

# Changes in the contraction ratio of transversus abdominis and quality of life in patients after total hip replacement and three-compartment knee arthroplasty with implant posterior stabilization

Zmiany współczynnika aktywacji skurczu mięśnia poprzecznego brzucha oraz jakość życia u chorych po przebytej aloplastyce całkowitej stawów biodrowych i aloplastyce trójpředziałowej stawów kolanowych ze stabilizacją tylną implantu

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## Key words

Core stability, m. transversus abdominis, Rehabilitative Ultrasound Imaging (RUSI)

## Abstract

**Introduction:** Core stability is a reference term for the performance of the deep trunk muscles, which provide functional stability of the lumbopelvic area and control the human body in static and dynamic positions.

**Material and methods:** The study group consisted of 30 patients between the age of 42 and 76 years (mean=61.4) after total hip arthroplasty (total hip replacement, Group I) and total knee arthroplasty (three-compartment arthroplasty with posterior stabilization of the implant - Group II). In 18 (60%) patients, hip endoprosthesis was performed, whereas in 12 (40%), three-compartment knee endoprosthesis with posterior stabilization has been implanted. In the study group, Rehabilitative Ultrasound Imaging (RUSI) of the transversus abdominis muscle thickness was conducted at rest and in contraction, the transversus abdominis activation ratio was specified, the SF-36 Life Quality Questionnaire was applied and a three-week treatment cycle was performed. The tests were carried out twice, i.e. before and after treatment.

**Results:** In the group of patients after total hip replacement, the transversus abdominis (TrA) contraction ratio before the beginning of the exercise programme was  $0.79 \pm 0.06$ , and after its completion  $0.9 \pm 0.02$ . The observed difference was statistically significant at  $p < 0.001$ . In the group of patients after three-compartment knee arthroplasty, the TrA contraction ratio before the beginning of the exercise programme was  $0.78 \pm 0.09$ , and after its completion  $0.91 \pm 0.02$ . The difference of these values was statistically significant at the level of  $p < 0.05$ . The results of the SF-36 questionnaire in both groups indicate improvement in physical functioning. The observed difference was statistically significant at  $p < 0.001$ .

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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**Conclusions:** The performed three-week physiotherapy treatment in conjunction with deep muscle training increases the thickness of the TrA muscle during rest and contraction testing, and increases the transversus abdominis contraction ratio in Rehabilitative Ultrasound Imaging in the study groups. Furthermore, improvement in the level of physical functioning was observed within the studied groups.

#### Słowa kluczowe

Stabilizacja centralna, mięsień poręczny brzucha, fizjoterapeutyczne obrazowanie ultrasonograficzne

#### Streszczenie

**Wstęp:** „Stabilizacja centralna” (ang. *core stability*) jest terminem odnoszącym się do wydolności mięśni głębokich tułowia, które zapewniają stabilność funkcjonalną okolicy lędźwiowo-krzyżowo-biodrowej oraz kontrolują ciało człowieka w pozycjach statycznych i dynamicznych.

**Material i metody:** Grupę badaną stanowiło 30 chorych w przedziale wiekowym 42-76 lat (średnia 61,4 lat) po przebytej aloplastyce całkowitej stawu biodrowego (endoprotezoplastyce – Grupa I) i kolanowego (aloplastyka trójpředziałowa ze stabilizacją tylną implantu – Grupa II). Spośród nich 18. (60%) chorych stanowiły osoby, u których implantowano endoprotezę do stawu biodrowego, 12 natomiast, (40%) endoprotezę trójpředziałową stawu kolanowego ze stabilizacją tylną implantu. W grupie badanej wykonano fizjoterapeutyczne obrazowanie ultrasonograficzne (RUSI) grubości mięśnia poprzecznego brzucha w stanie skurczu i rozkurczu, określono współczynnik aktywacji mięśnia poprzecznego brzucha, zastosowano Kwestionariusz Jakości Życia SF-36 oraz przeprowadzono 3-tygodniowy cykl leczenia. Badania wykonano 2-krotnie tzn. przed rozpoczęciem i po zakończeniu leczenia.

