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Assessment of biomechanical parameters of the shoulder joint at the operated side versus non-operated side in patients treated surgically for breast cancer

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ABSTRACT

Aim: Isokinetic assessment of biomechanical parameters of the shoulder joint at the operated side versus non-operated side in patients treated surgically for breast cancer according to the type of surgery performed.

Background: Despite significant progress in medicine, comprehensive cancer therapy may still cause a number of undesired structural and functional effects. The most frequent complications include long-term weakening of muscles within the shoulder and upper extremity at the operated side.

Materials and methods: The study enrolled 57 patient, divided into two groups: mastectomy and BCT. Diagnostic tests were carried out on the groups to assess biomechanical parameters (peak torque, power, total work) of the shoulder joint in internal and external rotation.

Results: The results of the isokinetic test revealed a considerable reduction of dynamic properties of the muscle groups responsible for the function of the shoulder joint at the operated side. The deficits observed, depending on the angular speed and plane of rotation, were from 22.3% to 32.7% and from 23.1% to 29.4% for muscle power and total work, respectively. The least noticeable loss was that of muscular torque, ranging from 6.5% to 18.3%.

Conclusion: None of the treatment methods applied ensured a full release of the restriction within the shoulder and upper limb. The deficits observed may constitute a serious disorder of the musculoskeletal system; therefore, a clinical study of biomechanical parameters of the shoulder joint may be an important control of patients' functional status after breast cancer treatment.

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1. Background

Breast cancer is the most common malignancy in women. The incidence has been on a rising trend for several decades now. However; owing to early detection programmes and modern treatment methods, the survival rate in patients with that type of cancer is growing. Two out of three diagnosed breast cancer patients are estimated to survive more than 20 years from diagnosis.[1]

It should be noted, however, that despite a significant progress in medicine, a comprehensive cancer therapy (surgery, radiotherapy, systemic adjuvant treatment) may continue to cause a number of undesired, adverse effects of both structural and functional nature. Complications related to cancer treatment may lead to a substantial deterioration of the quality of life and often prevent the patient from returning to her everyday activities from before the disease.

The literature contains a number of publications regarding structural and functional problems experienced by women after cancer therapy. These are most often defined as: "Weakening, impairment of the upper part of the body and upper extremity".[2] The most common symptoms are pain,[3–7] restricted mobility[8–10] and long-term weakening of the muscles located within the shoulder and upper extremity at the operated side that are characterised by considerable deficits of force, power and endurance at the operated side as compared to the healthy side.[10,11]

The latter are caused by direct effects of surgery, such as damage to the myofascial structure and neuropathy, that may result in muscle atrophy, significant overgrowth of scar tissue, adhesions, and radiation-induced tissue fibrosis. Other possible complications may include secondary loss of muscle activity related to the loading of the extremity at the operated side, and restricted mobility of the extremity that may be caused by fear of pain and lymphedema.

In available reports, the assessment of the biomechanical parameters was mostly performed through isometric testing: dynamometric hand muscle strength evaluation[10,12,13] or dynamometric maximum muscle contraction measurement in a set direction, in specific shoulder joint positions.[8,11,14]

In our study, the biomechanics of the shoulder was assessed in isokinetic conditions. The idea of diagnostic measurements and physiotherapeutic exercises performed in such conditions dates back to the 1960s. This area was pioneered by Hislop and Perrine who proposed tests where the work of the muscles is characterised by a constant speed of movement and a self-adjusting variable resistance depending on the force generated by the individual being tested.[15,16] Observation was made of the parameters that enabled to assess muscles' capability of releasing force (*peak torque*), generating power (*average power*) and maintaining adequate strength (*total work*). Those parameters are most frequently analysed and, consequently, most frequently described in literature.[17,18]

2. Aim

The aim of the study was to carry out an isokinetic assessment of biomechanical parameters of the shoulder joint at the operated side versus non-operated side in patients treated surgically for breast cancer according to the type of surgery performed.

