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THERMAL MEDICINE – THERAPY, PREVENTION, REHABILITATION
PHYSICAL THERAPY • BIOKLIMATOLOGY • BALNEOGEOLOGY • BALNEOCHEMISTRY

- The assessment of the impact of therapy using the Luna-EMG rehabilitation robot on the functional status of patients after total hip replacement
- The effect of a stay in a cardiac thermal station on the physical activity of patients with cardiovascular diseases: Analysis of subjective and objective indicators
- Balneotherapy as a support in the treatment of rheumatic diseases – the importance of natural therapeutic resources in symptom relief and quality of life improvement
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ORIGINAL ARTICLE

The assessment of the impact of therapy using the Luna-EMG rehabilitation robot on the functional status of patients after total hip replacement

Joanna Kuchciak, Agnieszka Przedborska, Aleksandra Milewska, Tristan Chodyczko, Robert Irzmański

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ABSTRACT

Aim: The aim of this study is to evaluate the impact of therapy using the Luna-EMG rehabilitation robot on the functional status of patients with hip joint prostheses.

Materials and Methods: The study included 39 patients (26 F, 13 M) after hip arthroplasty, aged on average 70.36 ± 7.63 years, undergoing rehabilitation with the Luna-EMG device and traditional methods in hospital conditions. Pain intensity, range of motion in the operated hip joints, superficial muscle tension, and quadriceps strength were evaluated using the Luna-EMG rehabilitation robot. Additionally, quadriceps strength was measured using the MicroFET 2 device.

Results: After the therapy, a statistically significant decrease in pain according to the VAS scale, improvement in the range of motion of the operated hips, and an increase in the average value of surface tension were observed in both groups. Additionally, in the group treated with the Luna-EMG robot, quadriceps strength increased significantly.

Conclusions: Training with the Luna-EMG rehabilitation robot improves all analyzed parameters, but no clear advantage of this method over traditional rehabilitation was observed.

KEYWORDS: rehabilitation, biofeedback, total hip replacement

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INTRODUCTION

Osteoarthritis is a civilization disease whose prevalence increases with age, affecting 4% of individuals aged 18-24 years and 85% of individuals over 75 years old. Between 1990 and 2020, the number of patients affected by this condition increased by 132%, reaching 595 million worldwide [1, 2]. The only effective treatment for advanced hip osteoarthritis is total hip replacement. The outcome of the treatment after surgery is determined by individually selected rehabilitation. Exercises, early mobilization, and gait reeducation aim to restore joint function and full daily life activity [3-5]. An important element of the therapy are exercises to improve muscles strength that have been reduced as a result of a long-term disease process and surgery.

Additionally, proprioception reeducation improves gait patterns, which is crucial for efficient locomotion [6, 7]. Currently, due to technological advancements, modern rehabilitation robots based on biological feedback are used in patient treatment. This therapy engages the patient's attention to a greater extent, allows him to better control movement and the effects of rehabilitation [8, 9].

One of the devices employing this system is Luna-EMG. It is specifically designed for neuro-orthopedic rehabilitation, proprioceptive, strength, stabilization training, and spasticity reduction. This device allows active patient engagement. By observing movements on the monitor, patients have the ability to correct their motions. The training supplemented with electromyographic (EMG) feedback from their own muscles stimulates the sensomotor cortex. Using biofeedback improves the quality and effectiveness of exercises because the patient receives real-time feedback about muscle activity, allowing them to consciously control and strengthen muscle tension. Training with specially designed games incorporated into the device further increases patient involvement, promoting muscle strength and improving coordination [10, 11].

AIM

The aim of this study is to evaluate the impact of exercises using the rehabilitation robot Luna-EMG on quadriceps femoris muscle strength and surface tension, hip range of motion and pain levels after total hip replacement.

MATERIALS AND METHODS

The study included 39 patients (26 F, 13 M) after hip arthroplasty, aged on average 70.36 ± 7.63 years, undergoing rehabilitation at the Orthopedic and Post-Traumatic Rehabilitation Clinic of the Medical University of Lodz. The average body mass index (BMI) of the group was 28.4±4.04 kg/m^2. All participants were informed about the study's purpose and signed an informed consent form. The research was approved by the Bioethics Committee at the Medical University of Lodz no RNN/128/23/KE on May 16, 2023. Patients were randomly selected using systematic sampling and divided into two groups. The experimental

group (n=29) received standard rehabilitation protocol with the addition of Luna-EMG robot exercises whereas the control group (n=10) received classical physiotherapy.

The research was conducted on the basis of an original questionnaire, which included pain intensity according to the VAS scale and measurement of active flexion and abduction range in the operated hip using a goniometer. Quadriceps femoris strength and surface tension were measured using the Luna-EMG rehabilitation robot.

Surface tension of the quadriceps muscle was measured using the EMG diagnostic mode. Special electrodes were placed on the patient's body according to the producers's instructions. The patient was asked to perform a maximum knee extension against external resistance. The device recorded data on maximum surface tension.

Quadriceps strength was also measured using the MicroFET 2 dynamometer. The test was conducted according to the producers's standardized guidelines, which included equipment calibration, patient position, stabilization, and device placement. This test was repeated three times by the same therapist, with the best result recorded in newtons (N) [12].

The tests were performed before and after a three-week therapy.

STATISTICAL ANALYSIS

The calculations were performed using the STATISTICA PL 13.3 statistical package. Quantitative variables were described by mean and standard deviation (SD), along with positional measures: median (Me), interquartile range (Q1; Q3), minimum, and maximum (Min-Max). The normality of variables was verified using the Shapiro-Wilk normality test. For non-measurable variables, the number of observations with a given feature variant (N) and its corresponding percentage (%) were presented. To compare pre- and post-rehabilitation results for quantitative variables with normal distribution, the paired t-test was used. For non-normal variables, the Wilcoxon signed-rank test was used. To compare the experimental and control groups, the independent t-test was used if both groups had normal distributions, or the Mann-Whitney U test was used in the absence of normality. A p-value of <0.05 was considered statistically significant.

RESULTS

After therapy, a statistically significant reduction in pain intensity was observed in both the experimental group (p=0.001) and the control group (p=0.0117), confirmed by the VAS scale results. The average pain intensity before therapy in the experimental group was 3.86±2.43, while after therapy it decreased to 1.83±1.44. In the control group, the average pain intensity before therapy was 5.5±3.1, and after therapy it decreased to 1.9±2.02 (Table 1).

After therapy, a statistically significant improvement in the range of hip joint flexion was observed in both the experimental group (p=0.0001) and the control group (p=0.0030). In the experimental group, the mean active flexion range of the operated hip increased from 77.24° ± 22.77° to 87.28° ± 15.32°. In the control group, the mean active flexion range increased from 68.8° ± 15.45° to 79.1° ± 18.83° (Table 2).

After therapy, a statistically significant improvement in the range of hip joint abduction was observed in both the experimental group (p=0.0001) and the control group (p=0.0077). In the experimental group, the mean abduction range of the operated hip increased from 26.45° ± 12.43° to 31.69° ± 12.42°. In the control group, the mean active abduction range increased from 22.7° ± 8.47° to 30.2° ± 9.53° (Table 3).

After therapy, a statistically significant increase in quadriceps surface tension, measured using Luna-EMG, was observed in both the experimental group (p=0.0125) and the control group (p=0.0166). In the experimental group, the average surface tension increased from 188.31 ± 104.18 μV to 238.18 ± 147.22 μV. In the control group, the average surface tension increased from 170.26 ± 67.35 μV to 215.13 ± 89.01 μV (Table 4).

After therapy, a statistically significant increase in quadriceps strength, measured using the Luna-EMG robot, was observed in the experimental group (p=0.0001). In the experimental group, the average strength increased

Table 1. Comparison of pain intensity before and after therapy in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	Control (N=10)	
VAS Before therapy	Mean ± SD	3,86±2,43	5,5±3,1	0,0953
	Median [Q1; Q3]	4 [3; 5]	6 [5; 6,75]	
	[Min; Max]	[0; 9]	[0; 10]	
	p-value(S-W)	0,1442	0,3506	
VAS After therapy	Mean ± SD	1,83±1,44	1,9±2,02	0,9370
	Median [Q1; Q3]	2 [0; 3]	1 [0,25; 3,5]	
	[Min; Max]	[0; 4]	[0; 5]	
	p-value (S-W)	0,0032	0,0239	
p- value (pre vs post)		0,0001	0,0117	

Source: compiled by the authors of this study

Table 2. Comparison of the flexion range before and after therapy in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	K Control (N=10)	
Flexion Before therapy	Mean ± SD	77,24±22,77	68,8±15,45	0,1051
	Median [Q1; Q3]	80 [65; 93]	70 [60,25; 77]	
	[Min; Max]	[15; 111]	[44; 92]	
	p-value (S-W)	0,0437	0,8984	
Flexion After therapy	Mean ± SD	87,28±15,32	79,1±18,83	0,1782
	Median [Q1; Q3]	89 [79; 94]	82 [63,25; 95]	
	[Min; Max]	[42; 121]	[48; 101]	
	p-value (S-W)	0,2899	0,2337	
p- value (pre vs post)		0,0001	0,0030	

Source: compiled by the authors of this study

Table 3. Comparison of the abduction range before and after therapy in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	Control (N=10)	
Abduction Before therapy	Mean ± SD	26,45±12,43	22,7±8,47	0,3837
	Median [Q1; Q3]	26 [21; 32]	21 [19,25; 24]	
	[Min; Max]	[0; 53]	[10; 43]	
	p-value (S-W)	0,9475	0,0711	
Abduction After therapy	Mean ± SD	31,69±12,42	30,2±9,53	0,7158
	Median [Q1; Q3]	32 [24; 40]	29 [26,25; 29,75]	
	[Min; Max]	[6; 54]	[20; 55]	
	p-value (S-W)	0,8258	0,0038	
p- value (pre vs post)		0,0001	0,0077	

Source: compiled by the authors of this study

Table 4. Surface tension measured using Luna-EMG in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	Control (N=10)	
Max tension Before therapy	Mean ± SD	188,31±104,18	170,26±67,35	0,6131
	Median [Q1; Q3]	204,77[100,45; 249,27]	179,14 [129,23; 196,41]	
	[Min; Max]	[30,96; 416,18]	[77,7; 310,19]	
	p-value (S-W)	0,3086	0,4726	
Max tension After therapy	Mean ± SD	238,18±147,22	215,13±89,01	0,8868
	Median [Q1; Q3]	191,08 [144,1; 264,59]	212,39 [175,13; 226,22]	
	[Min; Max]	[56,25; 626,52]	[100,01; 438,83]	
	p-value (S-W)	0,0016	0,0186	
p- value (pre vs post)		0,0125	0,0166	

Source: compiled by the authors of this study

from 21.08 ± 11.83 N to 29.43 ± 14.85 N. No statistically significant differences were observed in the control group (p=0.2026). In the control group, the average strength increased from 26.8 ± 19.13 N to 33.28 ± 16.4 N. However, this result was not statistically significant (Table 5).

After therapy, a statistically significant increase in quadriceps strength measured using the MicroFET 2 was observed in the experimental group (p=0.0059). In the experimental group, the average strength increased from 151.96 ± 68.82 N to 176.49 ± 77.55 N. No statistically significant

Table 5. Quadriceps strength measured using the Luna-EMG robot in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	Control (N=10)	
Max strength Before therapy	Mean ± SD	21,08±11,83	26,8±19,13	0,5365
	Median [Q1; Q3]	17 [10,4; 31,4]	17 [13,53; 40,78]	
	[Min; Max]	[4,8; 42,8]	[7; 58,7]	
	p-value (S-W)	0,0193	0,0478	
Max strenght After therapy	Mean ± SD	29,43±14,85	33,28±16,4	0,4368
	Median [Q1; Q3]	24,8 [19,2; 36,2]	30,7 [24,2; 49,73]	
	[Min; Max]	[9,3; 70,9]	[6,4; 53,6]	
	p-value (S-W)	0,0201	0,4081	
p- value (pre vs post)		0,0001	0,2026	

Source: compiled by the authors of this study

Table 6. Quadriceps strength measured using the MicroFET 2 in the experimental and control groups

Variable	Descriptive Statistics	Group		p-value (E vs C)
		Experimental (N=29)	Control (N=10)	
MicroFET 2 Before therapy	Mean ± SD	151,96±68,82	169,01±65,32	0,4982
	Median [Q1; Q3]	139,7 [111,9; 173,9]	179,35 [114,88; 212,05]	
	[Min; Max]	[15,5; 329,6]	[76,1; 260,2]	
	p-value (S-W)	0,4275	0,5315	
MicroFET 2 After therapy	Mean ± SD	176,49±77,55	206,66±60,36	0,2717
	Median [Q1; Q3]	167,1 [111,9; 234]	195,45 [181,35; 258,13]	
	[Min; Max]	[24,3; 338,1]	[88,5; 280,3]	
	p-value (S-W)	0,9443	0,4838	
p- value (pre vs post)		0,0059	0,0756	

Source: compiled by the authors of this study

differences were observed in the control group (p=0.0756). In the control group, the average strength increased from 169.01 ± 65.32 N to 206.66 ± 60.36 N. However, this result was not statistically significant (Table 6).

DISCUSSION

Rehabilitation after total hip replacement is a key component of the treatment process, aiming to restore full functionality to the patient and improve their quality of life. Physiotherapy, based on individually adapted exercises and physical treatments, continued with balneological therapy, facilitates body regeneration [13]. Traditional rehabilitation methods, although effective, often face limitations related to precision, monitoring progress, and adapting to the patient's individual needs. In recent years, robotic rehabilitation systems have gained significant popularity, offering an innovative approach to therapy due to advanced technology. These devices, equipped with mechanisms enabling precise measurements of strength, muscle tension, and range of motion, allow for the customization of therapy to the patient's needs, enhancing treatment efficacy and accelerating the rehabilitation process [14-16].

Robotic rehabilitation combined with a feedback component become even more effective. Biofeedback, as a method allowing patients to monitor and control parameters such as muscle strength, tension, and range of motion in real time, engages the patient consciously in the rehabilitation process. This enables them to track their progress, which helps to increase motivation and active participation in therapy. Furthermore, biofeedback helps patients along correcting movement errors, improving the quality and precision of exercises, which is particularly important in the early phase of rehabilitation after hip replacement [8, 17].

Studies present consistent results regarding the reduction in quadriceps muscle strength following total hip replacement. The operation leads to both the hip flexors and abductors critical weakness [18, 19]. Norozian et al. [20] confirm the beneficial effect of electromyographic biofeedback (EMG-BF) training in restoring quadriceps muscle strength after ACL reconstruction. Four weeks after surgery, the EMG-BF group showed a significant increase in quadriceps muscle strength, while no relevant difference was observed in the control group. Similar results

were obtained by Draper et al. [21], who found EMG-BF superior in facilitating quadriceps muscle strength recovery compared to electrostimulation after anterior cruciate ligament reconstruction. The results from both studies indicate the superiority of EMG-BF training over traditional orthopedic rehabilitation. In our own research, we also measured the maximum quadriceps muscle strength. The measurement results using the MicroFET 2 dynamometer and the Luna-EMG rehabilitation robot also showed a statistically significant improvement in this parameter in the study group after rehabilitation. The impact of training with the Luna-EMG robot on increasing muscle strength has also been discussed in publications by Trzmiel et al. [22] and Lewandowska-Sroka et al. [23].

After total hip replacement, one of the key rehabilitation goals, apart from restoring muscle strength, is to restore proper quadriceps muscle tension. For this purpose, it is recommended to perform isometric exercises of the quadriceps muscle in the first days after surgery, involving muscle contraction without movement in the knee joint [18,19]. During our study, we assessed the effect of training with the Luna-EMG robot on the maximum surface tension of the quadriceps muscle. The results clearly indicated a significant improvement in this parameter in the study group.

Post-surgery patients often experience pain, particularly during the early stages of rehabilitation [18, 24]. Kokic et al. [25] compared a group using electromyographic biofeedback (EMG-BF) with patients undergoing traditional rehabilitation program. The researchers found a statistically significant reduction in the NRS (Numeric Rating Scale) score for all study participants. No additional benefits were found by adding EMG-BF to the conventional rehabilitation protocol. Similarly, in our study, the results showed that the therapy applied in both groups significantly reduced pain symptoms.

The literature widely analyzes the impact of rehabilitation on the range of motion of the operated joint, especially in terms of its functional state [26, 27]. Correia et al. [28] found a positive effect of biofeedback training on the ROM in the operated hip. Our analysis also showed a statistically significant increase in the active range of motion for flexion and abduction of the hip, both in the study and control groups.

Based on the conducted research, it can be concluded that training using the Luna-EMG rehabilitation robot improves most of the evaluated parameters, such as range of motion, surface tension, and quadriceps muscle strength. Additionally, it reduces pain symptoms in the hip. However, no statistically significant differences were found between the study and control groups. Both the results of our own research and reports from other authors indicate that therapy using the Luna-EMG robot with visual biofeedback enables precise monitoring of rehabilitation progress.

CONCLUSIONS

The therapy used in both groups led to a reduction in pain for patients after total hip replacement.

Training with the Luna-EMG rehabilitation robot as well as traditional therapy improved the range of motion in hip flexion and abduction.

Both therapies increased quadriceps femoris muscle surface tension.

The training with the Luna-EMG rehabilitation robot led to a statistically significant increase in quadriceps femoris strength, confirmed by measurements using both the Luna-EMG robot and the MicroFET 2 dynamometer.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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ORIGINAL ARTICLE

COVID-19 convalescents' rehabilitation: Expediency and effectiveness

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ABSTRACT

Aim: To study the effectiveness of haloaerosoltherapy in COVID-19 convalescents and substantiate expediency of its use as method of respiratory rehabilitation.

Materials and Methods: 85 COVID-19 convalescents with manifestations of pneumonia were examined. Mild course of the disease was diagnosed in 33 patients, moderate – in 37, and severe – in 15 patients. Clinical and ventilation data, pro- and anti-inflammatory cytokines and cellular immunity were analyzed. Treatment included therapeutic physical exercises and group inhalations with dry rock salt aerosols (haloaerosoltherapy), 18-20 seances per course of treatment.

Results: It was found that some clinical manifestations persist in remote period of the disease in COVID-19 convalescents, which were confirmed by presence of ventilation disorders, imbalance of pro- and anti-inflammatory cytokines and supression of cellular immunity. Haloaerosoltherapy usage promoted improvement of studied data, most significantly in convalescents after mild COVID-19.

Conclusions: In COVID-19 convalescents certain clinical manifestations persist during long period, which were confirmed by ventilation changes, increased inflammation activity and suppression of cellular immunity. Haloaerosoltherapy contributes to decrease inflammatory process activity and increase in cellular immunity indices, accompanied by clinical and functional improvement.

