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Impact of personality-oriented programs of physical rehabilitation on the heart rate variability in women with post-mastectomy syndrome

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Abstract

Introduction. The aim of the study was to determine the effect of personality-oriented physical rehabilitation programs on the heart rate variability in women with post-mastectomy syndrome.
Methods. The following methods were applied: theoretical analysis of scientific and methodologic literature data, heart rate variability analysis, and mathematical statistical methods. The subjects of the study were 50 women with late symptoms of post-mastectomy syndrome. The study was conducted during the ambulatory rehabilitation stage after Madden radical mastectomy. All the indicators of the heart rate variability were equivalent in the main and comparison groups at the beginning of rehabilitation. The impact of training was examined every 6 months over the course of a year.
Results. Measurements were taken three times: at the beginning of rehabilitation and after 6 and 12 months. It was found that most of the investigated parameters of heart rate variability in both groups steadily improved during the year of rehabilitation. The average values of stress index and amplitude of mode after 12 months of rehabilitation were lower in the main group than in the comparison group but the values of the standard deviation of normal-to-normal intervals and the very low-frequency component of the spectrum were better by 6.48 ms ($p < 0.05$) and 203.29 ms^2 ($p < 0.05$), respectively.
Conclusions. The personality-oriented programs of physical rehabilitation were effective in augmenting heart rate variability and restoring autonomic balance in patients with post-mastectomy syndrome.

Key words: heart rate variability, breast cancer, physical rehabilitation

Introduction

Modern methods of treating breast cancer are based on the use of therapies with complex impacts on cancer, including radiation therapy, chemical therapy, hormone therapy and immunotherapy, but the priority method is still surgery [1–3]. The most common complications after breast cancer treatment are: restriction of the movement amplitude in the shoulder joint, decreases in the muscle strength and functional capacity of the upper extremity, breast oedema, pain, disorder of the cardiorespiratory and autonomic nervous system [4–8]. Together, these complications are referred to as post-mastectomy syndrome (PMS).

Heart rate variability (HRV) is an important indicator of deviations in the autonomic nervous system and its assessment remains the most informative non-invasive method of the quantitative evaluation of heart rhythm autonomic regulation. The close interaction between the sympathetic and parasympathetic parts of the autonomic nervous system and the humoral influence provides the optimal level of adaptation to the conditions of the internal and external environment [9–11].

Studies were performed to investigate the concept of using HRV data to assess the processes of adaptation and stress for predicting the individual health level [12]. In addition, Baevsky and Ivanov [13], as well as Baevsky et al. [14] proposed to employ HRV for the assessment of metabolic disorders in cancer patients. It is known that the reaction to malignancy and specific anticancer treatment is significantly bound with the state of homeostatic mechanisms. Autonomic nervous system is one of the major adaptive systems of the human body, which plays the key role in the regulation of homeostatic mechanisms. Results of scientific investigation indicate that physical exercises help to improve the functional state of the autonomic nervous system in cancer survivors [15–20].

Some papers have presented reduced functionality of the autonomic nervous system, reflected in relatively high values of stress index, amplitude of mode, and vegetative index in the decrease of neurohumoral regulation in women with PMS [21, 22]. Previous research [23, 24] has clearly shown that all patients who have undergone radical treatment for breast cancer have an extreme need for physical and psychological rehabilitation. However, the theoretical analysis of the available papers in the scientific literature suggests that the issues related to physical rehabilitation for patients with PMS have not been completely resolved.

Taken together, the above illustrates the importance of developing and introducing personality-oriented rehabilitation programs and determining their usefulness for an improvement of the functional state of the autonomic nervous system in patients with PMS.

The aim of the study was to determine the effect of personality-oriented physical rehabilitation programs on HRV in women with PMS.

Subjects and methods

The research was performed in the Regional Cancer Centre in Zaporizhia, Ukraine. It was conducted in accordance with the principles of the Declaration of Helsinki. All the patients were informed about the aim of the investigation. The total of 50 women with late symptoms of PMS participated in the research. Using a random sampling method, we formed the main group and the comparison group, with 25 individuals in each. The average age of the patients in the two groups was 55.44 ± 1.06 and 55.60 ± 1.14 years, respectively. All the participants had undergone radical mastectomy by Madden and adjuvant radiotherapy. The type of surgical and adjuvant treatment was similar among the patients in the studied groups. The time after surgery was 6 months.

The inclusion criteria were as follows: 50–60 years of age, recent history of modified radical mastectomy, consent to participate in the study, treatment-related pain, lymphedema, limitation of shoulder joint motion, and decreased muscle strength in the hand on the side of the operation. The exclusion criteria were: bilateral lymphedema, metastasis, primary lymphedema, pulmonary oedema, chronic nonspecific lung disease, congestive heart failure, or any contraindications limiting rehabilitation. All the women who were selected for the research met the eligibility criteria.

