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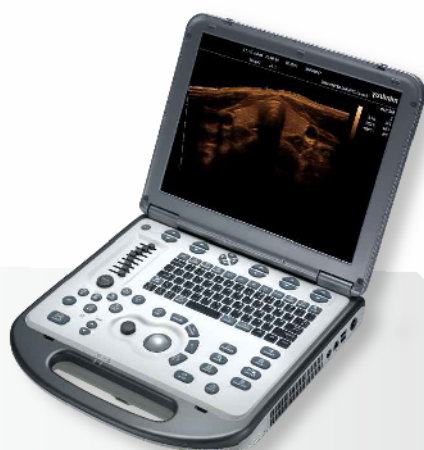
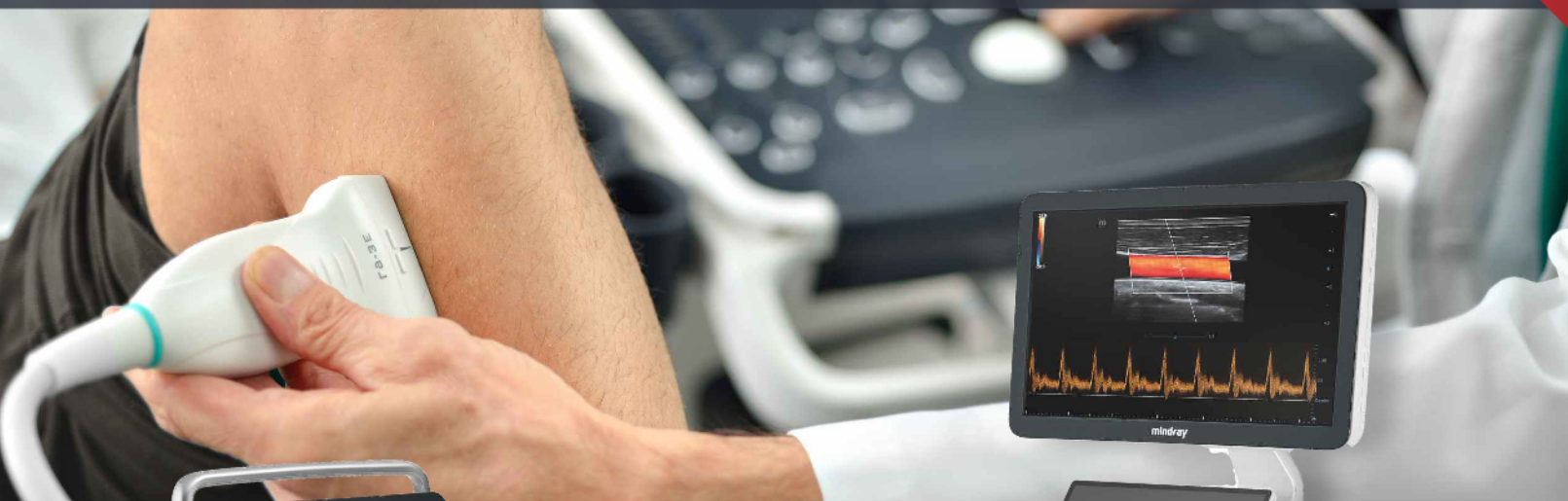
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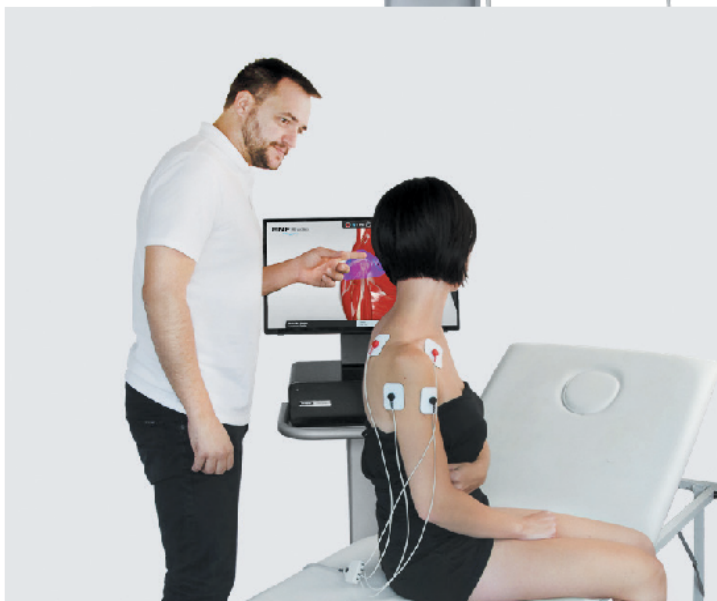
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Kinematic disorders of the scapula in a group of women after mastectomy – a systematic review

Zaburzenia kinematyczne łopatki w grupie kobiet po mastektomii – przegląd systematyczny

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Abstract

Background. Breast cancer is the most common neoplastic disease in the group of women. In terms of negative consequences of oncological treatment, disorders of the kinematics of the shoulder complex and coexisting disorders of motor control are also distinguished. **Aim of the study.** The aim of the study is to systematize information on motor disorders in terms of scapula kinematics in the area of the shoulder complex during upper limb elevation movements in the group of women after mastectomy. **Methods.** The systematic review is based on the search results of Science Direct, Ebsco, and PubMed. The systematic review was performed on the basis of PRISMA guidelines. **Results.** The analysis of the works showed the existence of disorders in the kinematics of the scapula in the group of women after mastectomy. In this group of patients, the scope of upwards rotation of the scapula during the elevation of the upper limb, its lowering, and functional movements was limited. **Conclusions:** The analysed articles indicate the existence of disorders of the scapula kinematics in the group of women after mastectomy. The obtained results indicate the necessity of implementing routine evaluation and motor re-education in the field of scapula kinematics disorders in the process of comprehensive rehabilitation in this group of patients.