3. Materials and methods

The study enrolled a group of 57 patients after breast cancer surgery reporting to the Rehabilitation Clinic of the Greater Poland Cancer Centre. The most common reasons for the patients to visit the clinic were functional problems within the shoulder, thorax and upper extremity at the operated side. Functional problems within the shoulder could be accompanied by persistent pain.

The other qualification criteria were the age of 35 to 65 years, and history of unilateral breast cancer surgery with adjuvant radiation therapy. Exclusion criteria included lymphedema or history of preventive mastectomy or breast reconstruction. Patients with confirmed comorbidities (diabetes, arthritis) as well as those who had undergone surgery for the upper extremities were also excluded from the study.

The study was conducted on patients in whom no clear evidence of relapse was found for at least half a year after the end of therapy. Patients' general health status was determined as good (0 or 1 according to ECOG), thus allowing a clinical assessment of biomechanical parameters.

Depending on the type of surgery performed, the patients were divided into two groups:

- MRM group – patients after Modified Radical Mastectomy,
- BCT group – patients after Breast Conserving Therapy.

The characteristics of the study groups are given in Table 1.

No significant differences were found between patient groups. Course of treatment, medical procedures performed and complications occurring during therapy are specified in Table 2.

For all the participating patients, the right hand was the dominant one. In the MRM group, cancer developed in the right side in 56.7% patients versus 51.9% in the BCT group.

This research project was approved by the Ethics Review Committee at the Karol Marcinkowski University of Medical Sciences, Poznań (decision No. 42/13). The patients participating in the research project had been informed of the method and scope of the study, as well as the form of data processing.

Table 1 – Statistical characteristics of study groups.

	Group 1 – MRM		Group 2 – BCT		Total	
	Mean	SD	Mean	SD	Mean	SD
Number of patients [n]	(n = 30)		(n = 27)		(n = 57)	
Age [years]	49.67	8.09	52.81	7.11	51.16	7.74
Height [cm]	163.90	5.39	162.85	6.22	163.40	5.77
Weight [kg]	70.92	10.93	67.26	13.04	69.18	12.01
BMI [kg/m^2]	26.42	3.93	25.27	4.27	25.88	4.06
Time after treatment [mo.]	27.47	25.47	32.15	23.83	29.68	24.60

Table 2 – Medical procedures applied/early post-operative complications.

	Group 1 – MRM		Group 2 – BCT		Total	
	[n]	[%]	[n]	[%]	[n]	[%]
Axillary lymph node dissection (ALND)	28	93.3%	17	63.0%	45	78.9%
Radiotherapy (RTH)	24	80.0%	27	100.0%	51	89.5%
Combined treatment	29	96.7%	26	96.3%	55	96.5%
Chemotherapy (CTH)	2	6.7%	4	14.8%	6	10.5%
Hormonal therapy (HTH)	4	13.3%	17	63.0%	21	36.8%
CTH + HTH	23	76.7%	5	18.5%	28	49.1%
Seroma	18	60.0%	8	29.6%	26	45.6%
AWS	10	33.3%	8	29.6%	18	31.6%
Necrosis	2	6.7%	–	0.0%	2	3.5%

Fig. 1 – Biodex System 4 Pro.

They were requested to give their written informed consent to participate.

The biomechanics of the shoulder was tested in isokinetic conditions using Biodex Medical System 4 ProTM (Biodex Inc, Shirley, NY). The results achieved were compared contralaterally – the operated extremity versus the non-operated one (Fig. 1).

The following parameters were taken into consideration:

- Peak Torque [Nm]
- Average Power [W]
- Total Work [J].

Tests were made in the concentric mode of muscle action.[19] The assessment of each of the parameters was made for internal and external rotation movements in three fixed angular speed levels: 120, 180, 240°/s. First, the test was performed for the healthy side. Then, for the operated side. Four measurements were made for either side according to the pattern specified in Study scenario. The first attempt was a test run.