KEYWORDS: rehabilitation, salt aerosol, COVID-19 convalescents

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INTRODUCTION

Coronavirus pandemic covered mankined five years ago, but its negative consequences in the form of post-Covid syndrome are still being felt. This is due to the lack of treatment strategy for post-Covid patients, when drug therapy must be supplemented with effective rehabilitation [1,2]. Clinical symptoms of disease caused by the SARS-CoV-2 virus are characterized by significant polymorphism: from asymptomatic virus carriage to severe pneumonia and systemic lesions. However, development of residual manifestations of post-Covid still remains unpredictable. These symptoms included constant fatique, breathing difficulties, dyspnea, cough, which are found not only in elderly patients, but also in young people, even if they had asymptomatic disease's course [3]. Therefore, rehabilitation treatment remains an important background for complete recovery of COVID-19 convalescents. Presence of post-Covid patients with pulmonary problems emphasizes the necessity for development of effective pulmonary rehabilitation [1,2,4].

Rehabilitation of COVID-19 patients must be aimed to respiratory symptoms relief, which can lead to improvement of psychological state and quality of life [5-7]. Since most common symptoms of post-Covid are chronic fatigue, dyspnea, muscles' and joints' pain, an important component of rehabilitation is complex of therapeutic physical exercises aimed in increasing vital capacity of lungs and tolerance to physical exertion [8-11].

In cases when the SARS-CoV2 infection causes persistent lesions in bronchopulmonary system, physiotherapy using laser therapy in combination with magnetotherapy and diathermy and use of low intensity ultrasound, which are aimed at reducing manifestations of inflammation and fibrosis, are also effective [10,12].

At the same time, in case of moderate respiratory manifestations of post-Covid, natural physical factors in form of balneotherapy (inhalation, drinking mineral waters, baths) and mud therapy are effective [13]. In particular, use of iodobromine brines inhalation in COVID-19 convalescents promotes decrease of bronchial obstruction due to inflammatory process liquidation [14]. Moreover, irrigation of respiratory tract mucosa with salt aerosols activates lytic enzymes of phagosomes [15].

Possible use of dry rock salt aerosols (haloaerosols) of certain concentration (not less than 4 mg/m^3), obtained using special devices (halogenerators) is also important. This treatment method (halotherapy, haloaerosoltherapy – HAT) is used in number of European countries, and its effectiveness has been proven in bronchial asthma, chronic bronchitis and COPD, post-pneumonic conditions, etc. [16-21]. Accounting similarity of some symptoms in chronic respiratory diseases and in COVID-19 convalescents, researchers proposed the use of haloaerosols as a method of respiratory rehabilitation in patients with post-Covid syndrome [4, 22, 23]. In general, the use of HAT in these patients is substantiated by the mechanism of influence

of this method, in particular: sanitizing effect, increased drainage function of bronchi (due to hyperosmolar effect), which leads to decrease inflammatory process activity in bronchi with subsequent improvement of ventilation and gas exchange, reduction of tissue hypoxia and decrese of systemic inflammation activity in general [24]. These processes lead to the improvement of immunological reactivity and stabilization of patient's condition in general.

AIM

To study the effectiveness of HAT in COVID-19 convalescents and to substantiate the expediency of its use as a method of respiratory rehabilitation in this group of patients.

MATERIALS AND METHODS

The investigation was carried out at the Government Institution "Scientific-Practical Medical Centre "Rehabilitation" (GI SPMC "Rehabilitation") (Uzhhorod). 85 COVID-19 convalescents aged 25-71 years (average age 53,1±0,81) were examined, who had no chronic bronchopulmonary pathology in anamnesis. Among them 67,1% women (57 patients) and 32,9% men (28 patients). All patients in acute period of disease had manifestations of pneumonia. The mild course of disease was diagnosed in 33 patients (group 1), moderate – in 37 (group 2), and severe course – in 15 patients (group 3). Moreover, 49 patients were admitted to rehabilitation within 2-3 weeks (up to 1 month) after inpatient treatment, and 36 examined – within 2-3 months after inpatient treatment (comparison group). During this period patients were not given any rehabilitation measures, therefore, the comparison of these groups enables to analyze potential changes of studied indices in case when therapeutic measures were not applied. When admitted to rehabilitation and at the end of it, patients underwent clinical, functional and laboratory examinations.

In addition, 24 practically healthy individuals were examined as control group for laboratory data.

When studying pulmonary function test (PFT) standard spirogram parameters were analyzed (FVC, FEV_1, PEF_{exp} and bronchial patency at different levels of bronchi – MEF_{25}, MEF_{50}, MEF_{75}). Results were evaluated as percentage to corresponding normal values.

For integrated evaluation of physical condition of patients, Six Minute Walk Test (6MWT) was performed with registration of pulse rate, blood oxygen saturation (SpO_2), and assessment of dyspnea severity according to Borg scale.

To study the inflammation activity, levels of proinflammatory (tumor necrosis factor – TNFα, interleukin 8 – IL-8) and anti-inflammatory interleukins (IL-4, IL-10) by enzyme-immunoassay were evaluated.

Cellular immunity data were studied by indirect immunofluorescence reaction using monoclonal antibodies ($CD3^+$, $CD22^+$, $CD4^+$, $CD8^+$) and the immunoregulatory index ($CD4^+/CD8^+$) was calculated.

The treatment complex consisted of physical exercises and HAT usage. Therapeutic physical exercises of general strengthening nature were the same for all groups of patients. They were performed daily, except Saturday and Sunday, for 15-20 minutes each, 15 procedures (sessions) per course. The course of HAT included adaptation period for 3-4 days, when the duration of the procedures was gradually increased (15 min, 30 min, 45 min, 60 min) and the main treatment period, which consisted of daily HAT seances lasting 60 minutes each, 18-20 seances per course. Initial concentration of haloaerosol during treatment seance was 40-50 mg/m^3. Aerosol particles up to 6 microns in size were about 70-75%, which ensured intensive haloaerosol influence throughout bronchi. The rock salt, which was used to create the aerosol, contained 98% of halite (mineral of sodium chloride).

The study was approved by Bioethical Expertise Committee of GI SPMC "Rehabilitation" and was conducted in accordance with the written consent of participants. Mathematical processing of obtained results was carried out using licensed programs of Mirocoft Excel LTSC MSO package. The Student's t-test was determined, and results were considered statistically significant at $p<0,05$.

RESULTS

Before treatment, a significant difference was observed between main clinical data and PFT indices depending on COVID-19 severity (Table 1). It should be noted that blood saturation level in all three groups was close to lower limit of normal. At the same time, no significant difference was observed between SpO_2 levels in convalescents after mild and moderate course of disease, however, the difference in the severity of dyspnea and distance in the 6MWT was statistically significant, which was also confirmed by ventilation indices.

In patients with mild COVID-19, almost all ventilation parameters, except MEF_{75}, were within normal values. In patients of 2-nd group, most parameters, except FVC and FEV_1, were reduced, especially at the level of medium and small bronchi (MEF_{50}, MEF_{75}). At the same time, all PFT data in convalescents after severe COVID-19 were significantly reduced compared to normal levels and corresponding values in the first two groups (in 1,4-1,5 times compared to 1-st group and in 1,2-1,3 times compared to 2-nd group).

Analysis of clinical and PFT data, depending on the time of rehabilitation beginning, did not reveal any significant difference between compared groups. In particular, in convalescents who were examined in 2-3 months after acute period only slight increase of SpO_2 was noted compared to those examined up to one month (96,3±0,44% vs. 97,2±0,23%; $p<0,1$), although ventilation indices did not differ significantly.

When studying the activity of inflammatory process by levels of pro- and anti-inflammatory cytokines (Table 2), a significant increase in proinflammatory cytokines was found compared to the control. TNFα level, which is associated with tissue damage, increased in 1,2-2,0 times without a significant difference between groups. The content of IL-8 increased more significantly (in 1,8; 2,5 and 3,2 times, respectively). In addition, it should be noted that IL-8 level in patients of 2-nd and 3-rd groups was significantly higher compared to convalescents after mild COVID-19 course, which confirms higher activity of

Table 1. Some clinical and functional indices in COVID-19 convalescents and their changes under the influence of rehabilitation

Indices, units	Severity of COVID-19 course			p'
	mild, 1-st group (n=33)	moderate, 2-nd group (n=37)	severe, 3-rd group (n=15)	
Resting dyspnea, points	1,1±0,14	1,7±0,15	2,9±0,24	p_{1-2} <0,01
	0,4±0,11	0,8±0,25	1,3±0,21	p_{2-3} <0,001
p	<0,001	<0,001	<0,001	p_{1-3} <0,001
Resting SpO_2, %	96,9±0,21	96,6±0,25	95,4±0,59	p_{1-2} - ns
	97,8±0,20	97,9±0,18	97,1±0,42	p_{2-3} <0,05
p	<0,001	<0,001	<0,05	p_{1-3} <0,05
6MWT, m	476,7±9,45	440,7±7,90	395,9±16,2	p_{1-2} <0,01
	505,3±10,1	468,2±7,47	452,4±13,4	p_{2-3} <0,02
p	<0,05	<0,02	<0,02	p_{1-3} <0,001
FVC, %	96,2±1,74	85,3±1,63	65,7±3,44	p_{1-2} <0,001
	102,0±1,71	91,4±1,25	79,8±2,50	p_{2-3} <0,001
p	<0,05	<0,01	<0,01	p_{1-3} <0,001
FEV_1, %	93,2±1,27	81,2±1,34	66,9±2,93	p_{1-2} <0,001
	99,0±1,31	89,0±1,15	79,0±2,54	p_{2-3} <0,001
p	<0,01	<0,001	<0,001	p_{1-3} <0,001
MEF_{75}, %	75,3±2,41	58,6±2,20	50,6±2,91	p_{1-2} <0,001
	83,3±1,83	71,4±2,04	61,5±2,72	p_{2-3} <0,05
p	<0,01	<0,001	<0,02	p_{1-3} <0,001

*Notes (here and in tables 2 and 3): 1) n – number of patients; 2) in the numerator – indices of patients before treatment; 3) in the denominator – indices of patients after treatment; 4) * – significant difference in indices of patients compared with control; 5) p' – significance of difference in indices between groups of patients before treatment; 6) p – significance of difference in indices of patients before and after treatment within one group; 7) ns – difference in indices is not significant.*

Source: compiled by the authors of this study

Table 2. Levels of some cytokines in COVID-19 convalescents and their dynamics under the influence of treatment

Indices, units	Control (n=24)	Severity of COVID-19 cource			p'
		mild (n=33)	moderate (n=37)	severe (n=15)	
TNFα, pg/ml		9,68±0,70*	8,73±0,73*	12,4±2,16*	p_{1-2} - ns
	6,15±1,20	5,47±0,44	4,99±0,53	5,31±0,95	p_{2-3} <0,2
p		<0,001	<0,001	<0,01	p_{1-3} <0,3
IL-8, pg/ml		28,3±2,88*	40,1±3,42*	49,8±6,84*	p_{1-2} <0,02
	15,7±2,00	15,4±1,76	23,2±3,28*	27,5±4,03*	p_{2-3} <0,3
p		<0,001	<0,001	<0,05	p_{1-3} <0,01
IL-4, pg/ml		8,32±0,77*	9,81±0,82*	10,9±1,60*	p_{1-2} <0,3
	16,1±1,13	14,2±1,56	12,3±1,21*	11,3±0,81*	p_{2-3} - ns
p		<0,01	<0,1	ns	p_{1-3} <0,3
IL-10, pg/ml		12,7±1,23*	16,1±1,06*	14,9±2,09*	p_{1-2} <0,05
	36,6±1,96	23,7±2,04*	24,4±2,07*	20,4±3,25*	p_{2-3} - ns
p		<0,001	<0,001	<0,3	p_{1-3} - ns

Source: compiled by the authors of this study

residual inflammatory process, that in combination with increase of TNFα, determines unfavorable prognosis for chronic pathology development.

These changes occurred on the background of valuable decrease in anti-inflammatory IL-4 and IL-10 by 2,3-2,8 times without significant difference between groups of patients. The pronounced imbalance of pro- and anti-inflammatory cytokines also confirms possibility of inflammation persistence and progression of post-Covid syndrome. In addition, when comparing these indices depending on the time after acute period, no significant difference was found. Only tendency to IL-10 increase in general from 13,3±1,02 pg/ml to 16,2±1,12 pg/ml (p<0,1) at normal values of 36,3±1,96 pg/ml was noted.

Table 3. Some indices of cellular immunity in COVID-19 convalescents and their changes under the influence of treatment

Indices, units	Control (n=24)	Severity of COVID-19 course			p′
		mild (n=33)	moderate (n=37)	severe (n=15)	
$CD3^+$, %		61,9±0,71*	56,6±0,61*	53,7±0,90*	p_{1-2} <0,001
	66,2±0,60	65,6±0,37	63,5±0,42*	62,5±0,73*	p_{2-3} <0,01
p		<0,001	<0,001	<0,001	p_{1-3} <0,001
$CD22^+$, %		21,3±0,54*	19,7±0,67*	18,8±0,89*	p_{1-2} <0,1
	15,2±0,29	17,5±0,35*	16,9±0,38*	16,7±0,33*	p_{2-3} - ns
p		<0,001	<0,001	<0,05	p_{1-3} <0,05
$CD4^+$, %		34,3±0,61*	30,4±0,47*	28,2±0,41*	p_{1-2} <0,001
	38,06±0,67	37,5±0,34	36,3±0,37*	34,8±0,63*	p_{2-3} <0,01
p		<0,001	<0,001	<0,001	p_{1-3} <0,001
$CD8^+$, %		27,2±0,43	25,6±0,52*	25,1±0,62*	p_{1-2} <0,05
	27,2±0,39	27,5±0,22	26,6±0,30	26,8±0,42	p_{2-3} - ns
p		ns	<0,2	<0,05	p_{1-3} <0,1
$CD4^+/CD8^+$		1,27±0,03*	1,20±0,03*	1,13±0,02*	p_{1-2} <0,2
	1,41±0,03	1,37±0,02	1,37±0,02	1,30±0,03*	p_{2-3} <0,2
p		<0,05	<0,001	<0,001	p_{1-3} <0,01

Source: compiled by the authors of this study

A somewhat different situation was observed in cellular immunity data, which play significant role in antiviral immunity (Table 3). In general, significant decrease in T-lymphocytes number was observed, which occurred mainly due to T-helper subpopulation. At the same time, significant decrease in the number of $CD8^+$-lymphocytes was found only in patients of 2-nd and 3-d groups. These changes indicate certain depletion of the immune system, which may contribute to persistence of chronic inflammation.

B-lymphocytes level was valuably increased, most significantly after mild course of the disease, indicating a straining in humoral link of immunity due to antigens' load. These changes in the immune reactivity were stable and observed in the examined patients, both in the period up to the first month after inpatient treatment, and after 2-3 months without significant differences between them.

So, both clinical and functional changes after COVID-19, as well as immune reactivity data and inflammation activity within 4 months after acute period of disease, do not change significantly, which may be the basis for chronic pathology formation associated with COVID-19 and significantly affect the patients' quality of life.

After rehabilitation course using HAT, positive dynamics of studied indices was observed, expressiveness of which depended on COVID-19 severity. The most demonstrative is significant increase in blood saturation, level of which at the end of treatment was the same in all three groups (Table 1).

Dyspnea severity also valuably decreased, but most significantly in convalescents after mild COVID-19. These changes were also confirmed by the distance covered by patients in 6MWT. At the same time, normalization of all studied PFT data was registered only in patients of 1-st group. In patients with moderate COVID-19, integral parameters (FVC, FEV_1) reached normal values, but minor obstructive changes were noted at the level of medium and small bronchi (Table 1). In convalescents after severe COVID-19, FVC and FEV_1 approached the lower limit of normal values, but bronchial patency at all levels remained reduced, especially in small bronchi.

Improvement of clinical and functional data was accompanied by inflammation activity decrease and elevation of cellular immunity indices. In particular, TNF-α level, significantly decreased up to control in all groups without significant difference between them (Table 2). Pro-inflammatory IL-8 level decreased to control values only in group with mild COVID-19. In patients with moderate and severe COVID-19 it remained elevated. At the same time, significant increase of anti-inflammatory IL-4 and IL-10 was noted only in patients of the 1-st and 2-nd groups, while in convalescents after severe COVID-19, their levels did not increase. This indicates certain persistence of systemic inflammation, especially in patients with severe COVID-19 and high probability of post-Covid syndrome progression.

Similar regularities were observed in cellular immunity data (Table 3). In convalescents after mild COVID-19, it was noted that all studied indices reached control levels, except B-lymphocytes, although their number valuably decreased. In patients of 2-nd and 3-rd groups, cellular immunity indices significantly improved, but only in convalescents after moderate COVID-19, the number of $CD8^+$-lymphocytes and immunoregulatory index ($CD4^+/CD8^+$) normalized.

DISCUSSION

This paper presents results of complex clinical and functional examination, as well as study of cellular immunity and inflammation activity in convalescents after COVID-19.

This range of examinations is in accordance with works of other researchers, as it allows assessing patients' physical condition and to determine the pathogenetic basis of post-Covid syndrome [2, 11, 12, 25]. Analysis of results was carried out depending on severity of COVID-19 and period that passed after inpatient treatment (up to 1-st month and after 2-3 months). According to researchers [3, 25], post-Covid symptoms can develop in any patient regardless disease's severity in acute period. This was confirmed by our studies. However, expressiveness of these changes in our investigations significantly depends on severity of COVID pneumonia. This difference is especially significant according to results of 6MWT, PFT data and some indices of cellular immunity and is important when conducting rehabilitation treatment.

Duration of post-Covid symptoms after acute period is of great importance in their assessment. A comparison of two groups of patients (who started rehabilitation before 1-st month after inpatient treatment and after 2-3 months) did not reveal a significant difference between them. That is, manifestations of post-Covid syndrome persist for a long time (for months) and do not significantly decrease without treatment. Other researchers have also such opinion. In particular, according to A. Mohan et al. [25] 76% of patients reported presence of at least one long-term symptom for 6 months after acute period, and P.W. Janus et al. [23] received data about presence of post-Covid symptoms for 7-8 months.

It is also considered that the basis for post-Covid changes' development is immune dysregulation and inflammation, which increase the risk of other diseases, in particular autoimmune [25]. Other researchers have also reported preservation of inflammatory activity for a long time after acute coronavirus infection [12, 14]. These data are fully in agreement with our results. A pronounced imbalance between pro- and anti-inflammatory cytokines with a significant predominance of the first ones persists in patients for 3 months. This may determine an unfavorable prognosis for chronic pathology development [25].

