test	Supine position: passive test of knee joint flexion and extension as well as internal and external rotation [31]
Posterior Pelvic Pain Provocation test	Supine position, hip flexed to 90 degrees on the tested side. Gentle pressure is applied to the bent knee long the long axis of the femur, while the pelvis is stabilised by the other hand of the tester on the contralateral anterior superior iliac spine [3]
Long Dorsal Ligament Test	Lying on the side, hip and knee flexed. Test involves palpation of the long dorsal ligament [3]
Gaenslen's test	Supine position. Trunk stabilised by flexion of the other limb in the hip and knee joint and pulling it towards the trunk. Tested limb is placed outside the couch in hyperextension [24]
Modified Trendelenburg test	Standing position. The patient lifts the lower limb flexed in the knee joint to a 90-degree angle [3]

Surface electromyography

The Myotrace 400 4-lead surface electromyograph manufactured by Noraxon Company from the USA was used to perform the examination. Analysis of results and data were recorded in the Myoresearch MasterEdition software. BioLead Lok paediatric electrodes (manufactured by Vermed, Lendersdorf, Germany), diameter of 30 mm, with Ag/AgCl sensors, were used in the examination. Before the electrodes were placed, the skin was cleansed with a salicylic acid alcohol solution to reduce its impedance. Cables were fixed to the skin with tape to minimize the movement of electrodes. Electrodes were placed bilaterally in supine position in the following sites:

- 1) Transverse/internal oblique abdominal muscle (TrA/IO) – 2 cm below the anterior superior iliac spine, in the inferomedial direction [31]
- 2) Lower rectus abdominis (RA) muscle – midpoint between the umbilicus and the pubic symphysis, 3 cm to the side [3].

Electrodes were placed at a distance of 2 cm from one another. Reference electrode was placed on the

right iliac wing. Mean amplitude of activity of the examined muscles [uV] expressed as % of submaximal activity of a given muscle was used to analyse abdominal muscle activity [15], [24] (the EMGs of each muscle during trunk exercise tasks are expressed as a value relative to its maximum [% EMGmax]).

SMVC normalization

In order to normalize test results, a test had to be performed before the exercises could commence. Submaximal Voluntary Contraction was used for normalization. Examined persons were lying on a mattress, with hips flexed at a 45-degree angle, knees flexed at a 90-degree and feet in neutral position. When the examiner said “up”, both limbs were raised 2 cm above the floor. Activity was maintained for 3 seconds, and then the examiner instructed the examined persons to lower their feet by saying “down”. This test was repeated 3 times, with a 15-second interval between each repetition [16], [18].

Abdominal bracing and posterior pelvic tilt

Patients performed the exercises in a supine position, with hips flexed at a 45-degree angle and knees flexed at a 90-degree angle. The lumbar region was in the neutral position. The exercises were performed with a normal breathing pattern, with no breath holding and no additional movement of the ribs, diaphragm or trunk. Before commencing the exercises, examiner-physiotherapist gave detailed verbal instruction and tactile feedback during trial to ensure proper technique of the exercises.

Abdominal bracing (AB) – the patients were asked to tense their abdominal muscles by inflating the abdomen when instructed, without pressing their back against the floor, and to hold this tension for 3 seconds [13].

Posterior pelvic tilt (PPT) – the patients were asked to inhale and exhale and during exhalation to press gently their back against the floor (flatten lower back) when instructed and hold the tension for 3 seconds [11].

Each exercise was repeated 3 times, with a 10-second interval between each repetition. PPT commands – “press” – “relax”; AB commands – “tense” – “relax”.

Statistical analysis

Statistical analysis was done using the Statistica 10.0 software. Differences between the right and left side of the body were assessed using the Student's *t*-test for dependent samples. Differences between exercises in each group were assessed using the Student's

t-test for independent samples. Factorial ANOVA with *post-hoc* test was used to assess the differences between the groups. Statistical significance of $p < 0.05$ was assumed.

3. Results

The studied groups were not homogeneous in terms of age. Women in control group were the youngest, while women in the group after a C-section were the oldest (Table 2).