At the beginning of physical rehabilitation, the patients were offered the opportunity to choose, in accordance with their own desires and goals, a personality-oriented program of physical rehabilitation which they would participate in for the following year. Before taking part in the experiment, the patients were interviewed and given clear explanations concerning the features of each program.

Two complex personality-oriented programs were created, one for the main group and one for the comparison group. The main group program included aqua aerobics (aqua motion, aqua building, aqua stretching), conditional swimming, and recreational aerobics; the program for the comparison group included conditional swimming and Pilates exercise. The individualization of exercises was carried out in each program by varying the environmental conditions, such as water and air conditions, and employing a complex combination of different means (see below). When forming the study groups, we adhered to the principle of strict randomization, which enabled us to compare the effectiveness of the proposed rehabilitation programs.

The personality-oriented programs included a reasonable choice of means, methods, and forms of physical rehabilitation. The collected data about the subjects referred to the process followed in the post-surgery period; age; characteristics of physical, functional, and psycho-emotional status; presence of collateral pathology; type of attitude toward the disease; and the volume of surgical intervention. The means, forms, and methods of physical rehabilitation thought to be most effective for reaching the assumed targets were selected individually for each patient in both groups.

General and special physical exercises were the main means of physical rehabilitation, but we also employed static and dynamic breathing exercises; breathing through preloaded lips, controlled coughing, autogenic drainage, manual pressing, and manual vibration; post-isometric relaxation; elements of labour therapy; lymphatic drainage massage and self massage; topical talks; consultations; and autotraining.

Special exercises for patients with different types of vegetative regulation disorders were applied in certain phases of the respiratory cycle. With parasympathicotonia, the focus was directed on increasing the duration of inhalation and breath holding after the inspiration phase. In the case of sympathicotonia, exercises aimed at extended exhalation and breath holding after the exhalation phase. Regulated breathing exercises were performed in a static (without limb or body movement) and dynamic (in combination with certain movements) modes. The training lasted 50–60 minutes per session and took place three times a week. Independent training performed by the patients included the fulfilment of therapeutic positions, self-massage, relaxation exercises, and auto-training.

The patients were involved in their relevant programs for a year, and the effectiveness was controlled every 6 months. The following methods were applied in the study: theoretical analysis of scientific and methodologic literature data, HRV analysis, and mathematical statistical methods. HRV indicators were assessed with the electrocardiographic complex KARDIOLAB (Scientific and Technological Centre of Radio-Electronic Medical Equipment and Technologies XAI-Medica of the National Aerospace University, Kharkiv, Ukraine, registration certificate number 6037/2007, conformity certificate number UA-MI/2p-2765-2009). The following indicators were assessed: standard deviation of the normal-to-normal intervals (SDNN), square root of the mean squared differences of successive normal-to-normal intervals (RMSSD), very low frequency (VLF), low frequency (LF), high frequency (HF), total power (TP), LF/HF ratio, stress index (Si), amplitude of mode (Amo). Electrocardiographic signal was recorded in the second standard chest leads. HRV parameters were calculated from short-term 5-minute recordings. All indicators of HRV were equivalent in the main and comparison groups at the beginning of the rehabilitation. Thus, the groups were homogeneous at the start of the study.

All these parameters were divided into three categories: time domain (changes over time), frequency domain (spectrum of oscillatory components), and geometric domain.

Time domain:

1) SDNN (ms), reflecting all the cyclic components responsible for variability in the period of recording;

2) RMSSD (ms), estimating high frequency variations in the heart rate.

Frequency domain:

1) VLF (ms^2), frequency of < 0.04 Hz, reflecting mainly the sympathetic system activity, but also the vascular tone loop of the baroreflex system, thermal regulation and the activity of the renin-angiotensin system;

2) LF (ms^2), frequency of 0.04–0.15 Hz, showing the activity of the baroreflex function (blood pressure maintenance) and both sympathetic and parasympathetic (vagal) activities;

3) HF (ms^2), frequency of > 0.15–0.40 Hz, indicating the parasympathetic (vagal) activity;

4) TP (ms^2), being the subsumption of the measurements between 0.003 and 0.4 Hz and serving as a benchmark of total variability;

5) LF/HF, the relative amounts of LF and HF power, a measure of balance between the sympathetic and parasympathetic nervous system activity [10].

Geometric domain (by Baevsky):

1) Amo (%), the number of cardiointervals, corresponding to the value of Moda, expressed as the percentage to the volume of the sample; it increases significantly in stress conditions;

2) Si, stress index of regulatory systems, characterizing the activity of sympathetic regulation mechanisms and the state of the central regulation contour [13].