In accordance with the above mentioned, feasibility of recovery treatment is recognized by all researchers, and the most recommended is method of therapeutic physical exercises [8-11]. At the same time, C. Arienti et al. [5] consider that effect of breathing exercises in patients with mild COVID-19 is uncertain.

K. Kwiatkowska et al. [4] and B. Uysal et al. [22], based on the similarity of clinical symptoms in chronic respiratory pathology and post-Covid syndrome, as well as taking into account mechanisms of haloaerosols' influence, substantiated the feasibility of using this method as respiratory rehabilitation in convalescents after COVID-19. However, results of concrete studies are not provided [4, 22].

Practical confirmation of the feasibility of haloaerosols usage is the work of P.W. Janus et al. [23], which provides evidence of treatment effectiveness in Wieliczka salt mines in 699 convalescents after COVID-19. Researchers noted a significant increase in chest mobility and improvement results of two-minute step test in 79% of examined. When analyzing these results, severity of COVID-19 was not taken into account, and the concentration of haloaerosol in the mine is only 3-8 mg/m^3. Haloaerosol with concentration of 40-50 mg/m^3, which we used in our investigation, has more pronounced local effect on bronchi. However, normalization of the studied indices was achieved only in convalescents after mild course of COVID-19. This determines the necessity of further improvement of rehabilitation programs.

CONCLUSIONS

In COVID-19 convalescents who had manifestations of pneumonia in the acute period, certain clinical symptoms persist for a long time, which are confirmed by ventilation disorders, increased activity of inflammation and decrease of cellular immunity indices. These changes indicate persistence of inflammation with possible further formation of chronic pathology and corresponding decrease in patients' quality of life. Expressiveness of these manifestations depends on severity of pathological process in acute period of disease.

Recovery treatment using haloaerosoltherapy contributes to the reduction of inflammatory process and increase of studied parameters of cellular immunity, which is accompanied by improvement in ventilation and clinical condition of convalescents. However, normalization of most of studied indices was achieved only in convalescents after mild course of COVID-19.

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ORIGINAL ARTICLE

Assessment of the impact of whole-body cryotherapy on the functional status of women with osteoarthritis and rheumatoid arthritis

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ABSTRACT

Aim: The aim of the study was to assess the impact of WBCT therapy combined with kinesiotherapy on pain, range of motion, and muscle strength acting on the knee joint, as well as the functional status of women with OA and RA.

Materials and Methods: The study enrolled 82 women with an average age of 61,98±7,52. The first group included women with osteoarthritis (n=41), and the second group included women with rheumatoid arthritis (n=14). All participants underwent a series of 10 whole-body cryotherapy sessions. In order to assess the effects of the therapy, the VAS scale, the Modified Laitinen Pain Questionnaire, the Timed Up and Go Test, the Short Physical Performance Battery, the measurement of the range of motion and muscle strength of the knee joint were used.

Results: The application of whole-body cryotherapy resulted in pain reduction and improvement in all conducted assessm ents in both groups of patients. The patients with osteoarthritis had a greater reduction of pain on the Laitinen scale with a lower BMI (rho=-0,34, p=0,03).The pain reduction improved Short Physical Performance Battery scores (rho=-0,46, p=0,002). In patients with rheumatoid arthritis, the results of the Short Physical Performance Battery were correlated with a reduction in the Timed Up and Go Test time (rho=0,66, p<0,001), an increase of the range of motion in the knee joint (rho=-0,33, p=0,04) and improvement in extensor muscle strength (rho=-0,48, p=0,002) and flexor muscles (rho=-0,37, p=0,02).

Conclusions: Systemic cryotherapy has a significant impact on reducing pain and improving the functional status of patients with osteoarthritis and rheumatoid arthritis. It increases the range of motion and muscle strenght of the knee joint, which translates into improved functional condition.

KEYWORDS: osteoarthritis, rheumatoid arthritis, systemic cryotherapy, functional status

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INTRODUCTION

Osteoarthritis (OA) and rheumatoid arthritis (RA) are diseases of multifactorial etiology, causing dysfunctions of a progressive nature within the musculoskeletal system. It is estimated that the problem of RA affects 1% of the world population, and OA over 4% and is constantly increasing. These diseases more often affect women than men [1-3].

The main clinical symptoms of both of these diseases are pain, joint stiffness, limitation of the range of motion and change in the contour of the joints, as well as a decrease in muscle strength, which results in reduced functional efficiency, which translates into progressive disability [2].

RA is characterized by chronic inflammation affecting the destruction of cartilage and bone tissue. Studies have shown that the destructive changes in OA, in addition to aging, genetic and obesity processes, are influenced by inflammation, especially the release of cytokines. [1-2, 4]. In the course of these diseases, various joints may be affected, but the involvement of large joints of the lower limbs – the hip and knee – mainly contributes to the progressive decline in functional efficiency [3-4].

So far, no effective method of treating these diseases has been found. Currently, appropriate pharmacotherapy mainly reduces pain and slows down the progression of the disease [1]. However, the side effects of the drugs used cause that alternative treatments are still being sought.

Whole body cryotherapy (WBCT) seems to be a promising method. There are several definitions of it, differing in wording, but they all agree that the cryochamber treatment is a , stimulus-based, stimulating, application of cryogenic temperatures to the patient's body surface for a short time (2-3 minutes) in order to induce and use physiological reactions to cold and facilitate kinesitherapy [5, 6].

Its effectiveness has been demonstrated in musculoskeletal and neurological diseases and in biological regeneration [7-9]. Its anti-inflammatory and anti-swelling effects are commonly described.

In addition, after the application of cryogenic temperatures, a decrease in the speed of nerve conduction in pain fibers and oxidative stress was observed, which reduces the feeling of pain and increases in its tolerance threshold [10].

AIM

The aim of the study was to assess the impact of WBCT therapy combined with kinesiotherapy on pain, range of motion, and muscle strength acting on the knee joint, as well as the functional status of women with OA and RA.

MATERIALS AND METHODS

The study was conducted among 82 women aged 44 to 80 years old (61,98±7,52). Based on the diagnosis, patients were divided into two groups. The first group included 41 women diagnosed with OA at 2/3 stage according to the Kellegren-Lawrence Scale [11]. The second group included 41 women who had been suffering from RA for at least 2 years. The diagnosis of RA was verified according to the criteria of the American College of Rheumatology and the European League Aganst Rheumatisin from 2010 [12].

The study was conducted at the Centre for Prevention and Rehabilitation NZOZ CREATOR Sp. z o. o. in Lodz (Didactic and Research Centre of the Medical University of Lodz). Women for the study were selected randomly.

The inclusion criteria were qualification for WBCT procedures by a physician, reporting symptoms in the knee joint, the ability to walk at least 10 meters, and providing written consent to participate in the study. The exclusion criteria were age below 40 years old, male gender, lack of an OA or RA diagnosis, and contraindications to WBC procedures and exercises.

The patients underwent a series of 10 whole-body cryotherapy treatments in a cryogenic nitrogen chamber with the symbol CR-20ll CH-l/A produced by Creator Sp. z o.o. from Wroclaw, after which they performed exercises. The treatments were performed 5 times a week, excluding weekends. Each time before entering the cryochamber, the patients had their blood pressure measured. The procedures were performed in accordance with the standards adopted for WBCT. Duration of the procedure: 3 minutes (30 seconds, vestibule with temperature approx. -60 degrees; 2 minutes, main chamber with temperature from -120 to -130 degrees; every 2 days reduced by 2 degrees). After the procedure, patients performed exercises for 30 minutes, consisting of riding on a cycloergometer, walking on a stepper or general rehabilitation exercises [13].

Patients were not recommended to modify their medications, as well as additional activities.

During the interview, data regarding age, height, and body weight were collected, and based on the latter two, the Body Mass Index (BMI) was calculated [14].

To assess pain in the knee joints, the Visual Analogue Scale (VAS) and the Modified Laitinen Pain Questionnaire were used.

The Timed Up and Go Test (TUG) and the Short Physical Performance Battery (PSSB) were used to assess functional performance. A knee joint range of motion was also examined, and the muscle strength of the knee flexors and extensors were measured. The tests were performed before the first entry into the cryochamber and after the end of a series of treatments.

On a 10-point VAS scale, patients marked their current pain on a 10 cm scale, where 0 means no pain and 10 means maximum imaginable pain [15]. The modified Laitinen Pain Questionnaire assesses 4 characteristics of pain: severity, frequency of occurrence, frequency of painkiller use, and limitation of motor activity. Each feature is scored in the range from 0 to 4, where 0 means no problem, and 4 means its highest severity [16].

The TUG (Timed Up and Go) test is used to assess dynamic balance and gait. It is applied to evaluate four basic activities of daily living, namely: standing up from a seated position, walking, turning, and returning to a seated position. During two trials, the patient is asked to perform the task in the shortest time possible (measured in seconds). The trial with the better time result is used for analysis [17].

The SSPB test is a well-documented tool for assessing the function of the lower limbs. 3 elements of physical fitness are tested, i.e. static balance, strength and endurance of the lower limbs and gait speed. Postural stability was assessed in standing with the feet in 3 positions (side-by-side, Semi Tandem Stand, Tandem Stand). Attempts maintained for 10 seconds were taken into account.

The next elements of the assessment included performing five sit-to-stand repetitions as quickly as possible without using the hands and walking 3 meters at a normal pace. The time for both tasks was measured in seconds. The interpretation of the results for all three tasks was based on a 5-point scale, where zero indicated inability to perform the task, and 4 indicated the best performance. Points were awarded based on the time cutoff proposed by Guralnik. The overall score of the SPPB test ranges from 0 to 12 points, where 0-3 indicates severe limitations, 4-6 moderate limitations, 7-9 mild limitations, and 10-12 no limitations [18].

The range of motion for knee flexion and extension was measured using a standard goniometer according to the examination methodology [19]. The patient was asked to perform the maximum active movement against the force of gravity. The results are presented in degrees.

The strength of the muscles acting on the knee joint was measured using a MicroFET 2 hand dynamometer (Hoggan Scientific, LLC, Salt Lake City, UT, USA). The device was calibrated according to the manufacturer's recommendations. Two measurements were carried out with a one-minute pause, encouraging the patient to have a maximal isometric contraction lasting 5 s first of the knee extensor muscles and then of the flexors.

The examination was performed by one tester in accordance with the recommended standardized guidelines regarding the patient's position, dynamometer application site, stabilization and verbal commands [20]. The results are given in Newtons (N) and the largest peak value of the two measurements is recorded.

Calculations were performed using the statistical software PQSTAT v. 1.8.4 and the R environment v. 3.6.1 (ARTool package). Quantitative variables were presented as mean and standard deviation or median with the first and third quartiles, depending on the distribution. The normality of distributions was verified using the Shapiro-Wilk test. Ordinal variables were described by providing frequencies for individual categories. Ordinal variables with a large number of categories were additionally characterized by presenting the median as well as the first and third quartiles. To determine the statistical significance of differences between groups and between pre- and post-procedure results-due to the failure to meet assumptions (lack of normality in the distributions

of variables in the compared groups) – the ART ANOVA (Aligned Ranks Transformation ANOVA) method was used, along with Tukey's correction for multiple comparisons, as well as the nonparametric Mann-Whitney U test and Wilcoxon signed-rank test. As a measure of effect size for group comparisons, the rank-biserial correlation coefficient was used. The relationship between the treatment effect and the pre-treatment variable value was determined using Spearman's correlation coefficients. The level of statistical significance was considered to be $p<0,05$.

STUDY LIMITATIONS

A small number of respondents. In later studies, it is worth assessing the long-term effect of the therapy.

ETHICAL STANDARDS

A positive opinion of the Bioethics Committee of the Medical University of Łódź (No. RNN/167/21/KE) was obtained.

RESULTS

The characteristics of the patients are presented in Table 1. Most female patients had a normal BMI.

As a result of a series of 10 WBCT sessions and exercises, both women with OA and RA experienced a reduction in pain and an improvement in all assessed functional indicators (TUG test, SPPB, range of motion, and muscle strength).

In patients with OA, the changes in the strength of the knee extensors were greater (Table 2).

Additionally, factors influencing progress in WBCT therapy were evaluated. In the group of patients with OA, a greater reduction in pain on the Laitinen scale was observed in women with a lower BMI (rho=-0,34, p=0,03). The reduction in pain on this scale improved functional performance in these patients on the SPPB test (rho=-0,46, p=0,002). In the group of patients with RA, an increase in the strength of knee extensors and flexors was associated with a reduction in the time to complete the TUG test (rho=0,36, p=0,02). Higher SPPB scores were correlated with a shorter time to complete the TUG test (rho=0,66, p<0,001), an increase in the range of motion in the knee joint (rho=-0,33, p=0,04), and improvements in the strength of the knee extensors (rho=-0,48, p=0,002) and flexors (rho=-0,37, p=0,02). In patients who experienced a reduction in pain assessed by the Laitinen scale, an increase in knee flexor strength was noted (rho=0,42, p=0,006).

DISCUSSION

The aim of the study was to assess the impact of WBCT therapy on pain, functional indicators, and muscle strength. The results obtained in both groups of women indicate an improvement in all assessed indicators, which is consistent with previous studies and reports from other authors [7-10].

In chronic diseases such as OA and RA, the associated pain increases the risk of disability. In our own studies, both in the VAS and Laitinen scales, a significant reduction in pain perception was observed in both groups.

A greater reduction in pain was observed on the Laitinen scale in women with OA and a lower BMI. This may be due to the fact that an increased level of free fatty acids, which occurs in obesity, is considered a mediator of inflammatory conditions [21].

Pain sensations lead to the protection of affected joints, placing them in forced positions, limiting the range of motion, which in turn results in a weakening of muscle strength [6].

Table 1. Characteristics of the study population

		OA(n=41)	RA(n=41)	Razem (N=82)
Age (years)	Mean ± SD	63,41±7,88	60,54±6,95	61,98±7,52
	Median [Q1; Q3]	65 [61; 69]	61 [57; 65]	63 [58; 67]
	Min; Max	44; 73	45; 80	44; 80
Weight (kg)	Mean ± SD	71,85±11,08	71,1±14,65	71,48±12,91
	Median [Q1; Q3]	70 [65; 80]	67 [60; 80]	70 [62; 80]
	Min; Max	50; 98	48; 121	48; 121
Height (cm)	Mean ± SD	161,27±5,06	162,05±6,24	161,66±5,66
	Median [Q1; Q3]	161 [158; 164]	162 [158; 166]	161,5 [158; 165]
	Min; Max	150; 171	149; 176	149; 176
BMI (kg/m^2)	Mean ± SD	27,52±4,06	26,94±4,45	27,23±4,24
	Median [Q1; Q3]	26,95 [25,71; 29,03]	26,77 [24,17; 29,41]	26,84 [24,41; 29,38]
	Min; Max	18,37; 36,44	18,78; 43,91	18,37; 43,91

Source: compiled by the authors of this study

Table 2. The influence of WBCT effects on pain and functional tests

parameter	group	Pre mean±SD median [Q1;Q3]	Post mean±SD median [Q1;Q3]	ANOVA interaction Time* Group
TUG	OA	6,97±2,73 6,61[5,71; 7,21]	5,85±2,62*** 5,4[4,9; 6,02]	0,169
	RA	7,08±2,35 6,45[5,67; 7,51]	6,16±2,2*** 5,73[4,89; 6,63]	
SPPB	OA	11[10; 12]	12[12; 12] ***	0,158
	RA	11[9;12]	12[11;12] ***	
LAITINEN	OA	5[4; 7]	2[1; 3] ***	0,9
	RA	6[5;8]	3[2;4] ***	
VAS	OA	5[4; 7]	3[0; 5] ***	0,503
	RA	5[4;6]	3[1;4] ***	
Knee joint range of motion	OA	112,07±12,55 115[105;120]	119,02±8** 120[115;120]	0,113
	RA	110,85±16,99 115[105; 120]	118,05±14,61*** 120[115; 125]	
Knee extensor strength	OA	123,47±54,61 118,3[77,4; 165]	172,45±61,38*** 180,1[141,9; 205,9]	<0,001
	RA	128,73±52,9 125,9[88,5; 170,8]	157,28±51,5*** 161[111,2; 188,2]	
Knee flexion strength	OA	76,43±39,71 71,1[36,4; 96,5]	99,88±42,17*** 97,4[76,9; 124,5]	0,465
	RA	76,23±33,5 75,1[47,1; 98,7]	96±36,32*** 92[74,7; 121,4]	

*OA – osteoarthritis, RA – rheumatoid arthritis, * – difference pre-post (in time) p<0.05, ** – difference pre-post (in time) p<0.01, *** – difference pre-post (in time) p<0.001*
Source: compiled by the authors of this study

A reduction in pain intensity may contribute to an increase in the range of motion or muscle strength, the decline of which also occurs as a result of the natural aging process, and after the age of 65 is accompanied by a decrease in muscle mass. Since the lower limbs are an important element of independence (enabling free movement), and the quadriceps femoris muscle is a key component in ensuring this, measurements of its strength appear to be an important aspect of assessing the effectiveness of therapy. This muscle is essential for performing activities such as standing up from a chair or climbing stairs. The use of handheld dynamometers to measure muscle strength is recommended in clinical practice as a quick and easy method for objectively assessing progress in therapy [9,20,22]. In our study, the increase in the measured strength of this muscle was accompanied by an improvement in scores on the SPPB tests and a reduction in TUG time.

The improvement in the strength of the knee extensors in women with OA was significantly greater than in those with RA. This may be due to the course, severity, and duration of the disease. In earlier studies conducted on a group of 21 RA patients, both women and men, the authors observed a significant reduction in pain, a decrease in morning stiffness duration, an increase in knee joint muscle strength, a reduction in TUG time, and an improvement in SPPB scores [9].

Most publications are based on a subjective assessment of pain. Due to the limited presence of scientific reports on objective methods of assessing the effectiveness of therapy, it is worth introducing them as a standard test, e.g. measuring muscle strength.WBCT is also increasingly used in sanatoriums and health resorts where musculoskeletal diseases, including OA and RA, are treated [6].

The mechanisms of the effects of extremely low temperatures on the human body are not yet fully understood. The use of WBCT in patients with both OA and RA brings measurable benefits in reducing pain and improving functional status. Therefore, when combined with exercise, it appears to be a promising method for supporting therapy and improving quality of life.

CONCLUSIONS

WBCT has a positive impact on reducing pain perception in patients with OA and RA.

Treatments using cryogenic temperatures affect the increase in range of motion and muscle strength of the knee joint.

WBCT therapy has a positive effect on improving functional status in both women with OA and RA.