Table 2. Characteristics of the studied groups

Group	1	2	3	<i>P</i> (Anova)
	Mean (SD)	Mean (SD)	Mean (SD)	
Age [years]	28.09 (3.3)	31.62 (2.77)	25.12 (4.67)	0.005
Weight [kg]	58.5 (8.14)	55.8 (9.20)	60.06 (7.07)	0.592
Height [cm]	1.66 (0.05)	1.65 (0.06)	1.70 (0.06)	0.121
BMI [kg/m ²]	21.11 (2.23)	20.39 (2.57)	20.76 (2.91)	0.825

Legend: BMI – body mass index, 1 – group of women after natural birth, 2 – group of women after a caesarean section, 3 – control group, nulliparous women, *p* – statistical significance level.

No statistically significant difference during activity of analyzed muscles between the abdominal sides in individual groups of women was observed for both AB and PPT exercises (Table 3).

Differences between exercises are statistically significant when analysing the activity of the RA muscles. Activity of these muscles is higher in PPT com-

pared to AB. It should be noted that the IO/TrA muscle activity in both exercises is similar (Table 4).

Table 4. Differences in abdominal muscle activity in individual groups between abdominal bracing and posterior pelvic tilt

Muscles activity	1	2	3
RRA AB vs. PPT	0.017	0.0156	0.142
LRA AB vs. PPT	0.0354	0.0318	0.085
RIO AB vs. PPT	0.663	0.739	0.7255
LIO AB vs. PPT	0.970	0.383	0.546

Legend: RRA – right rectus abdominis, LRA – left rectus abdominis, RIO – right internal oblique/transversus abdominis, LIO/TrA – left internal oblique/transversus abdominis, 1 – group of women after natural birth, 2 – group of women after a caesarean section, 3 – control group, nulliparous women, AB – abdominal bracing, PPT – posterior pelvic tilt.

Table 5. Differences in abdominal muscles activity between groups

Muscles activity	F	<i>p</i>
RRA AB	1.4380	0.2563
LRA AB	0.7493	0.4829
RIO AB	2.0998	0.1435
LIO AB	0.5517	0.5828
RRA PPT	0.7246	0.4944
LRA PPT	1.6563	0.2111
RIO PPT	1.5503	0.2318
LIO PPT	0.1461	0.8647

Legend: RRA – right rectus abdominis, LRA – left rectus abdominis, RIO – right internal oblique/transversus abdominis, LIO/TrA – left internal oblique/transversus abdominis, AB – abdominal bracing, PPT – posterior pelvic tilt, F – factorial ANOVA *p* – statistical significance.

Table 3. Comparison of abdominal muscle activity expressed as a percentage of submaximal voluntary contraction (% SMVC) of abdominal muscles on both sides in individual exercises

	1			2			3		
	Mean (% SMVC)	SD	<i>p</i>	Mean (% SMVC)	SD	<i>p</i>	Mean (% SMVC)	SD	<i>p</i>
Abdominal bracing									
RRA	11.519	9.009	0.226	19.147	11.762	0.773	24.076	25.489	0.080
LRA	13.684	13.22		20.058	14.641		22.506	23.168	
RIO	130.845	142.431	0.056	40.502	28.419	0.597	82.603	50.357	0.532
LIO	81	90.276		50.003	48.364		73.203	29.119	
Posterior pelvic tilt									
RRA	38.685	33.437	0.657	56.165	36.230	0.365	42.645	25.651	0.924
LRA	35.213	28.468		64.094	50.145		43.092	23.168	
RIO	106.528	114.104	0.070	45.201	26.951	0.189	75.727	28.257	0.343
LIO	79.691	75.715		74.793	61.224		65.324	25.028	

Legend: RRA – right rectus abdominis, LRA – left rectus abdominis, RIO – right internal oblique/transversus abdominis, LIO/TrA – left internal oblique/transversus abdominis, 1 – group of women after natural birth, 2 – group of women after a caesarean section, 3 – control group, nulliparous women, SD – standard deviation, *p* – statistical significance level, Student's *t*-test.

After analysing the activity of the examined muscles in both exercises between the groups, no statistical significance was found between the group of women after natural birth, the group of women after a C-section and the control group (Table 5).