Study scenario:

- test no. 1 – angular speed: 240 [°/s], no. of repeats: 5,
- test no. 2 – angular speed: 120 [°/s], no. of repeats: 3,
- test no. 3 – angular speed: 180 [°/s], no. of repeats: 5,
- test no. 4 – angular speed: 240 [°/s], no. of repeats: 10.

The overall measurement procedure consisted of the following actions:

- initial instructions to explain the course of the study,
- entering patient data (including date of birth, gender, weight, height, dominant hand and operated side),
- several-minute warm-up,
- patient taking a seat in a chair – the test is performed in a sitting position as it ensures a better stability than a lying one,[20]
- immobilising patients with belts crossed over the chest and a hip belt to eliminate compensatory torso movements.
- setting the dynamometer according to manufacturer's instructions (inclination 50°, rotation 20° towards the patients),
- adjusting and adapting an attachment used for examining the shoulder joint,
- setting the extremity being tested in the position retracted at an angle of 30–45° in the plane of the scapula – a recommended position in clinical practice,[21,22] considered to be physiologically safe, comfortable, and optimal in terms of torque produced,
- carrying out the test according to the adopted design,
- printing out test reports.

The statistical analysis was performed using Statistical 10.0 software (StatSoft Inc). Quantitative data were determined through measures commonly used in statistical inference; mean (M), standard deviation (SD). The conformity of the variables to the normal distribution was assessed with the Shapiro–Wilk test. When the 'normality' criterion was met, the groups were compared using the *t*-Student test. To check the relation between variables, Pearson correlation coefficients (*r*) were applied. The level of statistical significance (*p*) adopted to verify hypotheses was 0.05.

4. Results

4.1. *Analysis of the measured results for peak torque*

In the case of movements made in internal rotation in the group of post-mastectomy women, a statistically significant difference related to the loss of muscle strength was observed for the angular speed of 240°/s. The deficit measured was 13%.

Table 3 – Maximum shoulder joint muscle torque level in internal and external rotation movements. Comparison between the extremity on the operated and non-operated side.

Angular speed	Side	Internal rotation					External rotation				
		Mean	SD	Def	r	p	Mean	SD	Def	r	p
Group 1: MRM (n = 30)											
120°/s	Non-operated	17.25	8.83	6.49%	0.68	0.36	12.03	4.92	9.56%	0.67	0.11
	Operated	16.13	7.54				10.88	4.51			
180°/s	Non-operated	19.17	8.44	7.67%	0.74	0.18	13.10	5.63	10.66%	0.76	0.05
	Operated	17.70	7.93				11.70	5.09			
240°/s	Non-operated	21.67	8.70	13.04%	0.68	<0.05	13.64	5.27	18.33%	0.65	<0.05
	Operated	18.85	8.53				11.14	4.53			
Group 2: BCT (n = 27)											
120°/s	Non-operated	18.36	4.69	12.17%	0.52	<0.05	12.92	2.91	11.32%	0.25	0.06
	Operated	16.12	4.65				11.46	3.40			
180°/s	Non-operated	20.04	5.28	10.50%	0.61		14.81	3.08	13.25%	0.48	<0.05
	Operated	17.94	4.86				12.85	4.27			
240°/s	Non-operated	22.09	5.59	15.52%	0.65		14.94	3.51	13.14%	0.45	
	Operated	18.66	5.43				12.98	3.65			

Table 4 – Average power of the shoulder joint muscle torque in internal and external rotation movements. Comparison between the extremity on the operated and non-operated side.