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CONFLICT OF INTEREST

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ORIGINAL ARTICLE

Effects of upper limb peripheral nerve mobilization on motor function and nerve conduction among subjects with middle cerebral artery stroke

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ABSTRACT

Aim: To explores the effects of upper limb peripheral nerve mobilization (PNM) on motor function and nerve conduction in middle cerebral artery stroke patients.
Materials and Methods: An experimental study, where Sixty-six participants, aged 40-75 years, were divided into an experimental group (n=33) and a control group (n=33). The experimental group underwent PNM, while the control group received standard stroke rehabilitation therapy. Outcome measures included the Wolf Motor Function Test (WMFT) and nerve conduction velocity (NCV) for radial, median, and ulnar nerves.
Results: Both groups ($n = 33$ each) showed significant post-intervention improvements ($p < 0.05$). The experimental group demonstrated greater gains, with WMFT Time reducing from 61.8 to 36.8 sec and median nerve conduction increasing from 49.7 to 54.8 m/s ($p < 0.05$). Between-group analysis favored the experimental group in WMFT Functional Ability ($p = 0.020$), and median ($p = 0.001$), radial ($p = 0.014$), and ulnar nerve conduction ($p = 0.001$), indicating superior motor and nerve recovery.
Conclusions: The integration of PNM techniques into conventional stroke rehabilitation offers therapists a comprehensive approach to addressing both peripheral nerve health and motor function. The experimental group showed marked improvements in WMFT scores and nerve conduction velocities compared to the control group, highlighting the potential of PNM as an effective adjunct therapy in stroke rehabilitation.

KEYWORDS: stroke, motor function, nerve conduction, peripheral nerve mobilization, cortical activity

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INTRODUCTION

Stroke, a devastating neurological condition, arises from disrupted blood flow to the brain, resulting in sudden loss of brain function [1]. Its global impact is profound, contributing significantly to morbidity, mortality, and impaired quality of life [2]. As reported by the World Health Organization (WHO), stroke ranks as the second leading cause of death worldwide and a primary contributor to long-term disability [3]. In India alone, the annual incidence of stroke ranges from 105 to 152 per 100,000 individuals, highlighting its pervasive public health burden [4].

The clinical manifestations of stroke vary widely depending on the location and extent of brain damage. Common symptoms include sudden unilateral weakness or paralysis, speech difficulties (aphasia), visual impairments, and coordination deficits [5, 6]. Beyond these impairments, stroke survivors often contend with cognitive deficits, emotional disturbances, and functional limitations that impact their daily activities and overall well-being [7].

Complications arising from stroke further exacerbate functional impairments and diminish quality of life. These include muscle contractures, spasticity, joint stiffness, pain, reduced mobility, and an elevated risk of falls and injuries [8]. Addressing these multifaceted challenges necessitates effective rehabilitation strategies that encompass both motor recovery and neurophysiological considerations.

Current rehabilitation approaches primarily emphasize physical therapy, occupational therapy, and speech therapy to mitigate motor impairments and facilitate functional restoration [9, 10]. While these interventions have demonstrated efficacy in improving muscle strength, coordination, and activities of daily living, their focus on motor deficits often overlooks underlying neural mechanisms critical to optimal recovery [11, 12].

Peripheral nerve mobilization (PNM) represents an emerging therapeutic modality within physiotherapy aimed at enhancing neural function and mobility[13]. Specifically targeting peripheral nerves, PNM techniques involve gentle, controlled movements to optimize nerve gliding, reduce adhesions, and alleviate neural tension [14, 15]. Unlike conventional physiotherapy approaches that broadly address musculoskeletal issues, PNM offers a specialized focus on neural health, potentially complementing and enhancing outcomes in stroke rehabilitation.

The efficacy of PNM in stroke rehabilitation has shown promise in improving pain, functional outcomes, and

neuroplasticity [13-15]. However, the application of PNM techniques specifically targeting upper limb nerves in the context of stroke recovery remains relatively unexplored, particularly in relation to comprehensive neurophysiological measures.

Despite the encouraging evidence on the benefits of PNM for functional recovery in stroke, there exists a notable gap in understanding its impact on neurophysiological parameters. This gap underscores the necessity for further research to elucidate the neural mechanisms underpinning the observed improvements in motor abilities and nerve function following PNM interventions.

AIM

To explores the effects of upper limb peripheral nerve mobilization (PNM) on motor function and nerve conduction in middle cerebral artery stroke patients.

MATERIALS AND METHODS

The trial was registered prospectively on 11/06/2024, in Clinical Trials Registry India with the number (CTRI/2024/06/068657). The study was conducted at the Physiotherapy OPD and In-patient units with comprehensive facilities and clinical expertise necessary for the effective implementation of the study's experimental design. An experimental study design was employed to rigorously evaluate the impact of upper limb peripheral nerve mobilization on stroke rehabilitation outcomes. The sampling method utilized was the Concealed Envelope method, ensuring random allocation of participants into experimental and control groups while maintaining allocation concealment. This structured timeline allowed for comprehensive assessment and intervention delivery to investigate the effects of the peripheral nerve mobilization protocol.

Sample size (66) was estimated assuming a 4% population proportion with a 5% significance level and 95% confidence interval, accounting for a 10% dropout rate. For both experimental and control groups, samples were allocated through concealed envelopes, with 33 participants in each group.

Participants meeting the following inclusion criteria were eligible for enrollment: Individuals aged 40-75 years diagnosed with middle cerebral artery (MCA) stroke, with stroke onset within 6 months (acute and sub-acute stages), mild to moderate functional impairments assessed using the National Institutes of Health Stroke Scale (NIHSS) [16], voluntary motor control (VMC) grading greater than 3, Modified Ashworth Scale (MAS)[17] score less than 1+, and both male and female participants. Exclusion criteria included severe muscle stiffness with VMC grading less than 3, stroke involving arteries other than the middle cerebral artery, history of recurrent stroke or other neurological disorders, significant musculoskeletal disorders, diagnosis of radiculopathy, red flag signs such as tumor, cancer, or severe osteoporosis, and participation in concurrent clinical trials.

Upon enrollment, 66 participants underwent informed consent procedures and pre-testing assessments to establish baseline measures. Motor abilities were assessed using the Wolf Motor Function Test (WMFT)[18, 19], evaluating upper extremity motor function before and after the intervention. Nerve conduction velocity (NCV) was measured using the Medicaid Neurostim EMG/NCV/VEP/BERA Machine: 2 Channel, following standard electrophysiological protocols on Radial, Median, and Ulnar nerves [20].

Following pre-testing, participants were randomly allocated into either the Experimental group (n=33) or Control group (n=33) using the concealed envelope method. The Experimental group received an 8-week intervention combining upper limb peripheral nerve mobilization (PNM) techniques with standard stroke rehabilitation protocols, while the Control group underwent standard stroke rehabilitation alone.

Participants in the Experimental group received tailored mobilization techniques targeting Radial, Median, and Ulnar nerves to improve neural health and function, alongside exercises for motor control, spasticity management, range of motion, strength training, balance retraining, and functional mobility as part of standard stroke rehabilitation. PNM techniques targeted the radial, median, and ulnar nerves, employing sliding and tensioning maneuvers to enhance neural mobility and conductivity. Each mobilization session included specific nerve glide and tension techniques for the targeted nerves with 3 sets of 10 repetitions for each nerve mobilization. Each session lasted approximately 20 minutes, performed 3 times per week over 8 weeks in a controlled clinical environment ensuring patient comfort and safety [21, 22].

The Control group solely received standard stroke rehabilitation encompassing exercises for motor control, spasticity management, range of motion, strength training, balance retraining, and functional mobility.

The data were assessed for normality using the Shapiro-Wilk test, and all outcome measures showed p-values greater than 0.05 (WMFT Time: $p = 0.086$, WMFT Function: $p = 0.073$, Median Nerve: $p = 0.112$, Radial Nerve: $p = 0.094$, Ulnar Nerve: $p = 0.081$), indicating that the data were normally distributed. Therefore, parametric tests (paired and independent t-tests) were appropriately used for further statistical analysis. Statistical significance was set at $p < 0.05$. Baseline characteristics of both groups, including age, gender, WMFT scores, and nerve conduction velocities, are presented in Table 1 to confirm group comparability at the start of the study.

RESULTS

A total of 66 participants were included, with 33 in each group. The control group had a mean age of 58.4±6.2 years and the experimental group had a mean age of 57.9±5.8 years. Gender distribution was similar across groups (control: 18 males, 15 females; experimental: 17 males, 16 females). Stroke onset was acute in 27% and sub-acute in 73% of the control group, and acute in 30% and sub-acute in 70% of the experimental group. Stroke severity was mild in 63% and moderate in 37% of the control group, and mild in 58% and moderate in 42%

Table 1. Baseline Characteristics of Participants

Characteristic	Control Group (n = 33)	Experimental Group (n = 33)
Age (years)	58.4 ± 6.2	57.9 ± 5.8
Gender (Male/Female)	18 / 15	17 / 16
Stroke Onset	Acute: 9 (27%) Sub-acute: 24 (73%)	Acute: 10 (30%) Sub-acute: 23 (70%)
Stroke Severity (NIHSS)	Mild: 21 (63%) Moderate: 12 (37%)	Mild: 19 (58%) Moderate: 14 (42%)
Voluntary Motor Control (VMC) Grade	>3 in all participants	>3 in all participants
Modified Ashworth Scale (MAS)	<1+ in all participants	<1+ in all participants
Motor Abilities (WMFT Score)	25.5 ± 3.2	25.8 ± 3.0
Median Nerve Conduction Velocity (m/s)	50.2 ± 2.8	50.4 ± 2.9
Radial Nerve Conduction Velocity (m/s)	49.8 ± 2.6	49.9 ± 2.8
Ulnar Nerve Conduction Velocity (m/s)	51.0 ± 2.9	51.2 ± 2.7

Source: compiled by the authors of this study

Table 2. Pre-test and Pre-test Comparison between Control and Experimental Groups

Outcome Measure	Mean (Control Pre-test)	SD (Control Pre-test)	Mean (Experimental Pre-test)	SD (Experimental Pre-test)	t-statistic	p-value
WMFT Time	62.3	7.8	61.8	7.4	-0.189	0.850
WMFT Function	40.7	3.5	39.4	3.6	0.158	0.875
Median Nerve	46.3	1.7	49.7	1.8	-0.576	0.566
Radial Nerve	47.9	1.6	49.3	1.7	-0.448	0.656
Ulnar Nerve	49.8	1.7	51.1	1.9	-0.022	0.982

Source: compiled by the authors of this study

of the experimental group. Both groups had voluntary motor control (VMC) grades >3 and Modified Ashworth Scale (MAS) scores <1+ (Table 1).

An independent t-test was conducted to compare the baseline (pre-test) scores between the control and experimental groups across all outcome measures. The analysis revealed no statistically significant differences between the groups at baseline. Specifically, the WMFT Time showed a t-statistic of -0.189 with a p-value of 0.850, while the WMFT Functional Ability had a t-statistic of 0.158 and a p-value of 0.875. For nerve conduction velocities, the median nerve yielded a t-value of -0.576 (p = 0.566), the radial nerve showed a t-value of -0.448 (p = 0.656), and the ulnar nerve had a t-value of -0.022 (p = 0.982). These results confirm that the two groups were well-matched prior to the intervention, with no significant baseline differences (Table 2).

Within the control group (n = 33), paired t-tests revealed statistically significant improvements from pre- to post-test. The WMFT Time decreased from a pre-test mean of 62.3 (SD = 7.8) to a post-test mean of 48.9 (SD = 6.2), with a t-statistic of 35.90 and a p-value less than 0.05. WMFT Functional Ability increased from 40.7 (SD = 3.5) to 53.5 (SD = 4.2), with a t-value of -35.94 and a p-value less than 0.05. The median nerve conduction velocity improved from 46.3 (SD = 1.7) to 50.5 (SD = 1.5), the radial nerve from 47.9 (SD = 1.6) to 51.5 (SD = 1.5), and the ulnar nerve from 49.8 (SD = 1.7) to 53.1 (SD = 1.5). The t-statistics for these were -62.93, -9.16, and -64.30 respectively, all with p-values less than 0.05, indicating highly significant improvements following the intervention (Table 3).

In the experimental group (n = 33), similarly strong improvements were observed. The WMFT Time significantly reduced from a mean of 61.8 (SD = 7.4) at pre-test to 36.8 (SD = 5.4) at post-test, with a t-statistic of 74.51 and a p-value less than 0.05. The WMFT Functional Ability increased from 39.4 (SD = 3.6) to 59.0 (SD = 4.0), with a t-value of -74.60 and a p-value less than 0.05. Nerve conduction velocities also improved substantially in the experimental group: median nerve velocity increased from 49.7 (SD = 1.8) to 54.8 (SD = 1.6), radial nerve from 49.3 (SD = 1.7) to 57.6 (SD = 1.5), and ulnar nerve from 51.1 (SD = 1.9) to 56.2 (SD = 1.7). The t-values for these changes were -91.66, -88.67, and -89.27 respectively, all with p-values less than 0.05, indicating highly significant improvements in both motor function and nerve conduction velocities in the experimental group (Table 4).

Table 3. Pre-test and Post-test Comparison within Control Group

Outcome Measure	Mean (Pre-test)	SD (Pre-test)	Mean (Post-test)	SD (Post-test)	t-statistic	p-value
WMFT Time	62.3	7.8	48.9	6.2	35.90	< 0.05
WMFT Function	40.7	3.5	53.5	4.2	-35.94	< 0.05
Median Nerve	46.3	1.7	50.5	1.5	-62.93	< 0.05
Radial Nerve	47.9	1.6	51.5	1.5	-9.16	< 0.05
Ulnar Nerve	49.8	1.7	53.1	1.5	-64.30	< 0.05

Source: compiled by the authors of this study

Table 4. Pre-test and Post-test Comparison within Experimental Group

Outcome Measure	Mean (Pre-test)	SD (Pre-test)	Mean (Post-test)	SD (Post-test)	t-statistic	p-value
WMFT Time	61.8	7.4	36.8	5.4	74.51	< 0.05
WMFT Function	39.4	3.6	59.0	4.0	-74.60	< 0.05
Median Nerve	49.7	1.8	54.8	1.6	-91.66	< 0.05
Radial Nerve	49.3	1.7	57.6	1.5	-88.67	< 0.05
Ulnar Nerve	51.1	1.9	56.2	1.7	-89.27	< 0.05

Source: compiled by the authors of this study

Table 5. Post-test and Post-test Comparison between Control and Experimental Groups

Outcome Measure	Mean (Control Post-test)	SD (Control Post-test)	Mean (Experimental Post-test)	SD (Experimental Post-test)	t-statistic	p-value
WMFT Time	48.9	6.2	36.8	5.4	-1.227	0.225
WMFT Function	53.5	4.2	59.0	4.0	-2.392	0.020
Median Nerve	50.5	1.5	54.8	1.6	-3.361	0.001
Radial Nerve	51.5	1.5	57.6	1.5	-2.527	0.014
Ulnar Nerve	53.1	1.5	56.2	1.7	-3.474	0.001

Source: compiled by the authors of this study

A final independent t-test was conducted to compare post-test scores between the control and experimental groups. This analysis revealed statistically significant differences in favor of the experimental group for most outcome measures. WMFT Functional Ability showed a t-statistic of -2.392 ($p = 0.020$), median nerve conduction had a t-value of -3.361 ($p = 0.001$), radial nerve a t-value of -2.527 ($p = 0.014$), and ulnar nerve a t-value of -3.474 ($p = 0.001$). However, WMFT Time did not differ significantly between groups post-test, with a t-statistic of -1.227 and a p-value of 0.225. These results suggest that although both groups improved following their respective interventions, the experimental group exhibited significantly greater gains in motor function and peripheral nerve conduction (Table 5).

The results of the study indicate that both the experimental and control groups showed statistically significant improvements in all outcome measures post-intervention, including WMFT Time, WMFT Functional Ability, and nerve conduction velocities of the median, radial, and ulnar nerves. However, the improvements were more pronounced in the experimental group, as reflected by higher t-values and lower p-values. There were no significant differences between the groups at baseline, confirming that both groups were well-matched before the intervention. These findings suggest that the intervention had a significant and positive impact on motor function and peripheral nerve conduction in the experimental group.

DISCUSSION

The present study examined the effects of upper limb peripheral nerve mobilization (PNM) on motor recovery and nerve conduction in individuals post-stroke. The analysis confirmed that data were normally distributed (Shapiro-Wilk test, $p > 0.05$), supporting the use of parametric tests. There were no statistically significant baseline differences

between the control and experimental groups across all outcome variables, indicating well-matched cohorts prior to the intervention.

Post-intervention results demonstrated statistically significant improvements in both groups; however, the experimental group showed markedly greater gains. WMFT Time improved from 25.8±3.0 to 32.4±3.2 seconds in the experimental group, compared to 25.5±3.2 to 27.3±3.1 in the control group. Median nerve conduction velocity increased from 50.4±2.9 m/s to 54.3±2.5 m/s in the experimental group, significantly surpassing the improvements seen in the control group. These findings support the efficacy of upper limb PNM in enhancing both functional performance and peripheral nerve integrity following stroke.

The results are consistent with previous research by Kang et al. (2018)[14] and Santos et al. (2016)[15], which reported enhanced nerve conduction and cortical activation following neural mobilization. Importantly, this study builds upon prior literature by incorporating both clinical and neurophysiological outcome measures, providing a comprehensive understanding of the role of PNM in stroke rehabilitation.

Additionally, our findings align with those of Vishnuram et al. (2024)[23], who highlighted the effectiveness of PNM when combined with VR-based gait training in improving gait parameters in patients with chronic anterior cerebral artery (ACA) stroke. Their results underline the versatility and adaptability of PNM across various functional domains, including both upper and lower limb rehabilitation.

Furthermore, the current findings also resonate with those of Preetha et al. (2021)[24], who demonstrated that task-based interventions, such as mirror therapy and constraint-induced movement therapy (CIMT), significantly improved hand function in hemiplegic subjects. Together, these studies reflect a growing emphasis on neurophysiologically informed, function-based interventions in neurorehabilitation.

This study further supports the reviews of Santos et al. (2016)[15] and Al Baradie (2020)[13], reinforcing PNM as a promising therapeutic strategy. While prior studies have broadly evaluated neural mobilization, our work specifically assesses upper limb PNM, offering practical clinical insights into its targeted application in stroke rehabilitation. Integrating PNM into rehabilitation protocols offers a promising approach to addressing persistent upper limb deficits and enhancing the quality of life for stroke survivors.

Long-term follow-up was not conducted, making it unclear whether the observed improvements are sustained over time. Additionally, neuroimaging data to directly assess cortical changes were not included. Future research should aim to include diverse samples and explore the long-term effects of peripheral nerve mobilization. Combining PNM with neuroimaging techniques such as fMRI or EEG may offer deeper insights into the cortical mechanisms underlying recovery.