**Wyniki:** W grupie chorych po endoprotezoplastyce całkowitej stawu biodrowego współczynnik aktywacji skurczu mięśnia poprzecznego brzucha (TrA) przed rozpoczęciem programu ćwiczeń wynosił  $0,79 \pm 0,06$ , a po jego zakończeniu  $0,91 \pm 0,02$ . Ustalona jego różnica było istotna statystycznie na poziomie  $p < 0,001$ . W grupie chorych po endoprotezoplastyce trójpředziałowej stawu kolanowego współczynnik aktywacji skurczu TrA przed rozpoczęciem programu ćwiczeń kształtował się na poziomie  $0,78 \pm 0,09$ , a po jego zakończeniu  $0,91 \pm 0,02$ . Różnica tych wartości było istotna statystycznie na poziomie  $p < 0,05$ . Wyniki kwestionariusza SF-36 w obu grupach świadczą o poprawie funkcjonowania w sferze fizycznej. Różnica ta była istotna statystycznie na poziomie  $p < 0,001$ .

**Wnioski:** Przeprowadzona 3-tygodniowa fizjoterapia w połączeniu z treningiem mięśni głębokich wpływa na zwiększenie grubości mięśnia TrA podczas badania w rozkurczu oraz w skurczu oraz wpływa na zwiększenie współczynnika aktywacji mięśnia poprzecznego brzucha w fizjoterapeutycznym obrazowaniu ultrasonograficznym w badanych grupach. Zaobserwowano również poprawę poziomu funkcjonowania fizycznego w badanych grupach.

## INTRODUCTION

Core stability is a reference term for the performance of the deep trunk muscles, which provide functional stability of the lumbopelvic area and control the human body in static and dynamic positions.

Dynamic balance is defined as the ability of an individual to steadily maintain the body's center of gravity during movement and is an indispensable component of many forms of physical activity, such as walking, running and climbing stairs. The deep muscles are a kind of initiator of each of the body's movements, starting with its smallest components and ending with complex movement sequences. They form the so-called active corset, which is the basic requirement to ensure stabilization for spinal and limb movements<sup>1</sup>. The stability and resulting movement of the limbs depend on the efficiency of the muscles building the cylindrical belt surrounding the lumbar spine. Movement in the distal part is previously initiated, secured and controlled by the work of the deep mus-

cles<sup>2,3</sup>. Among others, Hodges and Tsao<sup>4</sup> draw attention to the role regarding the feedforward function of core stabilization for motion in distal parts. Feedforward is associated with the recruitment of deep muscles to create a global movement on a circuit<sup>6</sup>. The transverse muscle of the abdomen (Musculus Transversus Abdominis-TrA) along with its function is related to the movements of the chest, the iliac girdle and the spine, and participates in the control of the lumbar and pelvic complex<sup>7,2</sup>. Until recently, in physiotherapeutic practice, attention was mostly paid to improving the parameters of global muscle strength, recognizing that they play a superior role. It is now well-known that the activation and endurance of both muscle groups is as important as strength. The results of these studies indicate the role of core stability and motor control in order to correctly initiate functional movements, which is of particular importance in preventing dysfunction of the motor organ<sup>7,8</sup>. An important question concerning the importance of core stability is

imposed in terms of the movements in the hip and knee joints. Therefore, in the process of rehabilitation of patients with dysfunctions of the musculoskeletal system, emphasis should also be placed on deep muscle activation in relation to improving the quality of movement. In normal conditions, deep (local) body stabilizers must show activity while minimizing unwanted translational movements of the skeletal apparatus. This means that contraction of muscles is to guarantee the possibility of passive structure stabilization. Their role is to create proper conditions for economical work of the global muscles using the entire energy potential generated by the supplying muscles<sup>9</sup>.

## STUDY AIM

The aim of the study was to assess the impact of the proposed rehabilitation programme combined with core stabilization training in patients after complete total hip arthroplasty and three-compartment knee replacement with posterior stabilization of

the implant, and above all, to answer the following questions:

1. Does and in what manner does the proposed rehabilitation programme for osteoarthritis surgical patients by means of total hip replacement and three-compartment knee arthroplasty with posterior stabilization of the implant affect the thickness of the abdominal transverse muscle?
2. Does and in what manner does the proposed rehabilitation programme for the patients included in the study, combined with deep muscle training, affect the contraction ratio of the abdominal transverse muscle?
3. Does and to what degree does the proposed rehabilitation programme combined with deep muscle training for patients included in the study affect quality of life, especially functional physical fitness?