Key words:

mastectomy, motor control, breast cancer

Streszczenie

Wstęp. Rak piersi w grupie kobiet stanowi najczęściej występującą chorobę nowotworową. Ze względu na coraz skuteczniejsze formy leczenia zachowawczego oraz chirurgicznego przeżywalność w tej grupie jest coraz większa. W zakresie negatywnych konsekwencji leczenia onkologicznego wyróżnia się również zaburzenia kinematyki kompleksu barkowego oraz współistniejące z nimi zaburzenia kontroli motorycznej. Te aspekty zaburzeń nie są szeroko opisane w piśmiennictwie, co skłoniło autorów do stworzenia przeglądu systematycznego opierającego się na pracach oceniających kinematykę łopatki w tej grupie pacjentów. **Cel pracy.** Celem pracy jest usystematyzowanie informacji na temat zaburzeń motorycznych w aspekcie kinematyki łopatki w obszarze kompleksu barkowego podczas ruchów elewacji kończyny górnej w grupie kobiet po mastektomii. **Materiały i metody.** Przegląd systematyczny oparty jest na podstawie wyników wyszukiwania w ScienceDirect, EBSCO oraz PubMed. Poszukiwano następujących fraz: „kinematics and scapular and mastectomy”. Przegląd systematyczny wykonany został na podstawie wytycznych PRISMA. **Wyniki.** Analiza prac wykazała istnienie zaburzeń kinematyki łopatki w grupie kobiet po mastektomii. W tej grupie pacjentek zakres rotacji górnej łopatki podczas elewacji kończyny górnej, jej opuszczania oraz ruchów funkcjonalnych był ograniczony. Głównymi czynnikami negatywnie wpływającymi na kinematykę łopatki jest stan po przeprowadzeniu mastektomii wraz z współwystępowaniem dolegliwości bólowych w obrębie kompleksu barkowego oraz obrzęku limfatycznego. **Wnioski.** Analizowane artykuły wskazują na istnienie zaburzeń kinematyki łopatki w grupie kobiet po mastektomii. Problem ten stanowi złożone zjawisko, na które wpływ ma potencjalnie wiele czynników, w tym występowanie dolegliwości bólowych w obrębie kompleksu barkowego czy obrzęku limfatycznego w obrębie kończyny górnej. Uzyskane wyniki nakierowują na konieczność wdrożenia rutynowej ewaluacji oraz reedukacji motorycznej w zakresie zaburzeń kinematyki łopatki w procesie kompleksowej rehabilitacji w tej grupie pacjentek. Elementem zwracającym szczególną uwagę w opinii autorów niniejszego przeglądu jest fakt, iż w analizowanych pracach jest mała liczebność uczestników badania, co wskazuje również na to, że problematyka zaburzeń kinematyki łopatki w tej grupie pacjentów jest nowym zagadnieniem i wymaga przeprowadzenia w przyszłości badań na grupach o znacznie większej liczebności, umożliwiającą wymianę doświadczeń i wyników badań międzyośrodkowo.

Słowa kluczowe:

mastektomia, kontrola motoryczna, rak piersi

Introduction

Breast cancer is the most common neoplastic disease in women. Due to the more and more effective forms of conservative and surgical treatment, the survival rate in this group is increasing [1]. In the area of surgical treatment, various less and less invasive forms of interaction are used but, following specific indications, more invasive procedures, such as mastectomy, are also performed. Surgical procedures which, in many cases ensure the most effective treatment of neoplastic disease, are often associated with negative consequences for the function of the shoulder complex [2]. Disorders in the shoulder complex function [3, 4] are the result of pain, limited active and passive mobility, and lymphatic oedema of the upper limb and the chest [5, 6]. Information on the above-mentioned elements is widely reflected in the literature. This information is a recommendation for focusing the rehabilitation process also on the identified dysfunctions within the shoulder complex. Disorders in the functioning of the shoulder complex - a complicated phenomenon - are still a considerable challenge in the rehabilitation process. In terms of negative consequences of oncological treatment, disturbances in the kinematics of the shoulder complex and coexisting disorders of motor control are also highlighted [3, 4]. Unfortunately, these aspects of the disorder are not widely described in the literature, which prompted the authors, involved in physiotherapeutic treatment in this group of patients, to create this systematic review. It is worth mentioning that understanding the nature of movement disorders is a fundamental element in the diagnostic and therapeutic process of biomechanical rehabilitation. It is also a necessary direction while implementing elements of physical rehabilitation based on movement re-education in order to restore normal movement. The need to learn about the biomechanical functioning conditions, changed as a result of the performed treatment within the shoulder complex, is the basis for the subsequent identification of motor errors and the implementation of targeted elements of motor re-education at the stage of clinical work [3, 4, 7].

The purpose of the work is to systematize information on the motor disorders of the shoulder complex in the area of the scapula, from the viewpoint of biomechanical analysis of elevation of the upper limb movements in the group of women after mastectomy. An important aspect of this work is also to answer the question of how the kinematics of the scapula changes during movements of the upper limb as a result of lesions following the surgical treatment.

Materials and Methods

The systematic review is based on the search results from Science Direct, Ebsco, and PubMed. The following phrases were searched for: "kinematics and scapular and mastectomy". The time range covered the period of 2019-2021. The search revealed only 20 results (Science Direct-9, Ebsco-7, PubMed-4). Then, the obtained results were limited by removing 6 duplicates. In total, the authors independently analysed the titles and abstracts of 14 articles. Four original research papers were selected to assess the kinematics of the scapula during the upper limb