4. Discussion

Activating abdominal muscles after childbirth is extremely important. Their tension is reduced during pregnancy due to the growing fetus, and it should return to what it was before pregnancy during the postnatal period [11]. Our study tests abdominal muscles in two exercises in supine position in three groups of women: postpartum after natural birth, after C-section and nulliparous women. It is difficult to find evidence where postpartum women are divided into groups according to type of delivery in context of muscles activity. Comparison of women after natural childbirth and C-section concerned the study of pelvic floor muscle activity and the impact of the type of delivery on the urinary continence [2], [30]. Abdominal muscles activity after C-section may differ from that in women who gave birth naturally. Cutting of the abdominal fascia may lead to reduced stabilizing function [17]. In addition, damage to nerves which supply the pelvic girdle and abdominal muscles may further disrupt and hinder the return of their function after delivery [9]. Even though a C-section is a significant surgery on abdominal layers with frequent complications in the form of adhesions, endometriosis in the scar left after a C-section or abdominal and lumbar pain, all of which affect abdominal muscles, so far few publications have been devoted to analysis of abdominal muscle activity after delivery [21]. Our study shows that C-section does not have impact on abdominal wall 6–12 months postpartum, and no significant changes between groups in this period of time have been observed. The abdominal muscles play important role in maintaining posture, they control lumbar and pelvic stability and support abdominal viscera. These muscles play also role in breathing and in maintaining proper intra-abdominal pressure. Exhalation accompanying activation of the abdominal muscles reduces intra-abdominal pressure and, in our study, proper breathing pattern was consistently enforced in tested women [11]. The activity of abdominal muscles varies in different positions and exercises [4]. Static abdominal exercises may be beneficial for postpartum women, however the number

of studies which utilise the Evidence Based Medicine approach is small, and it is difficult to clearly determine the safety and effectiveness of these exercises [27]. In our study, there were no differences in muscles activity between groups, but activity of RA muscle varied between AB and PPT. Coldron et al. [6] tested RA in postpartum women, but they focused on DRA and measured cross-sectional area, thickness, width and inter-recti distance. According to their research, RA has impact on abdominal wall strength and stiffness, and it may be important to develop proper and safe exercise program to restore function of these muscles. One study dealt with analysis of the RA muscle after a natural birth compared to nulliparous women. It was found that the RA muscle after birth was thinner and wider in ultrasound examinations conducted during the period of 12 months after delivery [30]. Rectus abdominis muscles were also examined in the context of exercises used in the treatment of DRA. It was observed that isometric exercises considerably reduce the inter-recti distance during the period of 6 months after delivery [22]. Mota et al. [22] tested draw-in maneuver and abdominal crunch exercise in 6–8 weeks, 12–14 weeks and 24–26 weeks after delivery with the use of ultrasounds recording. They observed that draw-in maneuver enlarged inter-recti distance and crunch exercise significantly reduced inter-recti distance and activated RA in greater way than draw-in. Urogynaecological physiotherapists do not recommend crunch exercises in postpartum period, because performed incorrectly, may increase intra-abdominal pressure and increase overloading in pelvic floor and lumbar area [14]. Crunch exercises may be replaced by PPT exercise. PPT in supine position activates all layers of abdominal muscles. Drysdale et al. [7] compared PPT and abdominal hollowing. Their test confirmed that PPT produces much more RA EMG activity, and recruits global abdominal wall muscles in contrast to abdominal hollowing. In our study, PPT activates also IO/TrA muscles similarly to AB. TrA contraction through anatomy of this muscle has impact on inter-recti distance and its activation may reduce DRA in postpartum period. 35–60% of the fibers from the transversus abdominis TrA muscle connect to the linea alba, so its role in preventing and reducing DRA is significant [28].

Pelvic position plays important role in achieving proper activation of abdominal muscles [20]. Relating that information to this study, it can be assumed that PPT would be one of the exercises recommended for DRA, as it activates the RA muscle to a much greater extent than AB. The study needs to

be extended to compare the effectiveness of this exercise in both types of delivery for women who experienced DRA.

Future research in this area should include continued assessment of pelvic pressure during recreational and occupational activities common to women. Multidisciplinary work, involving physical and occupational therapy and pelvic floor specialities, may facilitate understanding and testing of effective techniques that can be used to simultaneously preserve pelvic floor integrity and back health during both recreational and occupational activities.

Limitations

Researchers suggest that stabilising activity of deep abdominal muscles should not exceed 15% [29]. This activity is much higher in our study, but we utilised the SMVC normalisation method instead of MVC. Women after delivery were treated as persons with abdominal muscle dysfunction, and, as a precaution, MVC techniques were not utilised to normalise the amplitude of the examined muscles. The highest TrA/IO muscle activity in % SMVC was noted in the group of women after natural birth, especially on the right side of the abdomen. Results for these muscles in other groups were similar to one another. To answer the question of what caused such a high deep muscle tension, the study needs to be extended on a larger group of women, with history taking extended to include a number of questions concerning positions during carrying and feeding. The information about sacral inclination might be useful to determine the pelvis orientation in postpartum period [20], [25].