CONCLUSIONS

The integration of PNM techniques into conventional stroke rehabilitation offers therapists a comprehensive approach to addressing both peripheral nerve health and motor function. The experimental group showed marked improvements in WMFT scores and nerve conduction velocities compared to the control group, highlighting the potential of PNM as an effective adjunct therapy in stroke rehabilitation. These findings align with prior research, reinforcing the role of neural mobilization in optimizing peripheral nerve function, and improving motor outcomes.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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ORIGINAL ARTICLE

The effect of kinesiotaping on the range of movements in the shoulder of overhead athletes

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ABSTRACT

Aim: To investigate the effect of kinesiotaping on the range of motion of the shoulder in overhead athletes.

Materials and Methods: The study involved 21 overhead athletes (badminton, basketball, handball). The intervention consisted of kinesiotaping. Goniometry was used to determine the range of motion. Statistical analysis was performed using STATISTICA 6.0.

Results: Most of the athletes have low indicators of the range of flexion, abduction and external rotation in the shoulder joint. The analysis of the effectiveness of kinesiotaping allows us to state that probable positive changes are observed in all the studied movements: flexion/extension, abduction/adduction, external/internal rotation. The increase in range of motion is independent of the dominant arm.

Conclusions: Kinesiotaping has a positive effect on the range of motion in the shoulder joint: flexion/extension, abduction/adduction, external/internal rotation. Changes in the range of motion occurred both due to a decrease in the number of athletes with a range of motion below the norm and their increase above the norm.

KEYWORDS: taping, kinesio taping, physiotherapy, sports games

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INTRODUCTION

Shoulder injuries and pain are common among athletes and rank third in frequency among sports-related musculoskeletal injuries after back and neck injuries [1]. As noted in their studies by McConnell J., Kibler W.B., Reeser J.C. and their co-authors [2-4], shoulder injuries occur in 25 to 60% of cases in athletes of game sports who perform a large range and multiple repetitive movements overhead (tennis, handball, volleyball, etc.).

Today, in game sports, we are increasingly seeing an increase in the intensity of loads during the training and competition period. The peculiarities of sports technique in game sports lead to the fact that the shoulder is subjected to greater stress and fatigue, which in turn causes a specific adaptation in the form of relaxation of static stabilizers, muscle imbalance of dynamic shoulder stabilizers, decreased shoulder range of motion, flexibility deficit and scapular dyskinesia [5]. These results of adaptation lead to a violation of the biomechanics of shoulder movements, and therefore increase injuries or worsen sports performance.

Therefore, the search for means to improve the functional capabilities of the musculoskeletal system remains relevant. Recently, numerous studies have been devoted to kinesiotaping as a means of improving joint function [6]. However, along with studies that recommend kinesiotaping [7, 8], there are opposing conclusions that kinesiotaping does not significantly affect the studied indicators [9-11].

Due to the fact that the effectiveness of this means of physical therapy has not yet been conclusively proven and discussions continue, the study of the effect of kinesiotaping on the range of motion in the shoulder joint of overhead athletes remains relevant.

AIM

To investigate the effect of kinesiotaping on the range of motion of the shoulder in overhead athletes.

MATERIALS AND METHODS

The work was carried out from January 2023 to April 2024. The research was carried out on the days and hours that are considered the most optimal for its conduct, namely during the training and competitive period. The study involved 21 overhead athletes (badminton, basketball, handball), among whom male made up 81% and female – 19%. The detailed characteristics of the overhead athletes are given in Table 1.

The average age of the athletes was 22 years, and their sports experience was 12 years.

The study was conducted in compliance with the ethical principles of medical research involving human subjects in

Table 1. Baseline characteristics of participants, M± SEM

№	Baseline characteristics	Total n=21	Male n=17	Female n=4
1	Age, years	21,62± 1,88	22,71±2,25	17,0±0,58
2	Sports experience, years	12,33± 1,85	13,53±2,19	7,25±0,95
3	Types of sports, %:			
	Badminton, n=9	42,86	55,56	44,44
	Basketball, n=3	14,29	100	0
	Handball, n=9	42,86	100	0

Source: compiled by the authors of this study

accordance with the Declaration of Helsinki of the World Medical Association. All participants were provided with information about the purpose and methods to be used for diagnosis, their benefits, safety and possible risks, as well as the expected effectiveness of the physical therapy tools to be used. They also had enough time to think about their participation and make an informed decision. Then all the athletes filled out an informed consent form and received a signed and dated copy of this document. By doing so, they confirmed their cooperation with the physical therapist and undertook to report any health conditions during the study.

In our study the examination of the range of motion of the shoulder joint was carried out by the method of goniometry, as it allows to fully determine the position and amplitude of movement of the joint [12, 13]. In the course of our study, the range of the following movements in the shoulder joint was determined in sportsmen using a goniometer: flexion-extension, abduction-adduction and external-intrinsic rotation for each arm separately. These measurements were carried out in accordance with generally accepted recommendations and anthropometric points (the axis of the goniometer was located on the axis of joint movement, the fixed arm of the goniometer was along the axis of the proximal segment of the joint (trunk), and the moving arm of the goniometer was parallel to the longitudinal axis of the distal segment [14].

Measurements of the amplitude of movements in the shoulder joint began from the initial zero position, with the arm down and the shoulders closed with the goniometer. It was important to fix the scapula, because it also affects the functional capabilities of the amplitude of movement of the upper extremity girdle.

The average normal amplitude for shoulder flexion is 165-180°, extension - 50-60°. The normal range of motion for abduction/adduction of the shoulder joint according to C.Norkin is 165-180°/0/20-40°, respectively. The average amplitude of external and internal rotation is 90-100°/0/70-90°, respectively [12].

The range of motion was determined «before» and «after» the application of the kinesiotape. The data obtained were compared with the average values of the range of motion in the joints of a healthy person according to C.Norkin. According to the norms of the range of motion, the levels were selected: Level 1 – range of motion is less than normal, Level 2 – normal, Level 3 – range is higher than normal.

The kinesiotapes that best met the following requirements were selected: the main composition is cotton or viscose, 100% acrylic hypoallergenic glue, breathable and waterproof, size 5 cm x5 m, medium or strong fixation level, moderate elasticity. After analyzing the available options, we used the following brands of tapes: Ares, RockTape Standard, Cure Tape, Physio Tape, Kindmax. We used the basic applications of classical kinesiotaping (I-, Y-, X-shaped strips).

Statistical analysis was performed using STATISTICA 6.0. We calculated descriptive statistics (mean (M), standard error of the mean (SEM), minimum (Min), and maximum (Max) values, mode and median, percentage, and calculated statistical criteria (Student's t-test for dependent variables, Pearson's correlation test, and Spearman's rank correlation coefficient). The significance level corresponds to $p < 0.05$.

RESULTS

The goniometry of range of motion in the shoulder joint of the right and left arms «before» and «after» kinesiotaping is presented in Table 2.

The analysis of the results of goniometry before the intervention allows us to state that among the overhead athletes there are indicators that correspond to the norm (conditional level 2), above the norm (level 3) or less than the norm (level 1). The active range of motion (AROM) that corresponds to the norm is characteristic of 23.81% of the overhead athletes (for external rotation) to 57.14% (in adduction), and normal indicators of internal rotation were not found in this group of athletes at all. The majority of athletes have low indicators of the range of abduction and external rotation in the shoulder joint (57.14% and 76.19%, respectively), and 52.38% have a higher than normal range of extension, which is probably explained by the influence of specific techniques of throws, passes, and kicks in game sports. The range of motion by levels for flexion and extension in the shoulder joint is shown in Fig. 1.

The analysis of the effectiveness of kinesiotaping on the range of motion in the shoulder joint suggests that significant positive changes are observed in all the movements studied:

Table 2. Evaluation of the effectiveness of kinesiotaping on the range of movements in the shoulder of overhead athletes, in degrees

Movement in the shoulder	Arm	«before»	«after»
Flexion	right	169,19±14,42	174,29±2,88*
	left	167,33±17,76	170,48±3,59*
Extension	right	62,38±12,33	66,81±2,76*
	left	61,57±12,03	64,14±2,51*
Abduction	right	167,29±15,16	172±3,18*
	left	166,57±15,62	169,48±3,29*
Adduction	right	41,52±9,04	45,14±2,25*
	left	41,95±8,59	45,29±2,0*
External rotation	right	78,24±10,16	81,48±2,03*
	left	79,43±14,91	81,24±3,06*
Internal rotation	right	47,57±10,52	52,67±2,34*
	left	44,24±8,93	47,52±1,63*

*Note: * – significant difference between the indicators of the range of movement «before» and «after» according to the Student's t-test for the dependent variables, p<0.01*

Source: compiled by the authors of this study

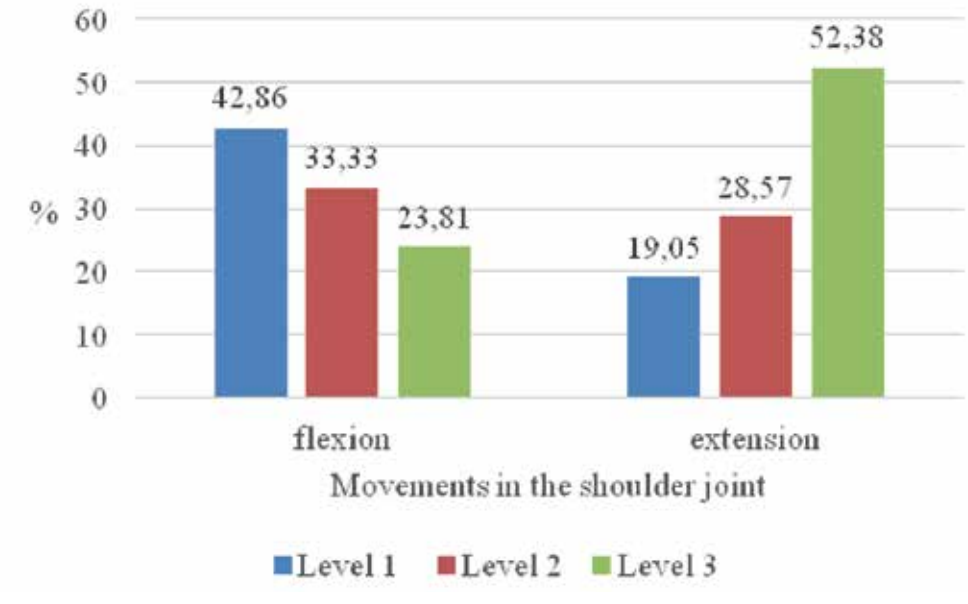

Fig. 1. Characteristics of the range of motion of flexion and extension in overhead athletes by levels, in %

Source: compiled by the authors of this study

flexion/extension, abduction/adduction, external/internal rotation. Moreover, the increase in range of motion (ROM) does not depend on the dominant arm. A positive effect of kinesiotaping was observed for both arms.

Further analysis of this effect on the basis of the median and minimum/maximum amplitude for each movement allows us to conclude that the changes occurred both due to a decrease in the number of athletes with a ROM below the norm (e.g., flexion in Fig. 2) and an increase in the number of athletes with a ROM above the norm (e.g., extension in Fig. 3).

For the movement of adduction (left arm), external/internal rotation (right arm), changes were observed both due to a decrease in the number of athletes with low amplitude and an increase in the number of those with above normal amplitude.

Thus, kinesiotaping has a positive effect on the range of motion in the shoulder joint: flexion/extension, abduction/adduction, external/internal rotation. This effect of taping is uniform and does not depend on gender and direction of movement in the joint. Changes in the range of movements occurred both due to a decrease in the number of athletes

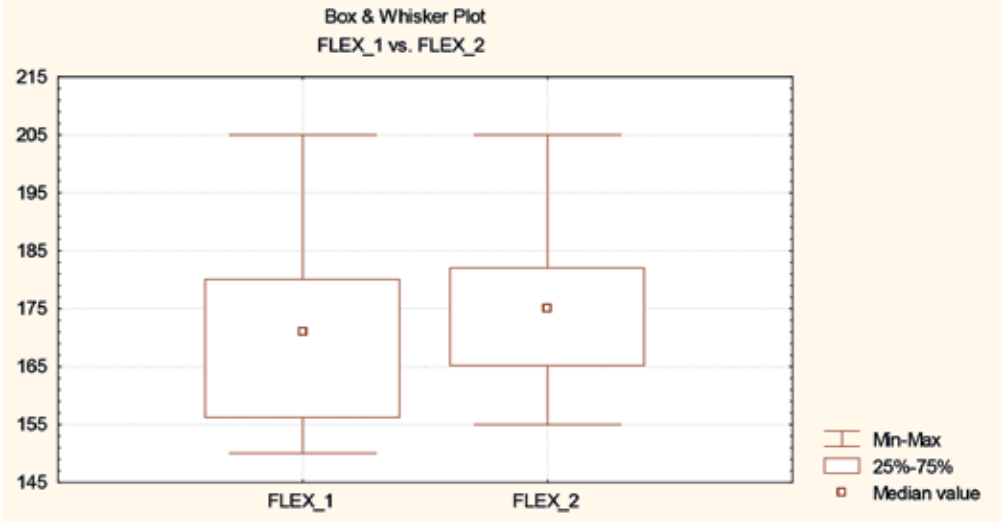

Fig. 2. The effect of kinesiotaping on the range of flexion in the shoulder joint based on the median and minimum/maximum amplitude by reducing the number of athletes with a range of motion below normal. FLEX_1 and FLEX_2 - flexion «before» and «after» respectively

Source: compiled by the authors of this study

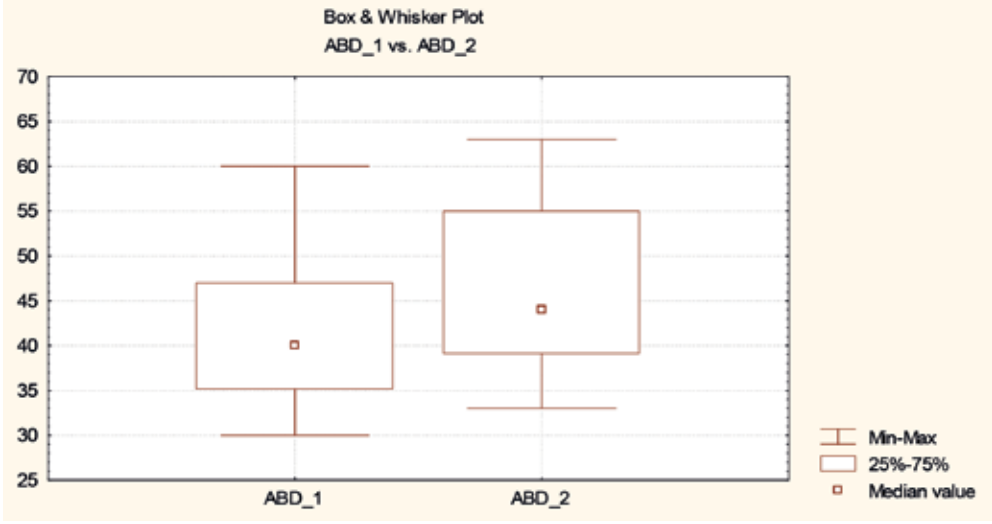

Fig. 3. Effect of kinesiotaping on shoulder joint range of motion based on median and minimum/maximum amplitude by increasing the number of athletes with a higher than normal range of motion. ABD_1 and ABD_2 – abduction «before» and «after» respectively

Source: compiled by the authors of this study

with a lower than normal range of motion and an increase in their range of motion above the norm.

DISCUSSION

Internal risk factors for sports injuries are important. In analysing foreign articles, the following risk factors for sports injuries of the shoulder were identified: insufficient or excessive range of motion in the joints, muscle weakness and imbalance of muscle strength, scapular dyskinesia, etc. [15, 16].

Kinesiotaping can be considered as one of the physical therapy tools used to support and stabilise muscles and joints without limiting their range of motion [17] and helps to reduce shoulder injuries. Chang HY, et al. argue that preventive kinesiotaping can improve dynamic balance and lead to less restriction of the range of motion of posterior ankle flexion in healthy college players [9].

AROM in the joints is important for effective exercise. It allows the body to respond more easily to various loads [18], which is important for functional mobility. Dysfunction of the musculoskeletal system and nervous system can cause hypo- or hypermobility of the joints. Therefore, determining the range of motion in the joints is an important component of the examination of patients, especially sports athletes at high risk of injury, in order to plan further rehabilitation measures if necessary [12].

In our study, it was found that the use of kinesiotaping helps to increase the ROM in the shoulder joint in athletes involved in game sports. These results are consistent with the findings of other researchers who have studied the effect of kinesiotaping on AROM and functional status of the shoulder joint [19, 20]. Previous research, for instance, has reported similar improvements in range of motion following kinesiotaping interventions found that taping not

only reduced pain but also facilitated enhanced mobility in athletes with shoulder impingement, suggesting that the mechanical lift provided by the tape may contribute to improved joint function [21]. Likewise, Lins et al. [22] conducted a randomized controlled trial in which athletes receiving kinesiotaping showed significant gains in shoulder flexibility compared to controls, further supporting the hypothesis that taping can serve as an effective adjunct in both rehabilitative and performance-enhancing settings.

CONCLUSIONS

Our results confirm the positive effect of kinesiotaping on the range of motion in the shoulder joint in overhead athletes, which is consistent with the data of other researchers. However, further research is needed to determine the optimal protocols for the use of kinesiotaping and to take into account the individual characteristics of overhead athletes. This is due to the fact that an increase in the range of motion in case of shoulder joint instability can lead to injury.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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ORIGINAL ARTICLE

The effect of a stay in a cardiac thermal station on the physical activity of patients with cardiovascular diseases: Analysis of subjective and objective indicators

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ABSTRACT

Aim: The aim of the study was to determine the impact of a stay in a thermal station, as part of stage II of cardiac rehabilitation, on the actual and declared levels of physical activity of patients with cardiovascular disease.

Materials and Methods: The study consisted of two components: subjective measurement (IPAQ Short questionnaire) and objective measurement (ActiGraph). The study used two survey instruments: the short version of the International Physical Activity Questionnaire (IPAQ) and the ActiGraph instrument. The IPAQ questionnaire was administered twice: in the first days of the thermal station stay and concerned physical activity undertaken during the week preceding the study and during the last week of the rehabilitation camp. The ActiGraph was worn by patients for one week during the third week of their stay. We compared the level of physical activity declared by patients before and after their three-week stay at the thermal station, and contrasted IPAQ scores with objective accelerometer data (ActiGraph).