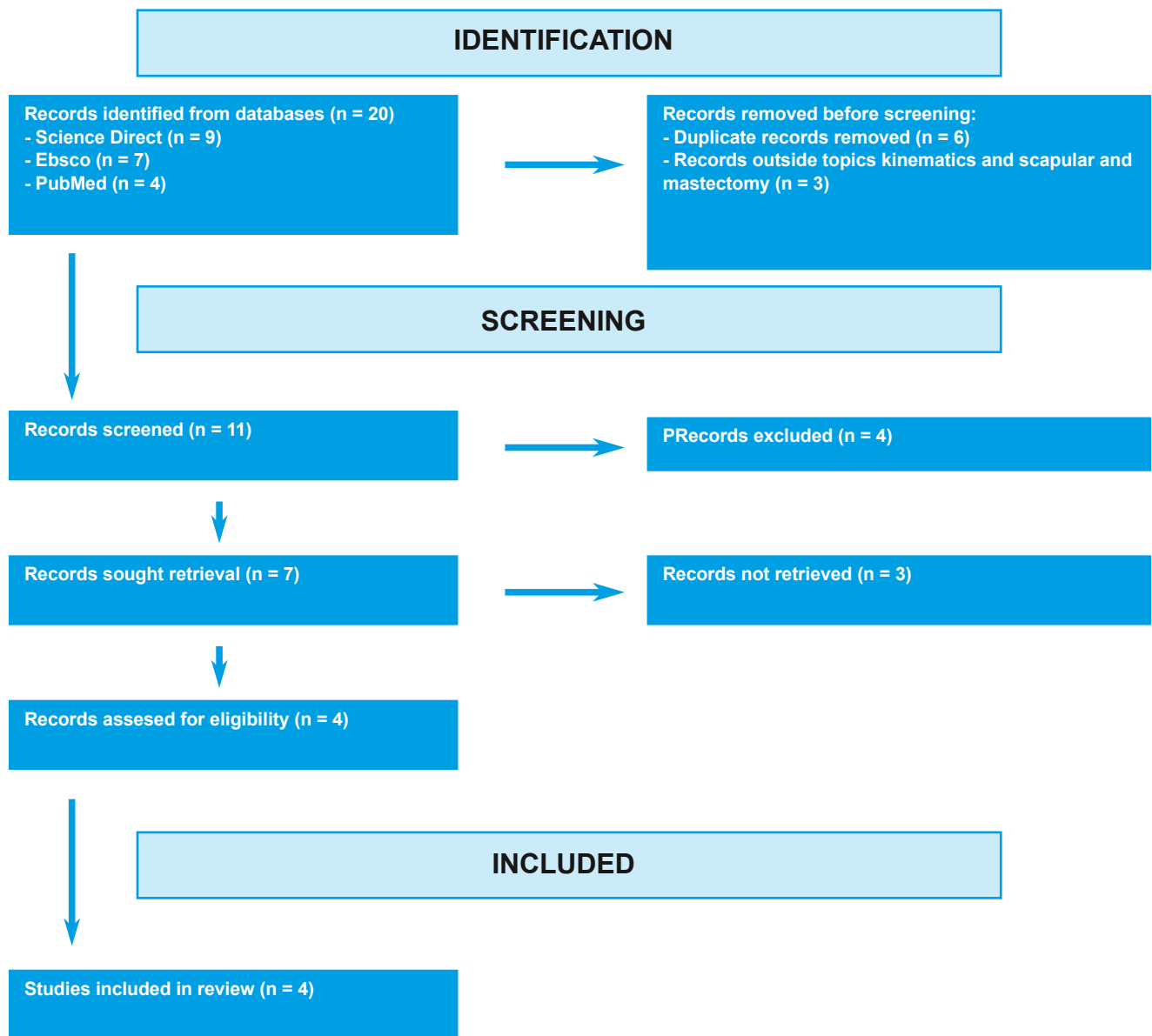


Figure 1. Flow diagram adapted from PRISMA showing the process of identifying and screening the articles for inclusion and exclusion [8]

elevation, assisted by digital biomechanical analysis devices that allow to determine angular values of the scapula movement. The selection was made on the basis of specific inclusion criteria: 1) studies involving patients who had previously undergone surgical treatment of breast cancer, 2) describing the angular values of the scapula movement during the upper limb elevation movement using biomechanical analysis systems, 3) written in English, 4) being research works.

The systematic review was based on the PRISMA guidelines (figure 1) [8]. Only 4 original research works were included in the review, the list is summarized in Table 1.

Table 1. Description of articles initially included by PRISMA methodology [8]

Article Type	Focus	Reference
Original research	Three-dimensional assessment of scapular movement during upper limb elevation in the scapular plane. Evaluation in a group of patients after modified radical/radical mastectomy. Evaluation of the impact of the presence of lymphedema on upper limb biomechanics.	Baran E. et al., 2021
Original research	Three-dimensional assessment of scapular movement upper limb elevation in the scapular, frontal and sagittal planes. Evaluation in a group of patients after mastectomy with and without pain. Assessing the impact of breast cancer surgery and pain on upper limb biomechanics during limb elevation in the scapular, frontal, and sagittal plane.	Lang A.E. et al., 2020
Original research	Three-dimensional assessment of scapular upward/downward rotation in the course of functional tasks: overhead reach and overhead lift. Evaluation in a group of patients after mastectomy with and without pain complaints. Assessing the impact of breast cancer surgery and pain on upper limb biomechanics during functional tasks.	Lang A.E. et al., 2019
Original research	Three-dimensional assessment of scapular movement in the scapular plane during upper limb elevation in the scapular plane. Evaluation in a group of patients after breast-conserving surgery or mastectomy. Assessing the impact of breast cancer surgery on upper limb biomechanics.	Ribeiro I.L. et al., 2019

Results

The analysis of the individual studies included in the review shows that both inclusion and exclusion criteria for patients from the breast cancer surgical treatment group were very similar (Table 2). The size of the studied groups was similar (Baran E. et al. N = 67; Lang A.E. et al. 2020 n = 50; Lang A.E. et al. 2019 n = 50; Ribeiro I.L. et al. N = 42).

Table 2. Inclusion and exclusion criteria for patients

Inclusion criteria
<ol style="list-style-type: none"> 1. > 18 years of age. 2. Breast cancer survivors. 3. Patients after modified radical/radical mastectomy or breast-conserving surgery. 4. Time since surgical intervention more than 6 months. 5. Use of three-dimensional assessment of the scapular motion during upper limb elevation by a biomechanical analysis system.
Exclusion criteria
<ol style="list-style-type: none"> 1. < 18 years of age. 2. Breast cancer survivors after breast reconstruction. 3. Treatment shoulder problems e.g. pain before surgery. 4. Previous shoulder surgery. 5. Time since surgical intervention less than 6 months. 6. BMI > 30.

A description of each publication is provided below, including information on the therapeutic interventions undertaken, the scales and tests used, and the results obtained.

1. Impingement pain affects kinematics of breast cancer survivors in work-related functional tasks/Lang A.E. et al, 2019 [9]

Lang A.E. et al., 2019 in their work performed a three-dimensional assessment of the scapula kinematics during functional tasks. The VICON MX20 system (Vicon Motion Systems, Oxford, UK) was used for motion analysis. Fifty women ($n = 50$) were examined, the study group consisted of women after mastectomy ($n = 25$) due to breast cancer. This group was divided into two subgroups. The subgroup of patients with pain in the shoulder complex, the number of which was $n = 13$, and the subgroup of patients with no pain, $n = 12$. The time from surgery in the group of patients with pain was 70.0 (39.7) months. This parameter in the group of patients with no pain was 42.5 (41.6) months. The division in the study group was made based on orthopaedic tests for the shoulder complex enabling the provocation of pain. In the group of patients with no pain, 10 were treated with chemotherapy and 7 with radiotherapy during oncological treatment. In the group with pain, 10 patients underwent chemotherapy, and 8 received radiotherapy in the course of oncological treatment. The time from surgical intervention for the pain group was 70.0 (39.7) months, and for the no pain complaints group it was 42.5 (41.6) months. In both groups, all patients were right-handed. The control group consisted of women who had not undergone surgical treatment for breast cancer in the past and had no history of breast cancer. These patients were free from pain and disorders of the shoulder complex. The size of this group was $n = 25$ [9].