5. Conclusions

In women after natural birth and after a C-section, who experienced no locomotor system symptoms, no statistically significant differences in abdominal muscle activity in PPT and AB were observed. The degree of activity of these muscles is similar in all 3 groups, which constitutes a good point of comparison for analysis in groups of women after delivery, who suffer from lumbopelvic complex pain and abdominal muscle dysfunction (such as DRI or pelvic floor muscle dysfunction).

In each studied group, PPT activated the rectus abdominis muscle to a much greater extent than just AB, which, in the case of abdominal muscle therapy, may be important for optimisation of therapeutic exercises.

References

- [1] BARBOSA A.M.P., MARINI G., PICULO F., RUDGE C.V., CALDERON I.M.P., RUDGE M.V.C., *Prevalence of urinary incontinence and pelvic floor muscle dysfunction in primiparae two years after cesarean section: cross-sectional study*, Sao Paulo Med. J., 2013, 131.
- [2] BLOMQUIST L., MCDERMOTT K., HANDA V.L., *Pelvic pain and mode of delivery*, Am. J. Obst. Gyn., 2014, 210, 423, e1-423.e6.
- [3] CALLABAN M., *Comparison of muscle activation in the active straight leg rise and double straight leg lowering test. A thesis presented to the collage of graduate and professional studies*, Department of Applied Medicine and Rehabilitation, 2011, Indiana State University.
- [4] CANAMERO DE L.S., DA LUNA-CARRERA I., DE LA HOZ GONZALEZ C.A., SOTO-GONZALEZ M., *Effects of an exercise program on diastasis recti in women*, Int. J. Health Sci. Res., 2019, 10, 90–99.
- [5] ÇITAK KARAKAYA İ., YÜKSEL İ., AKBAYRAK T., DEMİRTÜRK F., KARAKAYA M.G., OZYÜNCÜ Ö., BEKSAÇ S., *Effects of physiotherapy on pain and functional activities after cesarean delivery*, Arch. Gynecol. Obstet., 2012, 85, 621–627.
- [6] COLDRON Y., STOKE M.J., NEWHAM D.J., KATY C., *Postpartum characteristics of rectus abdominis on ultrasound imaging*, Man. Ther., 2008, 13, 112–121.
- [7] DRYSDALE C.L., EARL J.E., HERTEL J., *Surface electromyographic activity of the abdominal muscles during pelvic tilt and abdominal hollowing exercises*, J. Athl. Train, 2004, 39, 32–36.
- [8] EL-MEKAWAY H., ELDEEB A., ELBEGAWY A., *Effect of abdominal exercises versus abdominal supporting belt on postpartum abdominal efficiency and rectus separation*, Int. J. Med. Health Sci., 2013, 7, 75–79.
- [9] GIZZO S., ANDRISANI A., NOVENTA M., DI GANGI S., QUARANTA M., COSMI E., D'ANTONA D., NARDELLI G.B., AMBROSINI G., *Caesarean Section: Could Different Transverse Abdominal Incision Techniques Influence Postpartum Pain and Subsequent Quality of Life? A Systematic Review*, PLoS One, 2015, 10, e0114190.
- [10] GÜRŞEN C., İNANOĞLU D., KAYA S., AKBAYRAK T., BALTACI G., *Effects of exercise and Kinesio taping on abdominal recovery in women with cesarean section: a pilot randomized controlled trial*, Arch. Gynecol. Obstet., 2016, 293, 557–565.
- [11] KHANDALE S.R., HANDE D., *Effects of abdominal exercises on reduction of diastasis recti in postnatal women*, Int. J. Health Sci. Res., 2016, 6, 182–191.
- [12] KO Y.L., YANG C.L., FANG C.L., LEE M.Y., LIN P.C., *Community-based postpartum exercise program*, J. Clin. Nurs., 2013, 22, 2122–2131.
- [13] KOH H.W., CHO S.H., KIM C.Y., *Comparison of the effects of hollowing and bracing exercises on cross-sectional areas of abdominal muscles in middle-aged women*, J. Phys. Ther. Sci., 2014, 26, 295–299.
- [14] LIAW L.J., HSUM M.-J., LIAO C.-F., LIU M.-F., HSU A.-T., *The relationships between inter-recti distance measured by ultrasound imaging and abdominal muscle function in postpartum women: A 6-month follow-up study*, I. Orthop. Sports Phys. Ther., 2011, 41, 435–443.
- [15] MAEO S., TAKAHASHI T., TAKAI Y., KANEHISA H., *Trunk muscle activities during abdominal bracing: comparison among muscles and exercises*, J. Sports Sci. Med., 2013, 12, 467–474.
- [16] MARSHALL P., MURPHY B., *The validity and reliability of surface EMG to assess the neuromuscular response of the*