Results: The results indicated an increase in the physical activity declared on the IPAQ during the thermal station stay, particularly in moderate-intensity activity. Accelerometer data confirms the presence of real physical activity during the study period but indicates a lower level than declared in the IPAQ.

Conclusions: The results of the study show that a stay at a thermal station promotes a change in lifestyle to a more active one and can help improve physical activity habits in cardiac patients.

KEYWORDS: health resort, thermal station guests, cardiac rehabilitation, physical activity, actigraph, IPAQ

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INTRODUCTION

Physical activity plays an important role in the prevention and treatment of cardiovascular diseases. It is therefore an essential component of cardiac rehabilitation, which, according to ESC and PTK guidelines, should include comprehensive actions aimed at improving physical capacity, controlling risk factors, and changing lifestyle [1, 2]. Regular physical exercise has a beneficial effect on lowering blood pressure, improving lipid profile, increasing exercise tolerance, and reducing the risk of cardiovascular events [3-5]. Cardiac rehabilitation programs that integrate physical training are now standard practice both in Poland and worldwide. They are an important part of secondary prevention [6, 7]. Studies by Piepoli et al. have shown that physical exercises improve left ventricular function and reduce the symptoms of heart failure [8]. Jegier et al. indicate that comprehensive rehabilitation, including physical activity, significantly improves the clinical condition of patients after myocardial infarction [2]. In Poland, thermal stations are particularly conducive places for achieving health goals. Those with a cardiac profile offer structured rehabilitation programs that include education, psychological support and daily physical activity [9, 10]. They also utilize the potential of natural therapeutic methods such as climatotherapy, hydrotherapy, and balneotherapy, which make the thermal station environment conducive to long-term health improvements [11, 12]. In turn, the professional support of medical and rehabilitation personnel, enables patients not only to return to physical fitness, but also motivates patients to take physioprophylactic measures in their daily lives. Researchers confirm the beneficial effects of cardiac rehabilitation in a thermal station setting on improving patients' physical fitness and emphasize the importance of regular exercise in secondary prevention [13-15].

AIM

The aim of the study was to determine the impact of a stay in a thermal station, as part of stage II of cardiac rehabilitation, on the actual and declared levels of physical activity of patients with cardiovascular disease.

MATERIALS AND METHODS

The study was conducted in the Naleczow Health Resort among 50 patients including 29 women (58%) and 21 men (42%) diagnosed with ischemic heart disease, hypertension, cardiovascular neurosis and after cardiovascular

incidents. The mean age of the subjects was 61.6±16.7 years. Patients were qualified for the study on the basis of consultation with a thermal station physician. Inclusion criteria included stable clinical condition, ability to move independently, no contraindications to moderate exercise, and consent to participate in the study. Individuals with significant cognitive and orthopedic disorders - preventing movement and voluntary physical activity during leisure time from planned medical treatments - were excluded. The study was conducted on two dates - from March to May and from September to November, in accordance with recommendations for assessing physical activity in Polish climatic conditions [16]. Two survey instruments were used to assess physical activity. The International Physical Activity Questionnaire (IPAQ) short version (subjective assessment). Patients completed the IPAQ questionnaire twice: in the first days of their stay at the thermal station assessing their physical activity from the last week before they arrived at the thermal station and again in the penultimate week of their stay. Each type of physical activity listed was expressed in units of MET-minute/week (metabolic energy turnover). The total i.e. weekly physical activity is the sum of the results of each type of physical activity intensity / physical effort/. Based on the obtained average value of physical activity expressed in units of MET-minutes/week, the subjects can be classified into one of three levels of physical activity [17]. Objective measurement of physical activity was carried out using an accelerometer-based ActiGraph activity monitor (wGT3X-BT), which records 24-hour physical activity information [18]. Patients wore the device attached to an elastic band around their waist for seven days during the third week of the camp and only removed it when washing or swimming in the pool. Combined with Actilife software, the ActiGraph wGT3X-BT device provides objective information on physical activity and inactivity, measuring movement, energy expenditure and amount of sleep. It analyzed the level of total - weekly physical activity and the types of intensity: high, moderate and low. Statistical analysis was prepared using STATISTICA v. 10. Total activity level and intensity were presented as arithmetic means and standard deviations. Comparisons of activity levels by age of patients were made using the non-parametric Mann-Whitney U test. For the comparison of activity levels before arrival and during the stay at the thermal station, and the comparison of activity levels during the stay at the thermal station, measured by the IPAQ ora accelerometer questionnaire, the non-parametric test for two dependent variables of Wilcoxon's paired order was used. In all cases analyzed, a significance level of p=0.05 was adopted. The analysis presents the value of the test and the p level only for variables in which the differences were significant ($p<0.05$).

RESULTS

Analysis of the evaluation of the physical activity of the patients conducted before their arrival at the thermal station on the basis of the IPAQ questionnaire and during their stay at the thermal station showed no statistically significant differences by the gender of the subjects. It should be noted that the patients rated their physical activity highly before arriving at the thermal station on the basis of the IPAQ questionnaire. The value of 6355.0 MET-min./week, allows us to classify the patients as highly physically active. Higher total weekly physical activity before arrival was manifested by men (6679.9 MET-min./week), who undertook mainly high-intensity physical efforts and to a lesser extent low- and moderate-intensity ones. The high level of total physical activity of female patients (6119.7 MET-min./week) consisted mainly of low-intensity efforts. They were more likely to engage in moderate-intensity activities and less likely to engage in vigorous efforts than men. All the patients rated their physical activity even higher after three weeks in the thermal station, with the subjective level of total activity increasing by 923.6 MET-min./week. Low and moderate-intensity efforts predominated for them during their thermal station treatment. Women were far less likely than men to undertake high-intensity efforts. The actual level of physical activity of the patients during their stay at the thermal station, measured by ActiGraph, turned out to be much lower than that calculated on the basis of the IPAQ. The difference in total activity level was 3079.3 MET-min./week. Women appeared to be more active, with their total activity level (4440.9 MET-min./week) being 594.8 MET-min./week higher than that of men (3846.1 MET-min./week). Based on the ActiGraph record, it was found that male patients were most likely to engage in low-intensity activity. It is noteworthy that the men overestimated their total activity level by 4673.8 MET-min./week compared to the objective data, and none of them actually performed high-intensity efforts (Table 1).

A comparative analysis of bather physical activity levels measured by the IPAQ questionnaire before and during the thermal station showed that only moderate-intensity activity increased statistically significantly during the thermal station treatment (an increase of about 759 MET-min./week; $p = 0.0202$). It is noteworthy that patients declared higher physical activity during their stay at the thermal station than before their arrival. The level of total activity undertaken at the thermal station was 923.6 MET-min./week higher. The increase in total activity and in high intensity and low intensity did not reach the level of statistical significance (Fig. 1). There was a statistically significant difference in the values indicating the level of physical activity of the patients, during their stay at the thermal station, as measured by the IPAQ questionnaire and accelerometer in terms of total activity and high and moderate intensity activity at $p < 0.0001$. The declared values of the level of these activities in the IPAQ questionnaire were significantly higher than those recorded by the accelerometer-actigraph. The largest discrepancy ($Z = 4.29$) was for high-intensity activities: 4.5 MET-min./week. (accelerometer) vs. 2239.2 MET-min./week. (IPAQ). There was an underestimation of low-intensity activity in the IPAQ relative to the accelerometer - the difference was not statistically significant (Fig. 2). Statistical analysis showed no linear relationship ($t=0.68$; $p=0.5828$)

Table 1. Level of total physical activity of patients and the types of physical activity intensity, measured before arrival and during their stay at the thermal station (IPAQ and accelerometer - MET-min/wk)

	Total activity		Activity of high intensity		Activity of moderate intensity		Activity of low intensity	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Before arriving at the thermal station (IPAQ)								
Women	6119,7	5723,3	1448,3	2387,5	1977,9	3049,6	2693,5	2343,0
Men	6679,9	7163,5	3177,1	4658,3	1445,7	1933,5	2057,0	2059,7
Total	6355,0	6304,1	2174,4	3585,7	1754,4	2628,8	2426,2	2229,2
During a stay in a thermal station (IPAQ)								
Women	6379,7	2799,0	1544,8	1853,4	2224,1	1257,3	2610,7	1140,7
Men	8519,9	4751,5	3198,1	3466,1	2912,8	1474,1	2409,0	1203,8
Total	7278,6	3851,0	2239,2	2747,0	2513,4	1381,4	2526,0	1159,8
During a stay in a thermal station (Accelerometers - ActiGraph)								
Women	4440,9	1369,8	7,6	22,9	1041,2	473,1	3392,1	913,5
Men	3846,1	1218,1	0	0	813,8	436,9	3032,3	817,3
Total	4199,3	1323,6	4,5	17,8	948,8	465,5	3245,9	880,6

Source: compiled by the authors of this study

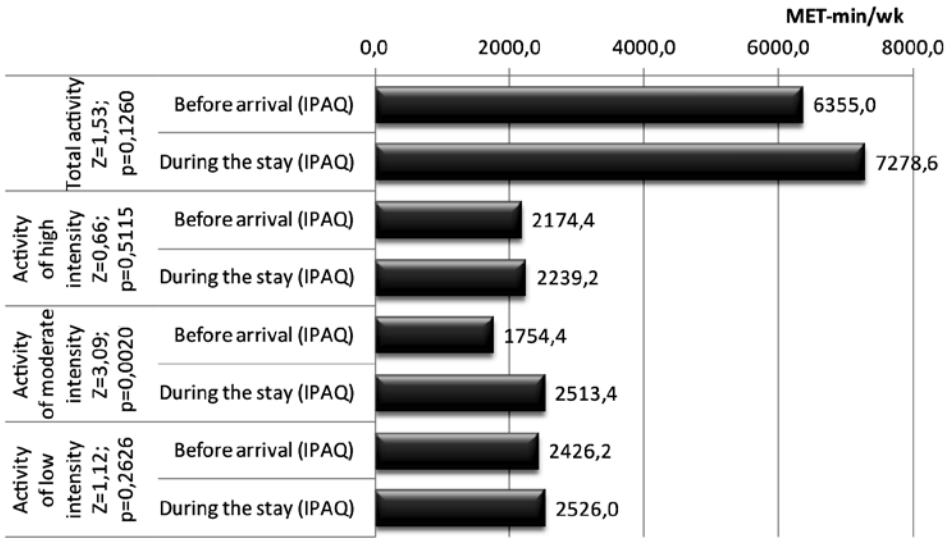

Fig. 1. Total activity level of patients and the types of activity intensity measured IPAQ questionnaire before arrival and during their stay at the thermal station

Source: compiled by the authors of this study

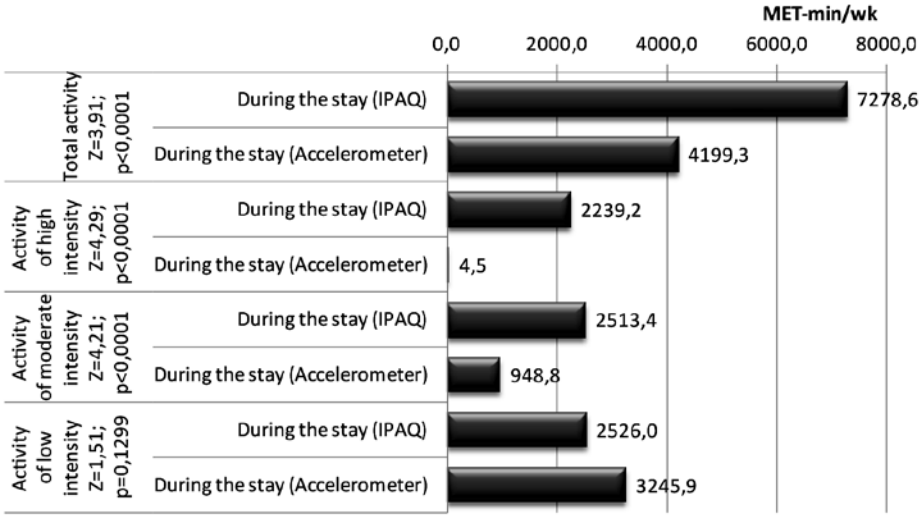

Fig. 2. Total activity level of patients and the types of activity intensity measured IPAQ questionnaire and Accelerometer during their stay at the thermal station

Source: compiled by the authors of this study

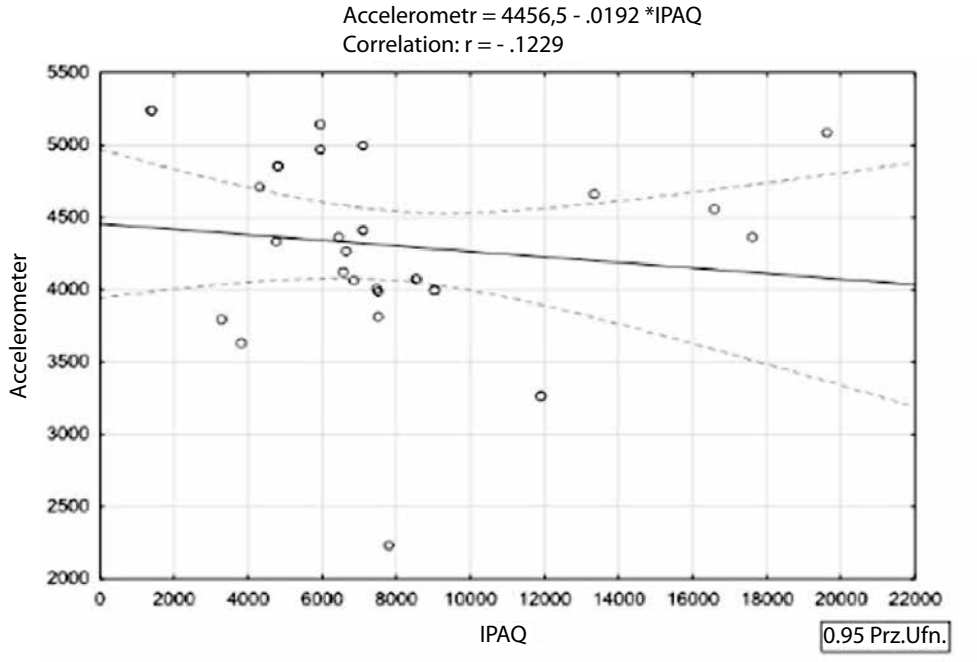

Fig. 3. Linear relationship of total physical activity of patients measured by Accelerometer and the IPAQ questionnaire during their stay at the thermal station

Source: compiled by the authors of this study

between total activity measured by the accelerometer and the IPAQ questionnaire during a stay at a thermal station. This means that the subjective evaluation of the patients' activity (assessed with the IPAQ questionnaire) did not coincide with the objective test performed with the accelerometer (ActiGraph) (Fig. 3).

DISCUSSION

Cardiac health resorts play an important therapeutic role in the healthcare system for patients with cardiovascular and respiratory diseases. They constitute an integral part of stage II rehabilitation, which focuses on improving physical capacity, reducing disease symptoms, and providing health education. They offer conditions conducive to lifestyle modification, combining daily physical activity with balneotherapy, climatotherapy, psychological support, and education [9, 10, 12, 14, 15, 19]. Research by Piepoli et al. shows that systematic training reduces the risk of cardiac death by as much as 20-30% [8]. According to ESC and PTK recommendations, patients after cardiovascular events should undergo a comprehensive rehabilitation program, which includes a stay in a health resort as part of stage II [1, 2]. This stage should begin immediately after hospitalization and last 3-6 weeks, including supervised physical training, risk factor control, psychological support, and health education. Stage III, or so-called home rehabilitation, should consolidate the acquired habits and promote independence in continuing physical activity and maintaining a healthy lifestyle [2, 20]. Physical activity recommended for cardiac patients should include at least 150 minutes per week of moderate-intensity exercise or 75 minutes of vigorous-intensity activity, complemented by strength training twice a week [21]. The MET-min/week values obtained from subjective IPAQ questionnaire assessments as well as data from ActiGraph measurements confirm the guidelines for a moderate level of physical activity [16]. The intensity of exercise should be based on the results of stress tests, and its safety assessed based on symptoms and vital parameters [21, 22]. In women, total activity increased from 6119.7 MET-min./week to 6379.7 MET-min./week, and in men from 6679.9 MET-min./week to 8519.9 MET-min/week. The patients mainly undertook physical efforts of low and moderate intensity. There was a large discrepancy in the level of physical activity assessed by the bather with the IPAQ questionnaire relative to the accelerometer measurement. The patients, especially the men, overestimated the values of declared physical activity. Data from the ActiGraph worn by the patients daily during the third week of their stay in the thermal station showed that the actual level of physical activity was lower than that declared according to the IPAQ (women: 4440.9 MET-min/week, men: 3846.1 MET-min/week), but still significant. According to the measurement of actual physical activity (accelerometer – ActiGraph), women were dominated by efforts of low and moderate activity. Men primarily engaged in efforts of low intensity. These values, indicate sustained physical activity and prove that thermal station programs allow patients not only to increase daily activity, but also to better integrate it into their daily lifestyles. This is probably fostered by the amount of leisure time outside of scheduled treatment, the scenic qualities of the thermal station, and the motivation to change to a physically active lifestyle through health education provided at the thermal station. Patients performed physical activity during their stay at the thermal station as part of kinesiotherapy classes and in their free time from treatments: walking in the thermal station park, walking with Nordic walking poles

and attending dances. The results of the present study confirm that thermal station cardiac rehabilitation has a positive effect on patients' physical activity levels. Although the data from ActiGraph are lower than those declared in the IPAQ questionnaire, they confirm the presence of real physical activity among patients. Similar results were presented by Szczygielska-Majewska et al. in their analysis of post-heart attack patients receiving thermal station treatment, where an increase in activity levels and improved well-being was observed [19]. In contrast, Antoniewicz's research confirms the existence of a discrepancy between self-assessment and actual activity, which may be related to the subjective sense of improved health and motivation in a supportive environment [23]. Taylor et al. in their meta-analysis showed that exercise-based rehabilitation programs reduce total and cardiovascular mortality [24]. Zwolińska-Mirek results indicate that thermal stations are effective environments for promoting activity. In her study, she showed that patients staying at thermal station resorts are physically active and show greater commitment to the rehabilitation program. Most of them declared that their stay at the thermal station contributed to a change in lifestyle to a physically active one after returning home [13]. It is worth remembering that balneological treatments (including peoidotherapy, hydrotherapy including the use of medicinal waters) and forms of climatotherapy can support the treatment of comorbid symptoms such as dyspnea, fatigue or hypertension [11], resulting in better exercise tolerance and improved quality of life for patients. Research by Oerkild et al. shows that home rehabilitation can be effective, but the environment offers a unique combination of natural conditions, education and supervision that work together to improve lifestyles [20].