The analyses of HRV indicators were performed with the Statistica for Windows software (version 8.00). The significance of differences between the main and comparison groups was determined by Mann-Whitney U test. Within-group comparisons were performed with the use of the Wilcoxon signed-rank test. Values of $p < 0.05$ were considered statistically significant.

Results

The conducted experiment revealed a positive influence of the developed personality-oriented physical rehabilitation program on the improvement of HRV in both groups.

Changes in the HRV parameters in the main group are presented in Table 1. These results suggest that most indicators of the vegetative function improved significantly after 6 months of rehabilitation, particularly the stress index, which improved by 104.16 conventional units (c.u.) ($p < 0.01$), indicating a reduction in the sympathoadrenal system activity and stress level. The results concerning spectral characteristics of HRV presented significant changes in the total activity of regulatory systems, particularly TP, which increased by 190.92 ms^2 ($p < 0.001$) by the preferential growth of VLF by 94.40 ms^2 ($p < 0.05$). All the studied HRV parameters increased statistically significantly during the second half of the year, except for the RMSSD and LF/HF ratio.

Table 2 presents changes in the HRV parameters in the comparison group. The main indicators characterizing the process of stress regulation systems decreased significantly after 6 months of physical rehabilitation: Amo decreased by 7.40% ($p < 0.01$), Si by 98.76 c.u. ($p < 0.001$); during the second half of the year, they were reduced by 3.76% ($p > 0.05$) and 87.12 c.u. ($p < 0.01$), respectively.

During the second half of the year, most of HRV indicators improved significantly: SDNN by 6.6 ms ($p < 0.001$), TP by 433.48 ms^2 ($p < 0.001$), LF by 264.16 ms^2 ($p < 0.01$), and HF by 75.48 ms^2 ($p < 0.05$).

The comparison of HRV indicators between the patients of the main group and the comparison group during rehabilitation is presented in Table 3. The value of Si was lower by 85.84 c.u. ($p < 0.05$) in the main group as compared with the comparison group after six months of training with personality-oriented programs of physical rehabilitation. The average values of Si and Amo after 12 months of rehabilitation were lower in the main group as compared with the comparison group by 114.60 c.u. ($p < 0.01$) and 9.32% ($p < 0.01$), respectively. The values of the SDNN and VLF component of the spectrum were better by 6.48 ms ($p < 0.05$) and 203.29 ms^2 ($p < 0.05$), respectively.

Discussion

In most cases, the structure of the HRV is characterized by lack of balance divisions of the autonomic nervous system, stabilization of regulation and its transition from the reflex level to the low – humoral and metabolic level, not able to quickly provide homeostasis.

Physical rehabilitation programs for patients with PMS are designed with the expectation of complex effects on physical, functional, and psycho-emotional states. The personality-oriented programs developed and verified here were based on the synthesis of existing physical rehabilitation methods for patients with cancer, and the patients were allowed to select the means according to their own attitudes toward the disease.

On the basis of the obtained indicators, we conclude that the patients improved with their TP, SDNN, LF, and HF, which suggests expansion of the adaptive capabilities of the autonomic nervous system.

The key to the effectiveness of physical rehabilitation of women with PMS is consistent and full implementation of tasks that will maximize their physical and functional state and improve the quality of life after leaving the hospital.

The achieved results confirm the effectiveness of the proposed physical rehabilitation programs and could be regarded as a reason to put them into practical use. The programs helped to increase the functionality of the autonomic nervous system in patients of both groups.

Table 1. The evolution of heart rate variability indicators ($M \pm SD$) in the main group patients during the rehabilitation

Indicator	Main group ($n = 25$)		
	Beginning	Six months	One year
SDNN (ms)	21.40 ± 7.46	26.04 ± 8.51***	36.64 ± 10.15•••
RMSSD (ms)	12.64 ± 4.30	17.20 ± 6.86***	21.40 ± 9.14
TP (ms^2)	506.76 ± 287.35	697.68 ± 384.22***	1261.96 ± 513.78•••
VLF (ms^2)	173.88 ± 136.00	268.28 ± 152.55*	450.92 ± 221.90••
LF (ms^2)	181.20 ± 124.04	226.24 ± 104.19	500.84 ± 255.22••
HF (ms^2)	145.72 ± 115.08	184.64 ± 125.64	278.36 ± 177.19•
LF/HF (c.u.)	2.05 ± 1.16	1.58 ± 1.04	2.05 ± 1.55
Amo (%)	65.24 ± 14.48	64.48 ± 13.70	50.96 ± 8.33•••
Si (c.u.)	483.60 ± 114.79	379.44 ± 119.33**	263.56 ± 105.63•••