## RESEARCH MATERIAL

The aim of the study was based on the research material collected from the Clinic of Traumatic Surgery and Orthopaedics of the 5<sup>th</sup> Military Clinical Hospital with Polyclinic - Independent Public Health Care Centre in Krakow (5WSK) and the Department of Systemic Rehabilitation of this hospital (ORO). It comprised 30 patients, including 18 (60%) in which total hip replacement using an uncemented Corail type endoprosthesis and using the cemented Avantage type (Group I) and 12, or 40%, in which PFC three-compartment arthroplasty endoprosthesis with posterior implant stabilization was performed (Group II). The group consisted of 22 (73%) women and 8 (27%) men. Those included in the trial underwent these operative procedures unilaterally, and their age ranged from 42 to 76 years, giving an average of 61.4 years. The research was carried out from March to November 2016, 12 to 24 months after the analyzed surgical procedures – with an average of 19 months.

The following inclusion criteria were adopted:

1. Undergoing one-sided hip arthroplasty with uncemented Corail type endoprosthesis, cemented Avantage type or three-compartment arthroplasty of the knee joint with PFC endoprosthesis including posterior implant stabilization.
2. Absence of abdominal cavity surgery.
3. Logical verbal contact with those included in the study.
4. Age between 42 and 76 years.
5. Level of allo- and autopsychic orientation of patients with a minimum of 7 points from the Mental State Questionnaire according to Pfeiffer-SPMSQ.
6. Informed consent to participate in the proposed study.

The study was planned and carried out in accordance with the Declaration of Helsinki. Participants were informed orally and in writing about the nature, purposes and conditions of testing and agreed to their participation.

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## RESEARCH METHODS

In the study group, the Short Portable Mental State Questionnaire according to the Pfeiffer-SPMSQ (inclusion criterion) was used, Rehabilitative ultrasound imaging (RUSI) assessment of abdominal transverse muscle thickness in the state of contraction and relaxation was performed, and the transverse muscle activation coefficient was determined, the Quality of Life Questionnaire SF -36 applied.

For all subjects included in the study, the thickness of the abdominal transverse muscle at rest and during its contraction was determined by means of stable linear examination using the Mind 50 digital ultrasound machine by Mindray with a linear head. Initial position of the patients was lying on the back with the lower limbs bent in the hip and knee joints with the feet resting on the base to loosen the abdominal wall. The im-

age-emitting head of the examined muscle was positioned medially with respect to the anterior upper spine. In order to unify muscle measurements among all subjects, a distance of 3 cm was measured from the upper anterior hip spica in medial direction. Then, at the appropriate depth of muscle occurrence, its thickness was measured. The thickness of the muscle during rest was assessed during free breathing with the patient lying on his/her back. However, its thickness during contraction was measured after contraction during active maximal abdominal exhaling according to the command “let the air out and draw your navel towards the spine”. Active exhalation allowed to isolate the contraction of the transverse muscle of the abdomen from the rest of its muscles in a volitional way. Before the actual measurement, each of the subjects performed several instructional tests. In order to avoid measurement errors, all tests were performed in the same conditions by one examiner, on the same ultrasound device. In all subjects, the abdominal muscle contraction ratio was also determined on the basis of the following formula proposed by Teyhen et al.<sup>10</sup>:

$$\text{TrA contraction ratio} = \frac{\text{TrA contraction}}{\text{TrA rest}}$$

Based on the SF-36 Quality of Life Questionnaire, the subjects' sphere of physical functioning was selected for the assessment. The maximum score that can be obtained, determining subjective evaluation, was 70 points. On this basis, subjective assessment of the quality of life is determined. The higher the obtained results, the worse the level of physical functioning and the quality of life assessment<sup>11</sup>. For all participants of the project, a 3-week training programme was implemented along with education. It contained two stages. The first (lasting up to a week) is the stage of learning to assume proper starting position, proper breathing control as well as correct and conscious activation of the deep muscle stabilizers. Basic, simple exercises inducing contraction of the ab-