Our study is part of this trend, demonstrating the potential of thermal station rehabilitation stays not only as a complementary treatment, but as a clinically relevant therapeutic intervention. It raises the observation that a health-promoting thermal station environment, through physical activity education, can increase patients' motivation for physioprophylaxis even after thermal station treatment. This is also supported by the conclusions of the work of Piotrowicz and Wolszakiewicz, who, analyzing the impact of physical activity in patients after myocardial infarction, pointed out the need for long-term support and control of the level of activity also after the end of the rehabilitation holiday [21]. In conclusion, the presented study confirms that physical activity is realized and effectively implemented in a thermal station setting. Exercise as part of health training takes place in a controlled setting and supports the patient's adaptation to long-term chronic illness. The effectiveness of treatment can be enhanced by individualizing the exercise program and implementing strategies to support continued activity after returning to the home environment. ActiGraph data provide an important complement to patient self-assessment and confirm the effectiveness of the thermal station program.

CONCLUSIONS

1. A stay at a cardiac thermal station contributed to an increase in physical activity among patients. The declared activity level (IPAQ) was higher after the stay than before.
2. Patients significantly overestimated their level of physical activity during their stay at the thermal station relative to the actual ActiGraph data. The greatest discrepancy occurred in men's declarations of engaging in high-intensity activity, which was not objectively recorded at all.
3. Women appeared to be more physically active during their thermal station treatment, obtaining higher values for all levels of actual physical activity than men.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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ORIGINAL ARTICLE

Restoration of physical and intellectual working capacity of combatants in the process of their rehabilitation

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ABSTRACT

Aim: The aim is to substantiate the means of restoring the physical and intellectual working capacity of combatants and determine their effectiveness.

Materials and Methods: The research, which was conducted in 2024-2025, involved 58 male combatants aged 26 to 54 years who underwent physical education and sports rehabilitation after treatment for gunshot wounds, injuries, and traumas of the musculoskeletal system. Physical working capacity was assessed by the Romberg test, the Rufier index, and the Stange test. Intellectual working capacity was determined by the Bourdon-Anfimov correctional test.

Results: The means of restoring the physical and intellectual working capacity of combatants through their physical education and sports rehabilitation have been substantiated. It has been found that in the course of the research all three groups demonstrated significant ($p < 0.05$-0.01) improvement in the Romberg test (by 1.57-2.36 s), Rufier index (by 0.83-0.91 c. u.), Stange test (by 9.07-12.0 s), concentration and sustainability of attention (by 3.31-3.78 %), intellectual working capacity (by 76.67-87.53 points), emotional state (by 1.11-1.35 points).

Conclusions: The article highlights the peculiarities and characterizes the specifics of using means to restore the physical and intellectual working capacity of combatants. It has been established that the complex use of targeted physical exercises, combined with other methods, enables the rapid and efficient restoration of the functional state of the musculoskeletal system, cardiovascular and respiratory systems, and improves cognitive functions and the emotional state of combatants.

KEY WORDS: means of rehabilitation, combatant, physical working capacity, intellectual working capacity, physical education and sports rehabilitation, physical exercises

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INTRODUCTION

The performance of service tasks by representatives of the security and defense sector in the context of hostilities involves significant physical and psychological stress. It is characterized by a risk to their lives and health [1]. Prolonged exposure to such stressful conditions reduces the level of physical working capacity of personnel and impairs their cognitive processes. This has a particularly acute impact on the observance of personal safety measures and the effectiveness of combat missions, potentially leading to negative consequences, including overfatigue, overstrain, professional burnout, injuries, and wounds [2]. The need to restore the physical and intellectual working capacity of combatants is primarily due to their prolonged stay in the combat zone, significant overexertion, and insufficient rest periods. In addition, it is essential to restore working capacity and improve the functional capacity of the body (or its individual systems) during physical education and sports rehabilitation (PESR) after treatment for various injuries, including surgical interventions, contusions, and other conditions. Depending on the type of injury, multiple means of PESR are used [3, 4]. PESR is considered a system of measures developed through physical exercises aimed at restoring and compensating for the body's functional capabilities, thereby improving physical and mental health, as well as overall health level [5, 6]. PESR under martial law aims to reintegrate combatants into socially active life in Ukraine, highlighting the need to find effective means.

The analysis of scientific studies [7, 8, 9] shows that restoration of combatants' working capacity during their PESR involves several stages, including: assessment of the functional state (determination of initial data); evaluation of physical and intellectual working capacity, comparing them with nominal indicators; determination of optimal means and methods of influence aimed at restoring working capacity (development of an individual plan); control measures; adjustment of plans [10, 11]. Based on the study of scientific literature [12], it has been found

that the following set of measures has a positive effect on the restoration of working capacity in combatants during their PESR: kinesiotherapy, therapeutic massage, biomechanotherapy, hydrokinesitherapy, physiotherapy, herbal medicine, natural physical factors, and hardening [13]. At the same time, scientists [14, 15] are convinced that physical exercises are the most effective means of combatants' PESR in martial law [16]. The primary tasks of PESR for wounded combatants are to prevent joint contractures, muscle hypotonia, and to introduce ergotherapy to facilitate patient adaptation after injuries and surgical treatment [17]. The combination of rationally selected PESR means, taking into account the individual characteristics of each patient, enables the gradual restoration of lost functions and the level of physical and intellectual working capacity in combatants [18].

AIM

The aim is to substantiate the means of restoring the physical and intellectual working capacity of combatants and determine their effectiveness.

MATERIALS AND METHODS

PARTICIPANTS

The research, which was conducted in 2024-2025, involved 58 male combatants aged 26 to 54 years who underwent PESR after their treatment for gunshot wounds of the upper extremities, injuries, and traumas of the musculoskeletal system. The PESR was performed in rehabilitation centers in Kyiv and Zhytomyr. The results were processed at the Department of Physical Education and Sports Rehabilitation of the S. P. Koroliov Zhytomyr Military Institute and the Department of Special Physical Training of the National Academy of Internal Affairs. Depending on age, the participants were divided into three groups: Group 1 – individuals aged 26-30 years (19 participants); Group 2 – those aged 31-40 years (17 participants); and Group 3 – those over 40 years (22 participants). The physical condition of the combatants enabled them to participate in the proposed physical activities and procedures. The effectiveness of the means for restoring physical and intellectual working capacity was determined at the beginning of arrival at the rehabilitation center and after four weeks of systematic training.

METHODS

The research involved the use of theoretical methods (analysis and generalization of literature), empirical methods (biomedical and biological testing), and methods of mathematical statistics. Physical working capacity was assessed by the Romberg test (static coordination), the Rufier index (cardiovascular system), and the Stange test (timed inspiratory capacity). Intellectual working capacity was assessed by the Bourdon-Anfimov test (concentration and sustainability of attention, level of intellectual functioning). Additionally, we examined the dynamics of combatants' emotional states using Doskin's method.

The Romberg test is a neurological assessment that evaluates a person's static balance and coordination. This test is based on the principles that an individual must use at least two of the following three elements to maintain the balance of their body: proprioceptive sensitivity (the ability to sense the position of one's body in space); vestibular function (the ability to sense the position of one's head in space); and vision (which corrects actions when the body position changes). In our research, a simple Romberg test was used: the patient stands with full support on two legs, eyes closed, and arms stretched horizontally forward with fingers spread. When assessing the Romberg test, attention is paid to the degree of stability (whether the combatant is standing still or swaying), trembling of the eyelids and fingers (tremor), and most importantly, the duration of balance. Maintaining a stable posture for more than 15 seconds without tremor is considered normal. A slight tremor of the eyelids and fingers when holding the posture for 15 seconds is satisfactory. If the posture is held for less than 15 seconds, it is unsatisfactory [19].

The technique for performing the Rufier index: after 3-5 minutes of rest, in a sitting position, the HR_1 was calculated for 15 seconds. Then, 30 squats were performed within 45 seconds, with arms extended forward. At the end of the squats, the heart rate was counted in the sitting position during the first 15 seconds (HR_2) and the last 15 seconds (HR_3) of the first minute of recovery. The assessment of the cardiovascular system's functional capabilities was carried out using the formula: $RI_f = (4 \times (HR_1 + HR_2 + HR_3) - 200) / 10$. The determination of the level of functional capabilities of the cardiovascular system involved the use of the following scale: excellent (0.1-5.0 c. u.); good (5.1-10.0 c. u.); satisfactory (10.1-15.0 c. u.); and unsatisfactory (15.1-20.0 c. u.) [20].

The Stange test, a functional test with a breath-hold during inhalation, was used to assess respiratory function. The test is performed while sitting. The subject should take a deep (but not maximal) breath and hold it for as long as possible, pinching their nose with their fingers. In healthy but untrained individuals, the breath-holding time ranges from 40-60 seconds in men, while the functional capabilities of the respiratory system are assessed as excellent if the breath-holding time is more than 60 seconds, good – 40-60 seconds, satisfactory – 30-40 seconds, poor – up to 30 seconds [21].

The intellectual working capacity of the combatant was assessed using the Bourdon-Anfimov correctional test [22]. The participants received forms with 1480 characters (37 lines of 40 characters each). The task was to underline the letter K and cross out the letter I in each line horizontally, while looking at the lines of letters. The goal was to process as many characters as possible and make as few mistakes as possible. The task was completed within 10 minutes. The following were taken into account: the total number of correctly processed characters, mistakenly crossed-out letters, and missed letters K and I. The indicator of concentration and sustainability of attention was determined by the level of accuracy (correctness) of work (A) in percentage according to the formula: $A = (C - W) / (C + O)$, where C is the total number of crossed out and underlined letters; W

is the number of erroneously crossed out or underlined letters; O is the number of erroneously omitted letters K and I. Concentration and sustainability of attention was assessed as low – up to 84 %; average – 85-89 %; above average – 90-94 %; high – 95 % and more. Intellectual working capacity (E) of the combatant was defined as the product of the accuracy indicator (A) and the total number of processed characters of the correctional table (S) according to the formula: $E = A \times S$. If E is 960 points or less, the level of intellectual working capacity is assessed as low, 961-1110 points – below average, 1111-1257 points – average, 1258-1405 points – above average, 1406 points and more – high.

The emotional state of the combatants was determined by Doskin's "WAN" (Well-being-Activity-Mood) methodology [23]. According to this methodology, it was necessary to assess one's state by selecting adjectives that were opposite in meaning. For each of the characteristics of the dominant emotional state (well-being, activity, mood), the methodology contains 10 pairs of emotional state features. On the scale, it is necessary to cross out the number that characterizes the current state of the combatant. The overall level of emotional state was determined as the arithmetic mean of the scores for the three characteristics of the emotional state. The emotional state was assessed on a 9-point scale: 8-9 points – high level of emotional state, 6-7 points – average, 4-5 points – sufficient, 3 points or less – low.

STATISTICAL ANALYSIS

The methods of mathematical statistics were used for correct processing of the data obtained. The reliability of the difference between the indicators was determined using the Student's t-test. The reliability of the difference was set at $p<0.05$. All statistical analyses were performed using SPSS software, version 10.0, adapted for medical and biological research. This research was carried out in accordance with the requirements of the Regulations on academic integrity at the S. P. Koroliov Zhytomyr Military Institute and the National Academy of Internal Affairs and the regulations of the World Medical Association Declaration of Helsinki. Prior consent to participate in the study was obtained from all respondents.

RESULTS

The restoration of physical and intellectual working capacity in combatants during PESR process is possible through the integrated use of recovery means, which are classified as pedagogical, medical and biological, and psychological. Pedagogical means of restoring working capacity are based on the body's natural ability to replenish energy and functional reserves, both during the load itself and after it is terminated. Pedagogical means include rational planning of the process of combatants' working capacity restoration following the functional capabilities of their body, correct construction of a separate training session with the use of means for fatigue relief, clear organization of work and rest, optimal alternation of rest intervals between individual exercises and individual training sessions, personal approach of a rehabilitation specialist to each combatant, etc. Medical and biological as well as psychological means of recovery help increase the body's resistance to loads, accelerate the reduction of acute manifestations of general and local fatigue, facilitate the effective recovery of energy resources, and expedite adaptation processes. By affecting the processes of metabolism, hematopoiesis, thermoregulation, plasticity, and energy utilization, medical and biological means help restore the functions of regulatory mechanisms, reduce fatigue, and increase working capacity, thereby accelerating the natural course of recovery. Among the medical and biological means of restoring working capacity are hygienic, pharmacological, physical, and rational nutrition. Hygienic approach ensures compliance with the duration and organizational forms of events, clothing, exercise content, climatic, geographical, and weather conditions, etc. Pharmacological methods include the use of drugs that help restore energy reserves, increase the body's endurance under stress, stimulate blood formation, and ensure the restoration of vitamins and minerals. They also involve adaptogens of plant and animal origin, along with warming, analgesic, and anti-inflammatory agents. The most common physical means are ultraviolet radiation, aero-ionization, cold and heat procedures, and massage. They act through the skin by physically irritating receptors. As a result, there is a reflex effect on the activity of the muscular system, internal organs, and the central nervous system. Psychological means include psychotherapeutic, psychoprophylactic, and psycho-hygienic methods. The psychotherapeutic means of recovery include induced sleep and rest, muscle relaxation, and special breathing exercises. Psychoprophylactic means include psycho-regulatory training and the use of music. Psycho-hygienic means include the reduction of negative emotions, comprehensive recreation, comfortable living conditions, etc. When applying the aforementioned restoration methods, we took into account the individual characteristics of the body, as well as the severity and specificity of the injuries and damages. The speed and quality of recovery processes can vary significantly from person to person. Accordingly, it is necessary to understand the natural ability of each organism to recover in order to select the appropriate recovery products, procedures, and regimens for its use. We also took into account individual differences in the body's perception of various restoration means, such as age, genetic predisposition, nutritional factors, unhealthy habits, and diseases.

To enhance the effectiveness of restoring the combatants' physical and intellectual working capacity who participated in our research, we employed physical exercises, including steady running, along with various medical and biological treatments, such as cold and heat therapies, and massage. The experiment lasted for four weeks and included: steady slow running three times a week with a heart rate not exceeding 130-140 beats per minute for Group 1 (first week: 15 min, 20 min, 30 min; second week: 30 min, 40 min, 30 min; third week: 40 min, 50 min, 40 min; fourth: 50 min, 60 min,

50 min). For Group 2, the heart rate during running did not exceed 120-130 beats per minute (first week: 10 min, 15 min, 20 min; second week: 20 min, 30 min, 20 min; third: 30 min, 40 min, 30 min; fourth: 40 min, 50 min, 40 min). For Group 3, the heart rate did not exceed 110-120 beats per minute (first week: 5 min, 10 min, 20 min; second week: 10 min, 20 min, 10 min; third: 20 min, 30 min, 20 min; fourth week: 25 min, 35 min, 25 min). Cold procedures were used daily, including a morning cold shower. General massage was performed twice a week, and thermal procedures were conducted three times a week on days free from running exercises: sauna once a week and hydrotherapeutic procedures (Charcot shower) four times a week. The results of assessing the dynamics of physical working capacity in combatants during their PESR are presented in Table 1. In contrast, the results for intellectual working capacity are presented in Table 2.

Evaluation of the dynamics of indicators of the Romberg test testifies that in all three groups of combatants there was an improvement of static coordination, that allows to speak about improvement of a functional state of the musculoskeletal system in combatants during their PESR: in the 1st group indicators of the Romberg test improved by 2.36 s ($p < 0.05$), in the 2nd – by 1.72 s ($p < 0.05$), in the 3rd – by 1.57 s ($p < 0.05$). It should be noted that at the beginning of the research, the Romberg test indicators in all three groups of combatants were at an unsatisfactory level. After rehabilitation, the indicators in Group 1 were within normal limits, and in Groups 2 and 3, they were within acceptable limits, with slight tremors of the fingers and eyelids.

The analysis of the Rufier index provides grounds to state that the cardiovascular system functionality is at a good level in Groups 1 and 2, and satisfactory in Group 3 at the beginning of the research. Positive dynamics were observed after the use of the proposed PESR method in combatants – in all three groups, there was a significant ($p < 0.01$) improvement in the Rufier index by 0.83, 0.87, and 0.91 c. u., respectively. The obtained results demonstrate the positive impact of combining running exercises with physical means on restoring the working capacity of combatants.

Evaluation of the Stange test indicators also demonstrates the positive impact of working capacity restoration measures during PESR on the functional state of the respiratory system of combatants. Thus, during the research period, all three groups demonstrated a significant improvement in the Stange test indicators, with 12.01 seconds in Group 1 ($p < 0.01$), 11.49 seconds in Group 2 ($p < 0.05$), and 9.07 seconds in Group 3 ($p < 0.05$).

The processing of the results of the Bourdon-Anfimov correctional test provides grounds to state that the offered exercises and restoration means have a positive influence on the dynamics of concentration and stability of attention in combatants. During the research period, the indicators of all three groups significantly ($p < 0.05$) improved by 3.78 %, 3.29 %, and 3.31 %, respectively (Table 2). The indicators for all three groups at the end of the research corresponded to the average level of concentration and attention sustainability. The overall level of intellectual working capacity also significantly improved in all research groups during their PESR: the difference between the indicators at the initial and final stages was 76.67 points, 83.80 points, and 87.53 points, respectively. After the research, the intellectual working capacity in all groups was above average. The results obtained can be attributed to the positive effect of the proposed complex on the functional capabilities of the cardiovascular system, resulting in improved blood flow efficiency and better oxygenation of the brain, which in

Table 1. Dynamics of indicators of physical working capacity in combatants during their PESR (n = 58)

Groups	At the initial stage	At the final stage	Reliability of the difference	
	Mean ±m	Mean ±m	t	p
Romberg test, s				
Group 1	13.15±0.77	15.87±0.65	2.70	p<0.05
Group 2	12.67±0.81	14.39±0.76	1.55	p>0.05
Group 3	11.94±0.82	13.51±0.80	1.37	p>0.05
Rufier index, c. u.				
Group 1	8.27±0.18	7.44±0.17	3.35	p<0.01
Group 2	9.48±0.16	8.61±0.17	3.73	p<0.01
Group 3	10.37±0.19	9.46±0.18	3.48	p<0.01
Stange test, s				
Group 1	45.17±2.74	57.18±2.65	3.15	p<0.01
Group 2	42.39±2.93	53.88±2.89	2.79	p<0.05
Group 3	39.67±3.04	48.74±2.91	2.16	p<0.05

Legend: Mean – arithmetic mean, m – error of the arithmetic mean; t – Student's t-test value; p – confidence interval

Source: compiled by the authors of this study

Table 2. Dynamics of indicators of intellectual working capacity and emotional state in combatants during their PESR (n = 58)

Groups	At the initial stage	At the final stage	Reliability of the difference	
	Mean ±m	Mean ±m	t	p
Concentration and sustainability of attention (Bourdon-Anfimov correctional test), %				
Group 1	85.38±0.96	89.61±0.91	2.86	p<0.05
Group 2	84.83±0.92	88.12±0.91	2.54	p<0.05
Group 3	86.63±0.88	89.94±0.89	2.64	p<0.05
Level of intellectual working capacity (Bourdon-Anfimov correctional test), points				
Group 1	1275.18±25.29	1351.85±24.86	2.16	p<0.05
Group 2	1262.37±27.04	1346.17±26.59	2.21	p<0.05
Group 3	1271.09±26.93	1358.62±26.61	2.31	p<0.05
Emotional state (WAN methodology), points				
Group 1	5.67±0.37	7.02±0.35	2.65	p<0.05
Group 2	5.44±0.41	6.85±0.40	2.46	p<0.05
Group 3	5.26±0.34	6.37±0.36	2.24	p<0.05

Legend: Mean – arithmetic mean, m – error of the arithmetic mean; t – Student's t-test value; p – confidence interval

Source: compiled by the authors of this study

turn affects the concentration, sustainability of attention, and productivity (working capacity) of the individual.