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, compared with the initial data
• $p < 0.05$, •• $p < 0.01$; ••• $p < 0.001$, compared with the data of six months
SDNN – standard deviation of the normal-to-normal intervals, RMSSD – square root of the mean squared differences of successive normal-to-normal intervals, TP – total power, VLF – very low frequency, LF – low frequency, HF – high frequency, Amo – amplitude of mode, Si – stress index

Table 2. The evolution of heart rate variability indicators (*M* ± *SD*) in the comparison group patients during the rehabilitation

Indicator	Comparison group (*n* = 25)		
	Beginning	Six months	One year
SDNN (ms)	21.64 ± 6.52	23.56 ± 6.24***	30.16 ± 11.27•••
RMSSD (ms)	13.73 ± 4.58	16.64 ± 6.88	20.64 ± 12.31
TP (ms^2)	487.43 ± 304.61	559.24 ± 193.32***	992.72 ± 455.40•••
VLF (ms^2)	141.38 ± 122.46	154.88 ± 133.73	247.63 ± 115.03
LF (ms^2)	179.83 ± 101.28	195.84 ± 109.19	460.00 ± 292.87••
HF (ms^2)	154.13 ± 98.92	202.88 ± 136.70*	278.36 ± 119.89•
LF/HF (c.u.)	1.45 ± 0.90	3.34 ± 1.24	1.64 ± 0.98
Amo (%)	71.44 ± 13.97	64.04 ± 10.55**	60.28 ± 13.40
Si (c.u.)	564.04 ± 219.54	465.28 ± 160.76***	378.16 ± 164.80••

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, compared with the initial data
• $p < 0.05$, •• $p < 0.01$; ••• $p < 0.001$, compared with the data of six months
SDNN – standard deviation of the normal-to-normal intervals, RMSSD – square root of the mean squared differences of successive normal-to-normal intervals, TP – total power, VLF – very low frequency, LF – low frequency, HF – high frequency, Amo – amplitude of mode, Si – stress index

Table 3. Comparison of heart rate variability indicators (*M* ± *SD*) between the main group (MG) and comparison group (CG) patients during the rehabilitation

Indicator	Six months		Twelve months	
	MG (*n* = 25)	CG (*n* = 25)	MG (*n* = 25)	CG (*n* = 25)
SDNN (ms)	26.04 ± 8.51	23.56 ± 6.24	36.64 ± 10.15	30.16 ± 11.27•
RMSSD (ms)	17.20 ± 6.86	16.64 ± 6.88	21.40 ± 9.14	20.64 ± 12.31
TP (ms^2)	697.68 ± 384.22	559.24 ± 193.32	1261.96 ± 513.78	992.72 ± 455.40
VLF (ms^2)	268.28 ± 152.55	154.88 ± 133.73	450.92 ± 221.90	247.63 ± 115.03•
LF (ms^2)	226.24 ± 104.19	195.84 ± 109.19	500.84 ± 255.22	460.00 ± 292.87
HF (ms^2)	184.64 ± 125.64	202.88 ± 136.70	278.36 ± 177.19	278.36 ± 119.89
LF/HF (c.u.)	1.58 ± 1.04	3.34 ± 1.24	2.05 ± 1.55	1.64 ± 0.98
Amo (%)	64.48 ± 13.70	64.04 ± 10.55	50.96 ± 8.33	60.28 ± 13.40••
Si (c.u.)	379.44 ± 119.33	465.28 ± 160.76*	263.56 ± 105.63	378.16 ± 164.80••

* $p < 0.05$, compared with the data of the main group and the comparison group in 6 months;
• $p < 0.05$, •• $p < 0.01$, compared with the data of the main group and the comparison group in 12 months
SDNN – standard deviation of the normal-to-normal intervals, RMSSD – square root of the mean squared differences of successive normal-to-normal intervals, TP – total power, VLF – very low frequency, LF – low frequency, HF – high frequency, Amo – amplitude of mode, Si – stress index

Prospects for further research include determining the effectiveness of the personality-oriented programs in improving the functional state of the upper limb in patients with PMS.

Limitation

Although the results are very optimistic, our study has several limitations. Firstly, the population involved constituted of female Ukrainian subjects, which limits the possibility to generalize the research onto other populations. Secondly, the study was conducted in one institution only; therefore, institutional bias might occur. Thirdly, the sample was small. In addition, minor differences among the examined women concerning lifestyle and genetic factors might affect the scientific results.

Conclusions

The developed personality-oriented programs of physical rehabilitation were individually designed exercise programs incorporating aqua aerobics, conditional swimming, recreational aerobics, and Pilates training, according to the patients' preferences. The study proved the programs to be effective for women with PMS.

Conflict of interest statement:
Authors state no conflict of interest.

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