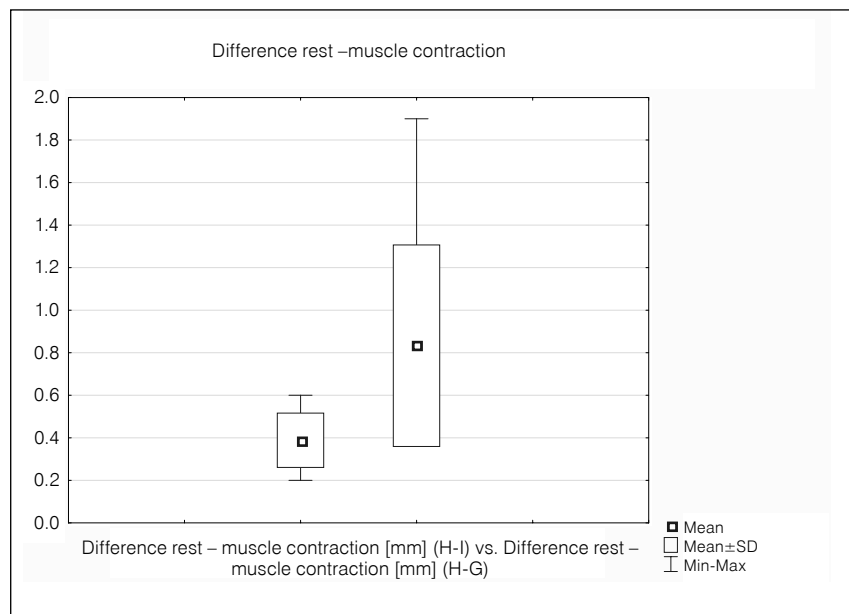
dominal transverse muscle were also given. The second stage is the use of learned positions in more difficult abdominal muscle exercises. The exercises are applied in different initial positions: standing, supported kneeling, lying on one’s back, lying on the side, sitting on a ball. The obtained results were subjected to statistical analysis by calculating Pearson’s correlation coefficient demonstrating the relationship between changes in the thickness of the abdominal transverse muscle and the physical functioning of patients after hip and knee endoprosthesis implantation.

### RESULTS

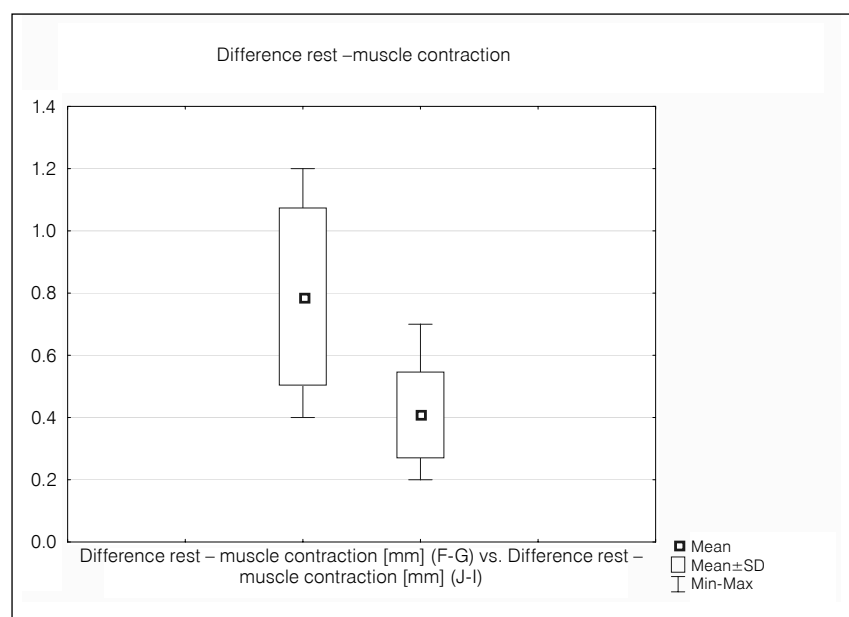
The obtained results were given in mean values and subjected to statistical analysis. In the group of patients after hip arthroplasty with the endoprosthesis, the average thickness of the abdominal transverse muscle measured at rest before beginning the rehabilitation programme was  $3.6\pm0.72$  mm, and after its completion,  $4.5\pm0.86$  mm. The difference obtained was statistically significant at  $p<0.001$ . In turn, the average thickness of the transverse abdominal muscle measured in contraction prior to treatment was  $2.9\pm0.56$  mm, and after its completion,  $4.1\pm0.77$  mm. The obtained difference in the results was statistically significant at the level of  $p<0.001$ . The contraction ratio before the programme was  $0.79\pm0.06$ , and after its end,  $0.91\pm0.02$ . The obtained difference in these results was statistically significant at the level of  $p<0.001$ . In turn, the difference between the measurements of abdominal transverse muscle thickness at rest and contraction before implementation of the programme was  $0.39\pm0.12$  mm. After its completion, the difference was  $0.79\pm0.28$  mm. The difference between the measurements was statistically significant at  $p<0.001$ . The results of the SF-36 questionnaire the rehabilitation programme were  $62.5\pm5.28$  points (pts.), on average, and after its completion,  $42.39\pm6.33$  points. The difference was statistically significant at  $p<0.001$ .