The functional tasks were overhead reach and overhead lift. The overhead reach consisted in reaching for an object weighing one kilogram, taking it down from a shelf suspended

at a height of 1.5 meters, and lowering it to the waist level of the examined person. The movement was also carried out without a load in the same way as in the load test. The overhead lift consisted in lifting a box weighing 5-8 kg from the waist level of the examined person onto a shelf at the height of 1.5 meters. During both procedures, the movements of the scapula in the aspect of its upward and downward rotation were assessed [9].

In terms of the obtained results, statistically significant differences were found in the right scapula upward rotation parameters as compared to the group of patients with pain, the control group, and within the study group. Patients with pain in the shoulder complex presented a lower range of maximum upward rotation of the scapula during functional tasks: overhead reach ($d = 0.80$, $p = 0.006$) and overhead lift ($d = 1.11$, $p = 0.027$) performed using the right upper limb. The maximum upward rotation during the overhead lift was, respectively, 32.3 (5.9) in the control group, 31.9 (8.9) in the pain-free group, and 25.4 (6.5) in the pain group. The maximum upward rotation during overhead reach was, respectively, 29.5 (8.6) in the control group, 29.2 (8.1) in the no pain group, and 22.9 (8.5) in the pain group. The largest difference of 11.2 degrees [9] was found in the angular range of the scapula upward rotation during the overhead lift movement.

2. Three-dimensional scapular kinematics, shoulder outcome measures and quality of life following treatment for breast cancer – A case-control study / Ribeiro I.L. et al., 2019 [10]

In their work, Ribeiro I.L. et al., 2019, assessed the kinematics of the scapula in the course of the upper limb elevation. The Flock of Birds Electromagnetic Tracking System (Asension Technology Corporation, Burlington, Vermont) was used for motion analysis. A total of 42 women were assessed ($n = 42$). The study group consisted of $n = 21$ women who had previously undergone a unilateral mastectomy in the form of breast conserving treatment or a single mastectomy performed within 6 years. 12 patients underwent surgical interventions on the right side, and 9 on the left side. Patients in the study group were free from pain in the area of the shoulder complex. This condition was confirmed by orthopaedic tests. The control group, $n = 21$, consisted of women who had not had breast cancer, had not undergone a mastectomy in the past and were free from pain in the shoulder area. The control group was matched to the study group in terms of sociodemographic variables. The movements of the scapula in the form of upward rotation, internal rotation, and anterior tilt were assessed. These parameters were assessed at 30, 60, 90, and 120 angles during the limb elevation [10].

In the assessment of the kinematics of the scapula in the internal/external rotation during the elevation of the arm, no statistically significant interaction was found ($p = 0.830$, $F = 0.469$, and $p = 0.589$, $F = 0.534$). Regarding the operated

side vs the non-operated side and the inclination of the scapula, there was a statistically significant interaction in the comparisons both between the groups, and within the groups ($p = 0.179$, $F = 1.517$, and $p = 0.657$, $F = 0.423$). The anterior inclination of the scapula was significantly greater on the operated side. The effect size was considered small within and between the groups for the scapula tilt, and the internal rotation (from -0.08 to 0.30) during the shoulder lift. A statistically significant interaction was demonstrated in the assessment of the scapula upward rotation ($p = 0.022$, $F = 2.572$). On the surgical intervention side, the range of scapula upward rotation within 120 degrees of the upper limb elevation was smaller than in the control group ($p = 0.010$, mean difference = 7.3° , Cohen's $d = 0.47$) [10].

3. Examining the assessment methods of scapular motion: Comparing results from planar elevations and functional task performance / Lang et al., 2020 [11]

In the work by Lang A.E. et al. 2020, a three-dimensional assessment of the scapula kinematics in the course of functional tasks was performed. The VICON MX20 system (Vicon Motion Systems, Oxford, UK) was used for the motion analysis. Fifty women were examined ($n = 50$). The control group consisted of 25 women with no pain in the shoulder complex ($n = 25$). The study group consisted of 25 women, $n = 25$, who had undergone a mastectomy in the past. This group was divided into two subgroups: the group with no pain $n = 16$, and the group suffering from pain in the shoulder complex $n = 9$. The mean period since the surgery, calculated in months, was 67.3 (34.7) for the pain group and 50.9 (45.7) for the group suffering no pain. The division in the study group was made having applied orthopaedic tests for the shoulder complex, enabling the provocation of pain symptoms performed on the right side. All patients in the study group were right-handed. In the group with pain, 6 patients underwent chemotherapy, and 5 underwent radiotherapy on the right side. In the group without any complaints, 13 patients underwent chemotherapy in the course of the oncological treatment, and 5 patients received radiotherapy on the right side [11].

The scapula upward rotation was evaluated during the right shoulder elevation, with its orientation in the scapular, sagittal and frontal planes. The scapula position was assessed at 30, 60, 90, 120 degrees, and the position of the maximum elevation of the upper limb. Statistically significant interactions between the groups were found. In the group of patients with pain complaints, the scapula upward rotation was lower than in the group of patients with no pain within the group of patients after mastectomy. The upward rotation during movement in the frontal plane at an elevation angle of 30 degrees ($p = 0.014$, $\eta^2 = 0.169$), and 60 degrees elevation angle ($p = 0.041$, $\eta^2 = 0.135$) was significantly lower in the group of patients with pain complaints around the shoulder complex. The analysis in the scapular plane showed a significant reduction of the described direction of movement at 30 degrees of elevation ($p = 0.049$, $\eta^2 = 0.125$). Examination in the sagittal plane showed a significant reduction in the scapula upward rotation range at 30 degrees ($p = 0.045$, $\eta^2 = 0.126$), 60 degrees ($p = 0.042$, $\eta^2 = 0.128$), and 90 degrees ($p = 0.049$, $\eta^2 = 0.120$) [11].