Angular speed	Side	Internal rotation					External rotation				
		Mean	SD	Def	r	p	Mean	SD	Def	r	p
Group 1: MRM (n = 30)											
120°/s	Non-operated	13.38	9.19	24.99%	0.71	<0.05	8.63	4.65	22.32%	0.76	<0.05
	Operated	10.04	7.48				6.71	4.29			
180°/s	Non-operated	14.13	10.13	26.96%	0.81		9.25	5.09	27.34%	0.80	
	Operated	10.32	8.00				6.72	4.49			
240°/s	Non-operated	14.16	9.86	30.77%	0.76		9.31	5.13	32.51%	0.66	
	Operated	9.80	7.11				6.28	3.62			
Group 2: BCT (n = 27)											
120°/s	Non-operated	14.25	6.81	25.76%	0.64	<0.05	9.84	3.90	23.37%	0.67	<0.05
	Operated	10.58	6.11				7.54	3.75			
180°/s	Non-operated	15.17	7.75	28.57%	0.64		10.60	4.58	28.69%	0.61	
	Operated	10.83	6.53				7.56	3.92			
240°/s	Non-operated	14.93	7.77	32.67%	0.67		10.34	4.27	29.11%	0.67	
	Operated	10.05	5.75				7.33	3.23			

For the speed of 120°/s and 180°/s, the loss of strength was insignificant. The deficit measured was 6.5% to 7.7%. In the group of women after conserving therapy, statistically significant differences were found in the peak torque values between the operated and healthy side for all angular speeds analysed. The deficit measured was 10.5% to 15.5%.

For movements made in external rotation in the group of post-mastectomy women, a statistically significant difference related to the loss of muscle strength was only observed for the angular speed of 240°/s. The deficit measured was 18.3%. For the speed of 120°/s and 180°/s, the loss of strength was less significant. The deficit measured was 9.6% to 10.7%. In the group of women after conserving therapy, statistically significant differences were found in the peak torque values between the operated and healthy side for the angular speeds of 180°/s and 240°/s. The deficit measured was approx. 13%. For the speed of 120°/s, the loss of strength was slightly lower and amounted to 11.3% (Table 3).

The study revealed a high correlation between the variables analysed. During the test for movements made in external rotation, slightly larger torque deficits were observed between the operated and healthy side as compared to movements in internal rotation.

4.2. *Analysis of average power*

The study revealed a significant loss of muscles' capability of generating power. Both in the MRM and BCT group, for all the angular speeds analysed, a statistically significant difference was confirmed in average power ($p < 0.05$) between the operated and healthy side. The average deficit measured for movements made in internal rotation was 25% to 32.7%. For movements made in external rotation, the average deficit measured was 22.3% to 32.5%. Each test revealed a high correlation between the variables analysed (Table 4).

4.3. *Analysis of the total work*

The study revealed a significant loss of muscles' capability of performing work. Both in the MRM and BCT group, for all the angular speeds analysed, a statistically significant difference was confirmed in total work ($p < 0.05$) between the operated and healthy side. The mean deficit measured ranged from 24% to 27.8% for internal rotation and from 23.1 to 29.4% for external rotation. Each test revealed a high correlation between the variables (Table 5).

Table 5 – Total work of the shoulder joint muscle in internal and external rotation movements. Comparison between the extremity on the operated and non-operated side.

Angular speed	Side	Internal rotation					External rotation				
		Mean	SD	Def	*r*	*p*	Mean	SD	Def	*r*	*p*
Group 1: MRM (n = 30)											
120°/s	Non-operated	47.74	32.38	25.35%	0.71	<0.05	29.44	14.95	24.77%	0.75	<0.05
	Operated	35.63	23.72				22.15	12.83			
180°/s	Non-operated	66.82	40.78	24.09%	0.80		41.10	17.23	25.89%	0.78	
	Operated	50.72	33.76				30.46	15.60			
240°/s	Non-operated	138.74	86.95	27.40%	0.68		87.17	40.46	29.39%	0.76	
	Operated	100.73	58.49				61.55	31.32			
Group 2: BCT (n = 27)											
120°/s	Non-operated	50.69	21.83	26.22%	0.57	<0.05	32.54	11.28	23.07%	0.60	<0.05
	Operated	37.40	17.69				25.03	10.42			
180°/s	Non-operated	75.63	33.69	26.21%	0.64		48.39	16.30	25.97%	0.56	
	Operated	55.80	26.82				35.83	14.12			
240°/s	Non-operated	145.16	58.51	27.80%	0.59		93.21	24.89	23.12%	0.66	
	Operated	104.81	43.80				71.66	23.65			