In the group of patients after the three-compartment knee arthroplasty with posterior implant stabilization, the average thickness of the transverse abdominal muscle measured at rest before the beginning of the exercise programme was  $3.9\pm0.88$  mm, and after its completion,  $4.9\pm1.16$  mm. The obtained difference in results was statistically significant at the level of  $p<0.001$ . In turn, the average thickness of the transverse ab-

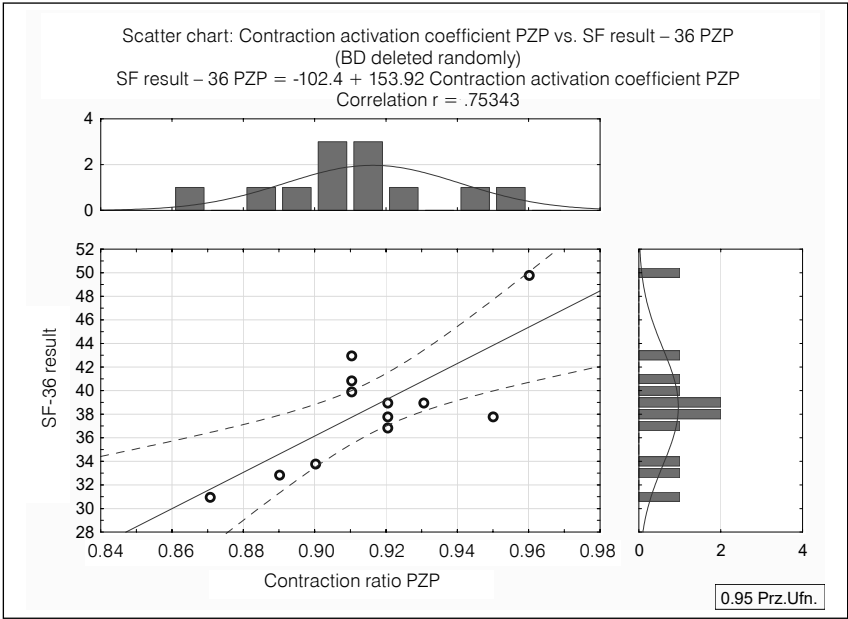
dominal muscle measured in contraction prior to beginning the exercise programme was  $3.1\pm0.72$  mm, and after its completion,  $4.5\pm1.09$  mm. The difference in the obtained results was statistically significant at the level of  $p<0.001$ . The contraction ratio before the programme was  $0.78\pm0.09$ , and after its completion,  $0.91\pm0.02$ . The obtained difference was statistically significant at the level of  $p<0.05$ . Consecutively, the dif-



**Figure 1**  
Graphic representation of statistical analysis regarding the variables under study



**Figure 2**  
Graphic representation of statistical analysis regarding the variables under study



**Figure 3**  
**Correlation between TrA contraction ratio and functioning in the physical sphere regarding the aspect of quality of life assessment**

ference between the abdominal transverse muscle thickness measurements at rest and contraction before beginning the programme was  $0.83 \pm 0.47$  mm. After its end, the difference was  $0.41 \pm 0.14$  mm. The difference between measurements was statistically significant at  $p < 0.001$ . Results of

the physical sphere examination using the SF-36 Questionnaire prior to the rehabilitative exercise programme amounted to an average of  $60.83 \pm 4.53$  points, and after its completion,  $39.58 \pm 4.96$  points. The difference was statistically significant at the level of  $p < 0.001$ . In Table 1, the

total results obtained in both studies are presented.