4. The association of breast cancer-related lymphedema after unilateral mastectomy with shoulder girdle kinematics and upper extremity function / Baran et al., 2021 [12]

In their work, Baran et al., 2021 assessed the scapula kinematics using the Flock of Birds Electromagnetic Tracking System (Asension Technology Corporation, Burlington, Vermont). The study group consisted of 67 women, $n = 67$, after mastectomy or modified mastectomy. The patients were divided into three groups according to the severity of lymphoedema at the upper limb level. This division was made on the basis of an earlier volumetric measurement using a water vessel, and an estimate of the displaced water volume for a limb volume evaluation.

The authors classified the severity of the oedema as follows: 0-200 ml of water displaced as a group with no oedema, 200-500 ml – the group with moderate oedema, and over 500 ml – the group with severe oedema. The group with severe lymphoedema consisted of $n = 27$ patients, the group with moderate oedema was $n = 18$, and the group with no oedema was $n = 22$. The mean time since the surgery, calculated in months, was 65.4 (34.4) for the severe oedema group, 38.6 (31.4) for the moderate oedema group, and 32.5 (26.8) The mean time in months from the clinical diagnosis of lymphedema was 22.8 (22.7) for the moderate oedema group, and 41.8 (31.3) for the severe oedema group.

All patients in the study group were right-handed. In the group of patients with severe lymphoedema, 14 patients (51.8%) were operated on the right side, in the group with moderate lymphoedema that number was 11 (61.1%), and in the group without lymphoedema, it was 11 (50%) The assessment of the scapula movement was: in upward rotation, internal rotation and anterior tilt in the course of the arm elevation in the plane of the scapula.

The evaluation included the assessment of the position of the scapula during the phases of the upper limb elevation and lowering phase at 30, 60 and 90 degrees. There was a statistically significant interaction between the groups in the scapula upward rotation during the limb elevation movement ($p = 0.017$, $F_{4.11, 131.51} = 3.09$). The extent of the scapula upward rotation during the phase of limb lowering was statistically significantly greater in the group of patients with no oedema as compared to the group with severe oedema at an angle of 90 degrees ($p = 0.016$), 60 ($p = 0.013$), and 30 ($p = 0.004$). There was no statistically significant interaction in the assessment of the internal rotation of the scapula in the upper limb elevation ($p = 0.38$, $F_{4.15, 132.7} = 1.05$). As to the anterior tilt movement, there was a statistically significant interaction between the groups ($p = 0.02$, $F_{3.47, 111.2} = 3.22$). The scapula anterior tilt angle of 30 degrees in the limb lowering phase was greater in the group with severe lymphedema, compared to the group with no oedema ($p = 0.015$) [12].

Tabela 1. Kwestionariusz przeglądowy/przesiewowy do dalszej analizy w zaburzeniach narządu ruchu (oraz w terapii sportowej)
Table 1. Review / screening questionnaire for further analysis in disorders of the musculoskeletal system (and in sports therapy)

Author/Rok Author/Year	Uczestnicy Participants	Interwencja Intervention	Pomiar wyników Outcome measurement	Wyniki Results
Baran E. et al., 2021	<p>n = 67(67 women)</p> <p>(non- lymphedema group n = 22; moderate lymphedema group n = 18; severe lymphedema group n = 27)</p> <p>Mean age (SD) of non- lymphedema group 50.9; moderate lymphedema group 55.2; severe lymphedema group 55.3</p> <p>Patients after modified radical mastectomy because of breast cancer diagnosis</p>	<p>Three-dimensional assessment of the scapular movement (internal rotation, upward rotation, and anterior tilt) in the scapular plane during the elevation (angle: 30–60–90) and return (angle: 90– 60–30) phases of the upper limb elevation.</p>	<p>Flock of Birds Electromagnetic Tracking System (Ascension Technology Corporation, Burlington, Vermont)</p>	<p>There was a significant interaction of group range during the elevation of the upper limb with respect to the upward rotation ($p = 0.017$). At 90–60–30 angle return phases, the scapular upward rotation was significantly higher in the non- lymphedema group than in the severe lymphedema group ($p = 0.016$, $p = 0.013$, $p = 0.004$).</p> <p>There was no interaction of group during the elevation of the arm for internal rotation of the scapula ($p = 0.38$).</p> <p>For the scapular anterior tilt, there was a group angle interaction, as well as the main effect of the group at the upper limb ($p = 0.02$). At the 30° angles, the return phase scapular anterior tilt was significantly higher in the severe lymphedema group than in the non-lymphedema group ($p = 0.015$).</p>
Lang A.E. et al., 2020	<p>n = 50 (50 women) (control group n = 25, breast cancer no pain group n = 16, breast cancer pain group n = 9)</p> <p>Mean age (SD) of the control group was 51.6; breast cancer no pain group was 53.1; breast cancer pain group was 55.6</p> <p>Patients after mastectomy following a breast cancer diagnosis.</p>	<p>Three-dimensional assessment of the scapular upward/downward rotation in the scapular, frontal and sagittal plane during the elevation of upper limb (angle: 30-60-90-120).</p>	<p>VICON MX20 (Vicon Motion Systems, Oxford, UK)</p>	<p>There was a significant interaction between groups (breast cancer no pain group vs breast cancer pain group) in the upward rotation. Scapular upward rotation in frontal plane was significantly reduced at 30° ($p = 0.014$) and 60° ($p = 0.041$), in scapular plane at 30° ($p = 0.049$), in the sagittal plane at 30° ($p = 0.045$), 60° ($p = 0.042$) and 90° ($p = 0.049$). The differences between the breast cancer patients with pain group and the control group were not statistically significant.</p>

Autor/Rok Author/Year	Uczestnicy Participants	Intervencja Intervention	Pomiar wyników Outcome measurement	Wyniki Results
Lang A.E. et al., 2019	<p>n = 50 (50 women)</p> <p>(control group n = 25, breast cancer no pain group n = 12, breast cancer pain group n = 13)</p> <p>Mean age (SD) of control group 51.6; breast cancer no pain group 52.8; breast cancer pain group 55.2</p> <p>Patients after mastectomy as a result of a breast cancer diagnosis.</p>	Three-dimensional assessment of the scapular upward/downward rotation during functional tasks: overhead reach and overhead lift.	VICON MX20 (Vicon Motion Systems, Oxford, UK)	<p>During the overhead reach and the overhead lift, in the breast cancer pain group, the right maximum scapular upward rotation was less than in the breast cancer no pain group and in the control group (overhead reach task p = 0.006; overhead lift task p = 0.027); with the biggest difference of 11.2° noticed at the right scapula during the overhead lift.</p>
Ribeiro I.L. et al., 2019	<p>n = 42 (42 woman)</p> <p>(surgery group n = 21, control group n = 21)</p> <p>Mean age (SD) of control group 50.7; surgery group 50.2</p> <p>Patients after breast-conserving surgery or mastectomy due to the breast cancer diagnosis.</p>	Three-dimensional assessment of scapular upward/downward rotation, anterior/posterior tilt, and internal/external rotation during the elevation of the upper limb (angle: 30-60-90-120).	Flock of Birds Electromagnetic Tracking System (Asensio Technology Corporation, Burlington, Vermont)	<p>Upward rotation of the scapula during the elevation of the upper limb, there was a significant interaction (p = 0.022). Pairwise comparisons indicated that the side of the surgery showed less upward rotation compared to the control group at 120° of the elevation (p = 0.010, mean difference = 7.3°).</p> <p>Internal rotation of the scapula during the elevation of the upper limb, there was no interaction (p = 0.830).</p> <p>Tilt of the scapula, a significant interaction (p = 0.179).</p> <p>The effect size was considered small intra- and inter-group for the internal rotation and the scapula tilt (ranged from -0.08 to 0.30) during the upper limb elevation.</p>