5. Discussion

The assessment of biomechanical parameters of muscle groups responsible for internal and external rotation of the shoulder joint was made in dynamic conditions according to an isokinetic protocol. The study was performed in an Open Kinetic Chain (OKC) where an isolated movement of individual muscle groups was made without the possibility of the weaker link being compensated by proximally and distally located muscles. The conditions assumed allowed the disclosure of an actual deficit of the link under study.[23]

The results obtained for the muscle peak torque in isokinetic conditions differ depending on angular speed and direction of rotation. Notably, lower disorders were observed in post-mastectomy patients. In that group, at lower angular speeds (120–180°/s), both for internal and external rotation, the deficit was of a moderate nature, amounting to 10%, and no statistically significant difference was found between the operated and non-operated side. With the increase of angular speed to 240°/s, the deficit rose to 13%. In the group of women after breast conserving surgery, with regard to peak torque, for each angular speed, both for external and internal rotation, the deficit fell within the range of 10–15%.

The 'total work' parameter characterises muscle endurance, i.e. the ability of the muscles to withstand a long-lasting physical effort of specific intensity without becoming excessively tired. The study, regardless of the angular speed assumed, revealed a considerable deficit of endurance for both study groups (MRM and BCT). For internal rotation movements, it was 24% to 27.8% and for external rotation, from 24.8% to 29.4%. Upper limits of the deficit related to tests performed at the angular speed of 240°/s. In line with the assumptions taken for the study, the test performed at the angular speed of 240–450°/s with the maximum of 15 repeated movements ensures the achievement of the most reliable results.

In the case of muscle average power, that may be described as muscle output, the deficit levels observed were similar to those for endurance. Irrespective of the study group, angular speed and internal/external rotation, the deficit between the operated and non-operated side exceeded 22.3% in each test, whereas for the tests at the angular speed of 240°/s it reached up to 32.7%.

Results of the biomechanical parameters analysis also indicate much higher deficit levels between the operated and healthy side, with the left hand operated. The observed difference in output (power) and endurance (total work) may be much higher than 30%. The highest difference was observed for total work in external rotation movement at the angular speed of 240°/s. For conserving treatment it was 40.7%, and for mastectomy, 46.4%.

The results of the isokinetic test of the biomechanical parameters revealed a considerable reduction of dynamic properties of the muscle groups responsible for the function of the shoulder joint at the operated side. While significant differences were found between particular study participants, a general loss of muscle performance was observed in terms of torque, power and endurance. The least noticeable loss was that of muscular torque. In that case, the asymmetry was found to range from several to 10–20%. The deficit of that value could even go unnoticed in manual tests, e.g. those performed using the Lovett scale. A much higher asymmetry was observed for power and endurance. The deficits in this regard, reaching up to 25%, represent a serious disorder of the musculoskeletal system.

6. Conclusion

The study was conducted on a selected group of women after cancer therapy. One of its aims was to check if conserving treatment, despite the great benefit of being less invasive, may cause functional disorders in the extent similar to that of mastectomy.

The results showed that none of the treatment methods caused a full release of the restriction within the thorax, shoulder and upper extremity. Restricted function of the shoulder is one of the most common complications in patients after breast cancer treatment. Conserving treatment has the advantage over mastectomy as far as cosmetic effects and physical appearance are concerned; however, it may lead to similar functional issues. With a growing number of patients, it becomes important that they are provided with adequate

specialised physiotherapeutic care that enables them to recover, as far as possible, to their performance level from before surgery. Only then can the combat against cancer be considered fully completed.

Conflict of interest

None declared.

Financial disclosure

None declared.

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