Between the examined groups, the thickness of the transversal abdominal muscle measured at rest, both before and after rehabilitation, there were no observed significant statistical differences in the mean measurements. Also in measurements of mean abdominal muscle thickness during contraction, before and after treatment, no statistically significant differences were noted between the two groups. Differences in mean values of abdominal transverse abdominal contraction ratio before and after treatment between the two groups were not statistically significant. On the other hand, the mean values of the abdominal muscle thickness difference between the examined groups measured at rest and in contracted state before and after the treatment, were significant at  $p < 0.001$  (before) and  $p < 0.05$  (after). In turn, the average results of the difference in abdominal transverse muscle thickness measured before and after the therapy at rest did not differ statistically in neither of the groups included in the study.

The results of quality of life-physical sphere assessment by means of

**Table 1**  
**Characteristics of the mean results for both study groups**

Assessed variables	Group I			Group II			Statistical significance	
	Mean±SD before rehabilitation	Mean±SD after rehabilitation	Test T Statistical significance	Mean±SD before rehabilitation	Mean±SD after rehabilitation	Test T Statistical significance	Before	After
Transverse abdominal muscle thickness measured at rest [mm]	3.6±0.72	4.5±0.86	-9.79 $p < 0.001$	3.9±0.88	4.9±1.16	-7.11 $p < 0.001$	$p > 0.05$	$p > 0.05$
Transverse abdominal muscle thickness measured during contraction [mm]	2.9±0.56	4.1±0.77	-12.73 $p < 0.001$	3.1±0.72	4.5±1.09	-7.62 $p < 0.001$	$p > 0.05$	$p > 0.05$
Contraction ratio	0.79±0.06	0.91±0.02	-9.05 $p < 0.001$	0.78±0.09	0.91±0.02	3.93 $p < 0.001$	$p > 0.05$	$p > 0.05$
Difference in measurement of transverse abdominal muscle rest and during contraction [mm]	0.39±0.12	0.79±0.28	-8.75 $p < 0.001$	0.83±0.47	0.41±0.14	5.71 $p < 0.001$	$p < 0.001$	$p < 0.05$
SF-36physical sphere result [pts.]	62.5±5.28	42.39±6.33	11.25 $p < 0.001$	60.83±4.53	38.58±4.96	10.76 $p < 0.001$	$p > 0.05$	$p > 0.05$

the SF-36 Questionnaire before beginning exercise and after its completion were not statistically significant in neither of the groups.

There were no significant correlations between the results of the contraction ratio, SF-36 scores or abdominal muscle thickness measurements, nor in the results of SF-36 in Group I. In contrast, in the group of patients following knee replacement, a strong positive correlation ( $r=0.753$ ) was found between the result of the SF-36 after completing the programme and the results of the contraction activation coefficient after the programme had ended, at the significance level of  $p<0.05$ .

## DISCUSSION

Postural control refers to the ability to maintain upright posture, position the center of gravity and perform free movements based on a properly functioning central nervous system. Motor control disorders result in dysfunctions and abnormal motor patterns<sup>12</sup>.

Hodges and Richardson<sup>13</sup> emphasize the role of the feedforward function of core stabilization for movement performed with the lower or upper limbs. It allows performance of correct movement without adverse compensation. The large number of publications appearing in recent years shows interest in the issues of core stabilization as a method of preventing back pain or traumatic injury to the musculoskeletal system. Insufficient stabilization and postural control of the trunk caused by impaired activation time of the deep muscles is the cause of increased mobility disability, which can be expressed as weakness of muscle strength, coordination and proprioceptive disorders<sup>6,14,15,16</sup>. The science of selective muscle contraction responsible for maintaining postural control and reaction speed is based on neurochemical stimulation of a certain group of neurons by performing a targeted movement that causes muscle tension. Deep muscles perform the role of internal trunk stabilizers responsible for functional movement. There-

fore, training the local stabilizers seems to have scientific justification for people with osteoarthritis of the knee and hip joints, or after allograft in motor control re-education. The creation of proximal stability provides a basis on which distal mobility is possible. Numerous methods are used to assess abdominal muscles in clinical practice: ultrasonography, electromyography or functional resonance. RUSI is a non-invasive and increasingly used method that allows to evaluate the morphology and function of muscles in real time. Qualitative and quantitative assessment is often used in functional diagnostics or in monitoring the rehabilitation process. There are many scientific reports confirming the reliability and credibility of TrA morphology assessment<sup>17,18,19,20</sup>.