Discussion

The conducted systematic review focused on the determination of disorders in the kinematics of the scapula in a group of women after mastectomy due to breast cancer. All selected works were based on the evaluation using recognized movement analysis systems. Oncological treatment employing surgery, radiotherapy, and chemotherapy may adversely affect the function of the upper limb in this group of patients [13]. Disorders in the functioning of the shoulder complex, and limitations in the function of the upper limb in the group of women after mastectomy in the course of breast cancer treatment constitute a complex therapeutic problem. Patients in this group present a wide spectrum of symptoms and deficits in the form of pain complaints of a different nature, from mechanically induced pain to neuropathic pain [14, 15, 16]. There is also a reduction in joint mobility, directly related to the limitation of tissue flexibility after a treatment resulting in scarring and fibrosis, as well as reduced movement parameters in the joints of the shoulder complex [17], moreover, lymphoedema may develop in the free part of the upper limb, as well as in the thoracic region [5,6,18]. There are also inextricably linked disorders of motor control and changes at the level of the shoulder-scapula rhythm, as part of the existing disorders of the shoulder complex [3,4]. Their occurrence is associated with a change in the quality of movement which, in the long term, may lead to the generation of pathological load on anatomical structures. As a result, accelerated tissue degeneration and pain generation may occur, which will ultimately be associated with a change at the level of movement patterns and limitation of the functions of the upper limb [7, 19, 20]. The works aimed at the assessment of shoulder-scapular rhythm disturbances, employing assessment of the kinematics of the scapula with the use of objective assessment methods such as biomechanical evaluation systems, as opposed to the works relating to other disorders, e.g. lymphoedema or joint mobility limitations are, unfortunately, not widely available in the literature. The review carried out by the authors made it possible to identify only four works meeting the criteria, which confirms significant gaps in the currently available literature. Therefore, this is an area that needs to be explored in the future. Expert knowledge of the kinematic disorders of the scapula and the influencing factors is the basis for understanding intricate problems of disorders of the shoulder complex functions, and is the starting point for directional evaluation, on the basis of which an individualized rehabilitation program is developed. The analysis of individual studies made it possible to identify clinically significant information on disorders of the kinematics of the scapula in a group of patients after mastectomy.

In their study, Baran et al. assessed the effect of lymphedema its occurrence and severity on the specific movement of the scapula during the elevation of the upper limb during the rising and lowering phase in a group of patients after mastectomy. The movements assessed were anterior tilt, internal rotation, and upward rotation of the scapula. The obtained results clearly indicate a significant reduction in the range of upward rotation during the descending phase in all assessed angles (90-60-30) in the group with severe oedema compared to the non-oedema group. Another statistically significant result was

an increase in the anterior scapula inclination of 30 degrees in the descending phase in the group with severe oedema compared to the non-oedema group [12]. Increased anterior tilt and decreased lower rotation occurring in the severe lymphedema group predispose this group to the formation of the subacromial and/or subcoracoidal ischemia mechanism. This condition is associated with pathological stress on anatomical structures located in these areas which, in a long-term perspective, may be associated with developing pain and inflammation [7, 21, 22]. In the long term, as a result of the summation of micro-injuries, the tendons of the rotator cuff muscles become damaged, which may lead to their complete damage [3,7,24]. Reduction in the upward rotation and an increase in the anterior tilt indicates the improper functioning of the muscles of the upper rotators in their eccentric action, which proves the existing disturbance of motor control. The trapezius muscle together with the serratus anterior muscle should inhibit the presenting downward rotation of the scapula in the lowering phase in a controlled manner. A greater range of the anterior tilt of the scapula may indicate the lack of proper activation and efficiency of the ascending part of the trapezius muscle in relation to the muscles tilting the scapula forward. Movement disturbances identified during the lowering phase indicate an imbalance in the neuromuscular control. The results indicate a reduction in the efficiency of the upward motion rotators of the scapula, and the muscles enabling the anterior tilt in terms of their eccentric action [3, 7]. Scientific records show that inhibition of the activity of the indicated group of muscles is associated with the possibility of generating pain in the shoulder-scapular joint, and is at the basis of the isthmus mechanism [25, 26, 27]. Patients in the study group underwent a mastectomy in the process of oncological treatment. The obtained results indicate the occurrence of disorders only in the phase of lowering the limb [12]. In a situation where tissue restrictions would significantly affect the kinematics of the scapula, it would be related to the occurrence of, for example, limited upward rotation the scapula also during the limb lifting phase, especially in the final range of the motion. Baran et al. reports indicate the presence of neuromuscular control disorders. This area of disorders in the group of patients after breast cancer surgical treatment is neglected in the process of physiotherapeutic evaluation. The fact that motor control deficits are present is connected with the necessity of taking these disorders into consideration in the diagnostics, and in the subsequent planning of the therapeutic process, taking into account the targeted tasks aimed at improving the control of the downward rotation and anterior tilt of the scapula [3,4,7]. In their study, the authors state that patients with severe lymphoedema represent the abnormalities in the kinematics of the scapula described above, compared to the group with no oedema [12]. The increased volume of the upper limb is associated with an increase in its weight which, in turn, places greater demands on the muscles controlling the scapula [28], which may be the reason for the analysed differences between the groups. However, there is a large discrepancy with respect to the time since surgery between the severe oedema group and the non-oedema group. The mean time for the severe oedema group is 65.4 months. and 32.5