- abdominal muscles to rapid limb movement, *J. Electromyogr. Kinesiol.*, 2003, 13, 477–489.
- [17] MATHAI M., HOFMEYER G.J., MATHAI N.E., *Abdominal surgical incisions for caesarean section*, *Cochrane Database Syst. Rev.*, 2013, 31, CD004453.
- [18] MCGILL S.M., JUKER D., KROPF P., *Appropriately placed EMG surface electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine*, *J. Biomech.*, 1996, 29, 1503–1507.
- [19] MENACKER F., DECLERCQ E., MACDORMAN M.F., *Cesarean delivery: background, trends, and epidemiology*, *Semin. Perinatol.*, 2006, 30, 235–241.
- [20] MICHNIK R., ZADOŃ H., NOWAKOWSKA-LIPIEC K., JOCHYMZYK-WOŹNIAK K., MYŚLIWIEC A., MITAS A.W. *The effect of the pelvis position in the saggital plane on loads in the human musculoskeletal system*, *Acta Bioeng. Biomech.*, 2020, 22, DOI: 10.37190/ ABB-01606-2020-02.
- [21] MORO F., MAVRELOS D., PATEMAN K., HOLLAND T., HOO W.L., JURKOVIC D., *Prevalence of pelvic adhesions on ultrasound examination in women with a history of Cesarean section*, *Ultrasound Obstet. Gynecol.*, 2015, 45, 223–228.
- [22] MOTA P., PASCOAL A.G., CARITA A.I., BO K., *Inter recti distance at rest, during abdominal crunch and drawing-in exercises during pregnancy and postpartum*, *Physiother.*, 2015, 101, E1050–E1051.
- [23] MOTTOLA M.F., *Exercise in the postpartum period: practical applications*, *Curr. Sports Med. Rep.*, 2002, 1, 362–368.
- [24] OLEKSY Ł., CZARNY W., BAJOREK W., KRÓL P., MIKA A., KIELNAR R., *The evaluation of shoulder muscle fatigue in volleyball players*, *J. Nov. Physiother.*, 2018, 8, 388.
- [25] OPALA-BERDZIK A., CIEŚLIŃSKA-ŚLIWEK J., GNAT R., *A prospective longitudinal comparison of the sacra inclination angle in women between their early and advanced pregnancy and 6 month postpartum follow up*, *Acta Bioeng. Biomech.*, 2019, 21, 127–134.
- [26] PASCOAL A.G., DIONISIO S., CORDEIRO F., MOTA P., *Inter-rectus distance in postpartum women can be reduced by isometric contraction of the abdominal muscles: a preliminary case-control study*, *Physiother.*, 2014, 100, 344–348.
- [27] THABET A.A., ALSHEHRI M.A., *Efficacy of Deep Core Stability Exercise Program in Postpartum Women with Diastasis Recti Abdominis: A Randomised Controlled Trial*, *J. Musculoskelet. Neuronal Interact.*, 2019, 19, 62–68.
- [28] URQUHART D.M., BARKER P.J., HODGES P.W., STORY I.H., BRIGGS C.A., *Regional morphology of the transversus abdominis and obliquus internus and externus abdominis muscles*, *Clin. Biomech.*, (Bristol, Avon), 2005, 20, 233–241.
- [29] VERA-GARCIA F.J., ELVIRA J.L., BROWN S.H., MCGILL S.M., *Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations*, *J. Electromyogr. Kinesiol.*, 2007, 17, 556–567.
- [30] WEIS G.A., TRIANO J.J., BARRETT J., CAMPBELL M.D., CROY M., ROEDER J., *Ultrasound assessment of abdominal muscle thickness in postpartum vs. nulliparous women*, *J. Man. Phys. Ther.*, 2015, 38, 352–357.
- [31] WORKMAN C., DOCHERTY D., PARFREY K.C., BEHM D.G., *Influence of Pelvis Position on the Activation of Abdominal and Hip Flexor Muscles*, *J. Strength Cond. Res.*, 2008, 22, 1563–1569.