Changes in muscle thickness of TrA after physiotherapy were observed in the presented study group. Both in patients with hip and knee arthroplasty, there were statistically significant results. The TrA contraction ratio also changed, and the obtained results were statistically significant in the study group. The evaluation of changes in deep muscle thickness under the influence of rehabilitation was also conducted by Cho<sup>3</sup> as well as Mannion et al.<sup>21</sup>, who presented similar observations. The scientific work of the above-mentioned authors underlines the quantitative changes in the examined muscles. Undoubtedly, however, they provide evidence that training based on the involvement of deep muscles using different techniques, influences their quantitative changes. Patients with motor dysfunction in addition to other symptoms, also manifest the presence of various painful ailments. The evaluation of TrA muscle thickness was also performed by Huang et al.<sup>22</sup>. In their research, they showed the influence of long-term actions including the activation of the TrA muscle on the change in the level of pain sensation (VAS), showing a relationship between the increase in abdominal muscle activity and lowering the level of pain sensations of the group. Disorders of the musculoskeletal system and accompanying ailments, es-

pecially occurring chronically, cause changes in the physical, mental and social spheres of patients. Movement and psychological limitations, especially for the elderly, can directly affect the quality of their lives. Quality of life associated with state of health has become the determinant of treatment process effectiveness. One of the factors affecting the level of quality of life assessment is the functional efficiency of a patient. The results of research by Hodges and Richardson<sup>24</sup> confirm this stance. The improvement of functioning in the physical sphere assessed with the use of the SF-36 Questionnaire was also noted in the presented studies. The rehabilitation programme combined with the core stabilization training induced improvement in the quality of life among the groups of patients after both hip and knee arthroplasty. Persons included in the study underwent surgery 1 to 2 years before implementation of the presented project. This is the time to obtain optimal functional and morphological stabilization after allograft surgery. However, after implementation of the exercise programme, not only the rate of activation of the abdominal transverse muscle was improved, which may translate into improved motor control, but marked improvement in physical functioning in the assessment of quality of life was also noted. Weakening of the deep muscles, including TrA, reduces dynamic stability of the trunk, causing loss of balance control. On the basis of the conducted research, Rocławski et al., as well as Węgorowski et al.<sup>26</sup>, present a similar stance. Stability of the lumbopelvic area is crucial to ensure proper limb movement and dynamic spine protection. Decreasing the efficiency of core stabilization and synergy of the trunk muscles as well as the iliac crest stabilizers have the effect of increasing the risk of traumatic injury to the limbs, lowering their muscular strength due to lack of control of the center of body mass. According to McGill et al.<sup>27</sup> and Kinoshita et al.<sup>28</sup>, it is predicted that patients with stronger stabilization before planned surgery for the implantation of joint endopros-

theses experience a return of function much faster<sup>27,28</sup>. Therefore, core stabilization exercises should become a key component of therapeutic programmes for patients with motor dysfunction. The RUSI exam can be used in broad clinical practice of physiotherapists in programme planning, as biofeedback, as well as in the evaluation of physical therapy effectiveness. Studies on the quality of life in patients, both after pharmacological and surgical treatment, contribute to the development of new, more effective standards of therapy. And their subjective assessment of health plays a special role in assessing the effectiveness of treatment.

## CONCLUSIONS

1. The rehabilitation programme proposed for patients operated on due to osteoarthritis by means of total hip replacement and three-compartment knee arthroplasty with posterior stabilization of the implant resulted in an increase abdominal transverse muscle thickness.
2. The rehabilitation programme proposed for the patients included in the study resulted in an increase in the value of abdominal transverse muscle activation.
3. The proposed rehabilitation programme for the patients enrolled in the study has positively influenced their quality of life, and above all, their functional physical fitness.

**Conflict of interest: none**

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