months in the non-lymphedema group [12]. The time since surgery for the severe oedema group is approximately twice as long, which makes a significant difference. Longer time after surgery is associated with a more extensive duration of comorbid disorders, including lymphoedema within the shoulder complex, so the parameters of the scapula movement may have been more disturbed. Therefore, it is difficult to state unequivocally that it is only the presence of severe lymphoedema that is the only factor contributing to the development of the examined deviations in the field of scapula kinematics. The group of patients with severe oedema represented the abnormalities of the scapula kinematics described above, which is very valuable information in terms of possible clinical implications of the work under discussion [12]. These implications, on the one hand, indicate the patients with lymphedema as a group with increased risk of kinematic disorders of the scapula, therefore, in the diagnostic and therapeutic process, these patients should be assessed and subjected to therapy focused on re-education of the brachioscapular rhythm, in parallel with the use of comprehensive anti-oedema therapy. In the future, in similar research studies assessing the influence of lymphedema on the kinematics of the scapula, it might be advisable to take into account similar time-since-surgery values in comparison with other groups where such large differences as in the currently discussed study do not occur.

In their work, Lang A.E. et al., assessed the kinematics of the scapula in a group of women after mastectomy, and the presence of pain in the shoulder complex. In this work, the authors assessed the angles of upward rotation of the scapula during functional tasks in the form of the overhead reach and overhead lift. In the post-mastectomy group of patients with pain in the shoulder complex during both assessed functional tasks, the range of upward rotation was narrower than in the other groups. The assessed functional activities were performed with an additional external load. The overhead reach with a weight of 1 kg, and overhead lift with a box weighing 5-8 kg. Adding an external load was an attempt to reproduce everyday life conditions and movements of the upper limb that the patients of this group deal with on a daily basis [9]. In the second paper, the authors also assessed the upward rotation of the scapula at elevation angles of 30, 60, 90, 120, and the full range of motion. This time, the movement was performed without load. The arm was oriented in the sagittal and frontal plane of the scapula. The study group also included patients after mastectomy, as in the study described above. The results of the observations indicate that there was less upward rotation of the scapula in the group of patients with pain complaints compared to the group of patients with no pain complaints. In a detailed analysis, the authors indicate that the upward rotation during movement in the frontal plane at 30 and 60 degrees is significantly lower in the group of patients with no pain complaints. Observations of the angle of the upward rotation in the scapula plane showed its reduction in the 30-degree position. The analysis of movement in the sagittal plane showed a reduction in rotation in the elevation of 30, 60, and 90 degrees [11]. The results obtained from both studies indicate the negative impact of the pain in the shoulder

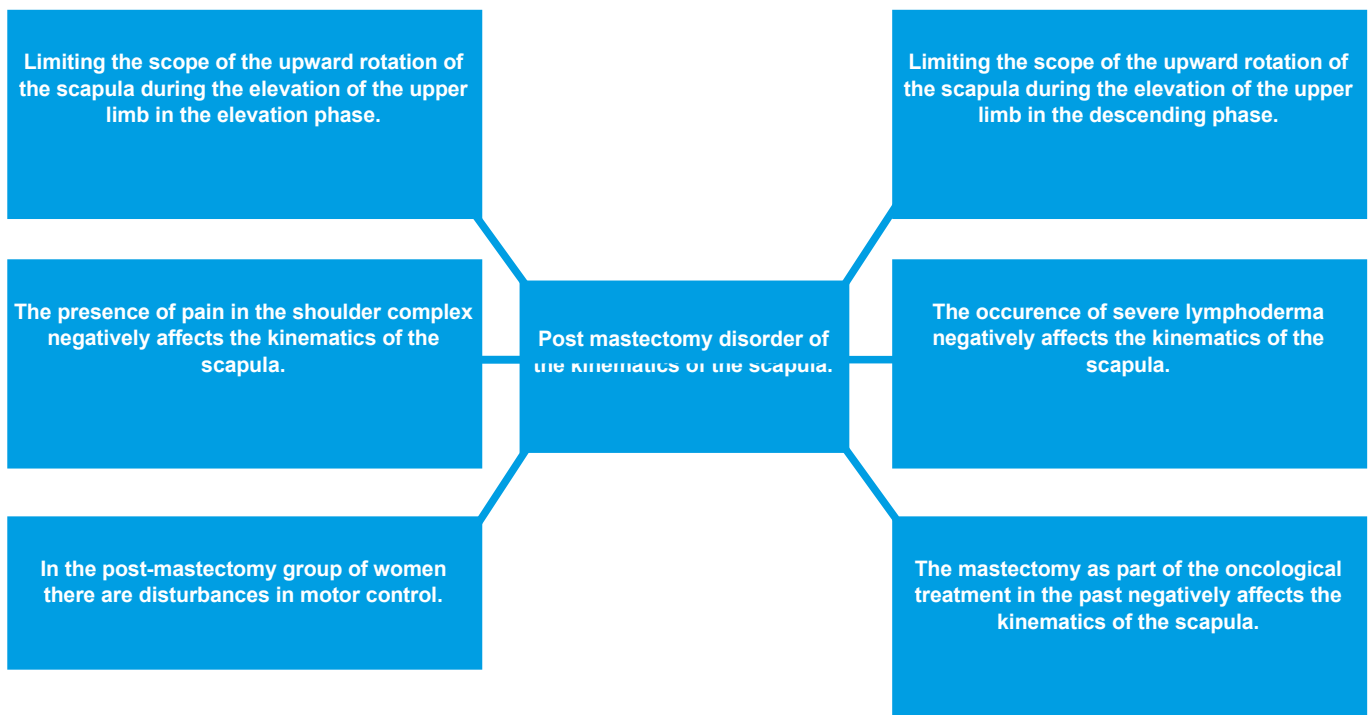
complex on the kinematics of the scapula. A reduced range of upward rotation occurring in the select positions mentioned above indicates the presence of neuromuscular disorders presenting as disturbances of the proper activation of the upper scapular rotators [25, 27]. In the case of merely myofascial restrictions in the area of the shoulder complex, limiting the scapula upward rotation, these limitations would also occur in the upper limb final elevation positions. Limiting the upward rotation of the scapula is a risk factor for the occurrence of increased stress on the structures of the brachioacromial joint, described in the discussion in reference to the work by Baran et al., 2021. In order to achieve the correct parameters of the upward rotation of the scapula, proper cooperation of all parts of the trapezius dorsal muscle and the serratus anterior is required [24]. The occurrence of pain within the shoulder complex will be associated with the possibility of inhibiting the activity of the upward rotators of the scapula [29, 30]. This condition will predispose to the occurrence of scapula kinematics disorders and motor control deficits. As indicated by the results of both works by Lang A.E. et al., actively present pain is potentially a very important factor causing neuromuscular disorders [9, 11]. The obtained results indicate the necessity to implement analgesic therapy in the rehabilitation process in the described group of patients who underwent a mastectomy. In terms of physiotherapeutic impact, it is also possible to implement manual therapy procedures in order to reduce pain parameters and improve the elasticity of soft tissues [31, 32, 33]. Along with the analgesic therapy, elements of the therapy related to the re-education of motor control should be implemented. Tasks aimed at the activation of the upper rotator cuff and the control of the dissociation of the scapula will contribute to the reduction of pathological load on the structures of the shoulder complex [3, 4]. In the case of chronic pain, it is necessary to take into account the inhibitory effect of ailments on muscle activation, but also the fact that reduced activation of the upper scapula rotators may be associated with the generation of pathological tissue load, which will constitute an additional pain generator [29, 30, 34]. Thus, it is reasonable to implement multidirectional treatment in the field of simultaneous pain reduction and motor re-education in order to break the reflex pain circle. In the group studied by Lang A.E. et al. in 2019, the average time since surgery shows a large difference compared to the intra-group. For the group with pain, the time was 70.0 months and for the group without complaints – 42.5 months [9]. Longer time from the surgery may be associated with the occurrence of more severe disorders within the shoulder complex. Similar values of the time from surgery in both groups would allow for more certainty to confirm the statement that pain within the shoulder complex in the group of women after mastectomy is one of the main factors influencing changes in scapula kinematics. The standardization of the time from the surgery is probably an aspect that should also be taken into account in the case of such a clinically complex and difficult to standardize group of respondents.

Ribeiro I.L. et al., 2019 assessed the kinematics of the scapula among women who have undergone surgery in the form of mastectomy or sparing treatment in the past. The authors compared the group of patients after surgical treatment without pain in the shoulder complex with the control group. During

the elevation of the upper limb, angular measurements of the upper scapula rotation, internal rotation, and its anterior tilt were taken. The position of the scapula was assessed in the range of 30, 60, 90, and 120 degrees of limb elevation. In terms of the obtained results, the researchers proved that on the operated side, the angle of the anterior scapula on the operated side was greater in relation to the parameters on the non-surgical side and in relation to the control group. A statistically significant reduction in the rotation of the upper scapula also concerned the operated side in relation to the non-operated side and the control group. These results refer to position 120 of the arm elevation [10]. The authors, like in the works of Lang A.E. et al. 2019, 2020 assessed the kinematics of the scapula only during the limb lifting phase. The reports obtained in this study correspond to the results of the previously analysed studies. Increased anterior tilt and reduced downward rotation of the scapula during the elevation of the upper limb is associated with abnormal activation of the upper scapula rotators and the potential presence of myofascial restrictions [25, 27]. The existing differences between the described studies in terms of the elevation angles of the upper limb in which there are restrictions in the movement of the upper scapula rotation or an increase in its anterior inclination indicate that the approach to the evaluation of patients in this group should be meticulous and individualized. It is difficult to create a specific pattern of disturbances for this group of patients in terms of indicating certain critical angles in the elevation of the upper limb. However, on the other hand, on the basis of the reports obtained in the analyzed studies, it can be concluded that in the group of patients after surgical treatment of breast cancer, there is a deficit in the activity of the upper scapula rotators, which will be influenced by a number of factors. They include the presence of pain at the level of the shoulder complex [9, 11] and lymphoedema of the upper limb [12]. However, the work of Ribeiro I.L. et al., 2019 shows that patients with no pain complaints also suffer from disorders of the scapula kinematics, which may indicate mastectomy as a factor favouring the occurrence of scapula kinematics disorders and pain conditions [10].

The problem of scapula kinematics disorders and motor control deficits in this group is complex. On the basis of the analysed studies on clinical implications, it is worth noting the need to assess the shoulder-scapular rhythm both in terms of the lifting and the lowering phase of the upper limb. It is also important to conduct the evaluation in various planes of movement, i.e. the scapular, frontal and sagittal. The assessment itself should be meticulous so that the clinician could capture the existing abnormalities relating to different angular values and phases of the elevation movement in an individual approach to each patient. Moreover, at the stage of therapeutic process planning, the coexistence of pain symptoms or lymphoedema should be accounted for as additional factors which may adversely affect the brachioscapular rhythm. Comprehensive therapy is based on the implementation of analgesic procedures and anti-oedema therapy, but much more attention should be paid to the elements of motor control re-education in order to improve the kinematic parameters of the scapula, which would translate into an improvement in the functionality of the upper limb in the described group. The

subject of scapula kinematic disorders is an area of research that requires intensive exploration because of the large group of patients who undergo surgical procedures every year in the course of oncological treatment. Curing an oncological disease saves lives, and conducting comprehensive therapy within the shoulder complex is associated with the possibility of improving the quality of life. What is worth emphasizing is the limited availability of original research studies assessing the kinematics of the scapula using recognized digital motion analysis systems, the use of which enables the objectification of results and the accuracy of measurements. The authors of this study also noted the lack of research work carried out on large groups, as well as groups with less differentiated parameters, e.g. in relation to the time from surgery compared to patients with and with no pain complaints. Conducting such studies would make it possible to systematize the potential impact of a given type of disorder on the kinematics of the scapula by determining which groups of patients are at a high risk of significant movement disorders of the upper limb. Such research would also enable the exchange of expert knowledge between centres, which is currently scarce.



Conclusions

1. Scapular kinematic abnormalities include the phase of raising, lowering of the upper limb and selected functional movements. The main disturbance is the occurrence of limitation of upper scapular rotation during both phases of movement. There is also an increase in anterior tilt and internal rotation of the scapula.
2. The pain in the area of the shoulder complex and a severe form of lymphedema is a predisposing factor for motor errors in scapular kinematics.
3. The presence of abnormalities in the scapulothoracic rhythm is a predisposing factor to limitation of upper limb function in

the described group of patients and is one of the reasons for pathological loading of anatomical structures, which may be associated with pain and the development of functional limitations in the future.

4 The identified errors in scapular kinematics and factors predisposing to their occurrence constitute important information which should be taken into account during the diagnostic and therapeutic process within the scope of modern physiotherapy standards.

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