Evaluation of the dynamics of combatants' emotional state characteristics revealed a significant ($p < 0.05$) improvement in their emotional state during the process of PESR in all groups. The improvement was 1.35 points in Group 1, 1.14 points in Group 2, and 1.11 points in Group 3. The research demonstrated the effectiveness of substantiated means in restoring both physical and intellectual working capacity in combatants during their PESR.

DISCUSSION

The relevance of the research is confirmed by the publications of other scholars [24], who argue that the outbreak of hostilities in Ukraine has led to the actualization of rehabilitation and restorative areas in the field of physical education, as the problem of returning combatants to everyday life after participation in hostilities is urgent. These areas are based on the consistent use of various physical education and therapeutic activities and means [25, 26]. The use of means to restore working capacity under martial law and in the absence of systematic vocational rehabilitation is particularly relevant, as it is necessary to ensure the social integration of combatants into their social environment.

The obtained results confirm the evidence of other scientists regarding the positive impact of the complex use of physical exercises, particularly slow running, in combination with medical and biological means of restoring physical and intellectual working capacity during PESR. According to scientific research [27], the effectiveness of methods for restoring working capacity varies. In particular, the scientific literature indicates that 44.2 % of experts note the low to average effectiveness of pharmacological means in restoring the working capacity of security and defense sector employees under service conditions, mainly through the use of various drugs [28]. According to experts, physical means are more effective, including the use of temperature procedures, such as hydrotherapy and massage [29]. These means of restoring working capacity are based on changes in the body's reactivity, increasing its resistance to stressful environmental factors, acting through the skin by physically irritating receptors. As a result, there is a reflex effect on the activity of the muscular system, internal organs, and the central nervous system. The high effectiveness of hydrotherapy (shower, bath, steam bath) is emphasized by 40.3 % of experts and 54.8 % – its average effectiveness [15].

A survey of specialists from medical institutions and organizations suggests that after treatment in a hospital, a significant number of combatants still need psychological support and restoration of the body's functional capacity. PESR for combatants after injuries and severe contusions can last from 1-2 to 5-6 months or longer. The complex of rehabilitation treatment measures is designed to restore the bodies of combatants after the acute period, aiming to prevent primary disability or further deterioration of health, while also improving overall physical condition [1, 3, 4]. Injuries and prolonged hospitalization with restricted mobility can lead to muscle atrophy and weakening, which in turn prevent entire movement, activity, and overall well-being. The results of our research do not contradict the findings of other scientists [30], but rather expand and supplement them.

CONCLUSIONS

Based on the study of scientific, educational, and methodological literature, the article highlights the

peculiarities of using means to restore the physical and intellectual working capacity in combatants during their PESR, characterizing the specifics of pedagogical, biological, medical, and psychological means of restoring working capacity. It has been established that the complex application of dosed physical exercises in combination with means of restoring physical and intellectual working capacity allows to improve the functional state of the musculoskeletal system, cardiovascular and respiratory systems, to positively influence the intellectual and emotional spheres of combatants, to achieve the optimal level of personal adaptation and development of professionally essential traits that ensure military and professional working capacity and longevity. It has been found that, during the research, all three groups of combatants demonstrated a significant ($p < 0.05$-0.01) improvement in the Rufier index (per c.u.).

It has been established that in the course of the research in all three groups of combatants there was a significant ($p < 0.05$-0.01) improvement of the Romberg test indicators, which allowed to estimate the functional state of the musculoskeletal system, (by 1.57-2.36 s), the Rufier index (by 0.83-0.91 c. u.), the Stange test (by 9.07-12.01 s), concentration and sustainability of attention (by 3.31-3.78 %), intellectual working capacity (by 76.67-87.53 points), emotional state (by 1.11-1.35 points). The obtained results are recommended for use in the course of PESR in security and defense sector of Ukraine.

PROSPECTS FOR FURTHER RESEARCH

We see prospects for further research in substantiating the means of restoring the working capacity in combatants with other diagnoses during their PESR.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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REVIEW ARTICLE

Balneotherapy as a support in the treatment of rheumatic diseases – the importance of natural therapeutic resources in symptom relief and quality of life improvement

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ABSTRACT

Aim: The aim of this review paper is to provide an overview of the current state of scientific knowledge regarding the treatment of rheumatic diseases, with particular emphasis on balneotherapy as a complementary therapeutic approach.

Materials and Methods: The literature search was conducted across three major databases: PubMed, Scopus, and Web of Science. The search terms included combinations of: "Rheumatic Diseases", Rehabilitation", "Functional Recovery", "Physical Therapy", "Balneotherapy", "Spa Therapy", "Mineral Waters", "Therapeutic Mud", "Therapeutic Gases" and "Quality of Life Improvement". Articles in both Polish and English were included.

Conclusions: Although balneotherapy does not replace traditional pharmacological treatments, such as the use of anti-inflammatory and analgesic medications, it constitutes a highly valuable component in comprehensive therapy. Through its synergistic interaction with other treatment methods, it may contribute to the improvement of motor function, the reduction of muscle tension, and an overall increase in patients' quality of life. An increasing number of studies confirm the effectiveness of balneotherapy in the treatment of rheumatic diseases while also emphasizing the need for further development of this method. The introduction of standardized treatment protocols in rehabilitation medicine may not only enhance the efficacy of therapeutic procedures but also allow for better adaptation of therapy to the individual needs of patients.

KEYWORDS: rheumatic diseases, balneotherapy, medical resort, rehabilitation, functional recovery, mineral waters, therapeutic mud, therapeutic gases, quality of life improvement

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INTRODUCTION

Rheumatic diseases, such as rheumatoid arthritis and fibromyalgia, are a group of disorders characterized by chronic pain, inflammation, and limited joint mobility. This therapy is also applied in the treatment of osteoarthritis [1]. The treatment of these diseases requires a comprehensive approach that includes both pharmacotherapy and supportive therapies, such as balneotherapy. This traditional treatment method, based on the use of natural mineral water sources, peat mud, and other therapeutic substances, has been an integral part of therapy for various rheumatic disorders for centuries [1, 2]. Balneotherapy has been shown to provide numerous benefits, both physical and psychological, in the treatment of patients with rheumatic diseases. It is a therapeutic method that utilizes natural mineral waters, peat mud (medicinal peat), therapeutic mud, and gases such as carbon dioxide and hydrogen sulfide. This method is based on the use of the physical, chemical, and biological properties of these natural resources, which exhibit anti-inflammatory, analgesic, regenerative, and relaxing effects. Balneotherapy is widely applied in health resorts and rehabilitation centers, where access to natural mineral water sources is particularly convenient [3]. Various forms of balneotherapy are utilized, including mineral baths, peat mud compresses, mineral inhalations, hydrotherapy, and thermotherapy. Mineral baths involve the use of water from natural mineral sources, often enriched with additional substances such as sulfur, magnesium, or calcium, and are applied as full-body baths or localized joint baths. Peat mud compresses, composed of natural therapeutic peat, exhibit warming, anti-inflammatory, and circulation-enhancing properties, making them particularly effective when applied to inflamed areas, especially the joints. Mineral inhalations are beneficial in cases where rheumatoid arthritis affects the respiratory system, as inhaling gases found in mineral waters, such as carbon dioxide or hydrogen sulfide, may improve respiratory function and help reduce stress. Hydrotherapy, which employs various forms of water application, including warm, cold, or pressurized water, is frequently used in the form of water massages to stimulate circulation and enhance joint mobility. Lastly, thermotherapy utilizes the heat from thermal waters to improve blood circulation, leading to better tissue nourishment and a reduction in inflammatory conditions [3, 4].

AIM

The aim of this review paper is to provide an overview of the current state of scientific knowledge regarding the treatment of rheumatic diseases, with particular emphasis on balneotherapy as a complementary therapeutic approach.

MATERIALS AND METHODS

By analyzing the existing literature and available research, the paper seeks to compare different therapeutic strategies and highlight the role of balneotherapy in managing conditions such as rheumatoid arthritis and osteoarthritis. Special attention is given to the mechanisms through which balneotherapy exerts its effects, its clinical applications, and the most commonly used forms of this therapy. These include treatments that leverage the anti-inflammatory, analgesic, regenerative, and relaxing properties of natural therapeutic resources such as mineral waters, peat mud, and healing gases.

STUDY DESIGN

The article is based on a literature review concerning the application of balneotherapy in the treatment and supportive therapy of rheumatic diseases. The analyzed studies focus on the effectiveness of various balneotherapy techniques in alleviating symptoms, improving joint function, and enhancing patients' overall quality of life. Particular attention is given to the therapeutic mechanisms of mineral waters, mud therapy, and other natural healing resources in managing chronic inflammatory conditions. The analyzed sources include scientific publications available in databases such as PubMed, Scopus, and Web of Science, published between 2000 and 2024.

INCLUSION AND EXCLUSION CRITERIA

The analysis included original studies, systematic reviews, and meta-analyses focused on the application of balneotherapy in the treatment and adjunctive therapy of rheumatic diseases. The examined studies assess the efficacy of various balneotherapy techniques in alleviating symptoms, improving joint function, and enhancing the overall quality of life in patients. Particular emphasis was placed on the therapeutic mechanisms of mineral waters and other natural healing resources in managing chronic inflammatory conditions. Studies exclusively involving pediatric populations and publications lacking peer review were excluded to ensure the reliability and relevance of the findings. Additionally, the methodological quality of the included studies was carefully considered to provide a comprehensive and evidence-based evaluation of balneotherapy's therapeutic potential in rheumatology.

LITERATURE SEARCH PROCESS

The literature search was conducted across three major databases: PubMed, Scopus, and Web of Science. The search terms included combinations of: "Rheumatic Diseases", Rehabilitation", "Functional Recovery", "Physical Therapy", "Balneotherapy", "Spa Therapy", "Mineral Waters", "Therapeutic Mud", "Therapeutic Gases" and "Quality of Life Improvement". Articles in both Polish and English were included.

ETHICS

The literature review relied exclusively on already published data, eliminating the need for ethical committee approval.

LIMITATIONS

The identified limitations stem from the heterogeneity of the studied groups and the rehabilitation methods applied. Variations in observation periods and sample sizes across the analyzed studies complicate the generalization of findings.

REVIEW AND DISCUSSION

Balneotherapy, particularly in the form of bathing in warm mineral waters, is recognized as one of the most widely used and effective methods supporting the treatment of rheumatic diseases. Its therapeutic effects are based on the combination of the physical and chemical properties of medicinal waters, allowing for the achievement of multidimensional therapeutic benefits. The heat generated by thermal waters exerts a relaxing effect on muscles and joints, leading to a reduction in muscle tension and facilitating the dilation of blood vessels, which, in turn, improves blood circulation in areas affected by inflammation. These processes contribute to a decrease in pain perception, a reduction in swelling, and the alleviation of inflammatory symptoms, which has been confirmed by scientific research. Mineral waters rich in sulfur, as well as other elements such as calcium, magnesium, and sodium, play a significant role in the treatment of inflammatory joint conditions. Sulfur, as a key component of sulfurous waters, exhibits anti-inflammatory properties, which have been documented in numerous clinical studies [5]. Furthermore, bathing in sulfurous waters has been shown to modulate the body's immune response by regulating the levels of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which play a crucial role in the inflammatory processes associated with rheumatic diseases[6]. The reduction of these inflammatory markers contributes to the alleviation of disease symptoms and enhances the overall functioning of patients. Studies have also indicated a range of additional benefits associated with baths in mineral-rich waters. Regular engagement in balneotherapy has been shown to improve motor functions, increase the range of motion in joints, and reduce morning stiffness. In one systematic review, it was observed that sulfur baths significantly alleviate pain symptoms in osteoarthritis and rheumatoid arthritis [7]. Therapeutic waters, such as sulfur-rich ones, have been shown to influence metabolic and immunological processes, indicating their potential in the comprehensive treatment of rheumatologic diseases [6]. Additionally, the minerals present in therapeutic waters influence enzymatic activity within articular cartilage and the synovial membrane, potentially supporting the regeneration of joint structures. Specifically, calcium and magnesium participate in the regulation of cellular homeostasis, enhancing the stability of cell membranes and reducing oxidative stress, which is a contributing factor to chronic inflammation in rheumatologic diseases [7]. This action may be significant in slowing the progression

of inflammatory changes and improving patients' quality of life. Furthermore, medicinal waters may also influence metabolic and immunological processes. Studies have demonstrated that baths in sulfur-rich waters can regulate the activity of antioxidant enzymes, thereby reducing oxidative stress levels, which contribute to the progression of rheumatologic diseases [6]. This action is significant not only in the context of symptomatic treatment but also in the potential influence of balneotherapy on the pathophysiological mechanisms underlying chronic inflammation.

Through the regular application of balneotherapy, a significant improvement in the range of motion in joints affected by the inflammatory process is achieved. This mechanism results from several factors, including the thermal effects of medicinal waters, their chemical properties, and the hydrostatic effect. Warm water facilitates the dilation of blood vessels, leading to improved microcirculation and an increased supply of oxygen and nutrients to joint tissues, thereby promoting their regeneration [8]. At the same time, the anti-inflammatory and analgesic effects of balneotherapy lead to a reduction in periarticular swelling, which facilitates movement and decreases functional limitations [9]. Hydromassage and baths in mineral waters contribute to the relaxation of muscles and periarticular tissues, which plays a crucial role in reducing joint stiffness. Heat stimulates enzymatic activity in articular cartilage and increases the production of synovial fluid, thereby enhancing the lubrication of joint surfaces and reducing friction. Studies have demonstrated that bathing in sulfurous waters can lead to an increased concentration of sulfur in synovial fluid, which supports cartilage regeneration and alleviates the severity of pain symptoms [10]. Moreover, sulfurous water exhibits anti-inflammatory effects by modulating pro-inflammatory cytokines, such as IL-6 and TNF-α, which results in a reduction of the inflammatory response within the joint and the surrounding tissues [11]. The impact of balneotherapy on joint range of motion is particularly significant for individuals suffering from chronic rheumatic diseases, such as rheumatoid arthritis, in which joint stiffness is one of the predominant clinical symptoms. Clinical studies have demonstrated that regular water therapy significantly reduces morning joint stiffness and improves motor function, leading to an increase in patients' independence in daily activities [9]. In addition to biomechanical benefits, balneotherapy also contributes to the improvement of proprioception, which may reduce the risk of falls and injuries in patients with limited mobility. The reduced load on the joints in the aquatic environment allows for a gradual increase in movement intensity without the risk of tissue damage. Systematic reviews have demonstrated that after several weeks of regular bathing in medicinal waters, a significant improvement in joint mobility is achieved, and these effects may persist for an extended period after the completion of therapy [8].

Mineral waters, particularly those rich in sulfur, magnesium, bicarbonates, and other bioactive components, have long been utilized in the treatment of various diseases, including rheumatic conditions. Numerous studies confirm that the regular use of mineral water baths, especially sulfurous ones, exhibits anti-inflammatory effects, which are essential in the therapy of rheumatoid arthritis (RA). Sulfurous waters contain dissolved hydrogen sulfide, which possesses anti-inflammatory and analgesic properties while also supporting regenerative processes in damaged joint tissues. Research indicates that bathing in such waters may lead to a reduction in joint swelling, an improvement in joint mobility, and a decrease in pain intensity [12]. Additionally, mineral water can contribute to the improvement of microcirculation in the inflamed area, which facilitates better oxygenation and nourishment of joint tissues. Mineral baths and peat compresses play a significant role in improving microcirculation, which results in the more efficient delivery of oxygen and nutrients to tissues and accelerates the removal of metabolic toxins from the body. In the case of rheumatic diseases, such as rheumatoid arthritis, chronic inflammation may lead to the excessive accumulation of metabolic byproducts, including pro-inflammatory cytokines, reactive oxygen species, and uric acid, which further exacerbate degenerative processes and impair joint function [9]. Peat compresses exhibit anti-inflammatory and detoxifying effects due to the presence of humic acids, fulvic acids, and other bioactive compounds, which support the elimination of harmful substances and regulate metabolic processes within cells. Studies confirm that the organic substances contained in peat influence the reduction of inflammatory markers, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which may lead to a decrease in the severity of rheumatic symptoms and a slowdown in the progression of degenerative changes [13]. Mineral water rich in carbon dioxide additionally enhances blood circulation by dilating blood vessels, which leads to improved oxygen and nutrient supply to tissues and consequently supports the regeneration of damaged structures, such as articular cartilage and the synovial membrane. This mechanism is based on the vasodilatory effect of carbon dioxide, which, through a local increase in the partial pressure of CO_2 in the blood, results in an elevated concentration of nitric oxide (NO), exerting a relaxing effect on blood vessel walls. This effect is particularly beneficial in the treatment of patients with rheumatic diseases, in whom microcirculatory disorders may lead to tissue hypoxia and joint structure degeneration [9]. Furthermore, the regular application of mineral water baths may contribute to the improvement of tissue metabolism, which promotes better functioning of the musculoskeletal system. Enhanced blood flow and reduced muscle tension around the joints lead to decreased stiffness and joint pain, facilitating daily physical activity. Additionally, increased tissue perfusion supports the more efficient removal of inflammatory mediators and toxic metabolic byproducts, thereby reducing the risk of further damage to articular cartilage and other structures of the locomotor system [13]. In conclusion, mineral baths and peat compresses not only enhance microcirculation but also support regenerative processes by stimulating blood flow,

reducing inflammation, and accelerating the elimination of toxins. Their regular application may serve as a significant adjunct in the treatment of rheumatic diseases, alleviating symptom severity and improving patients' quality of life.

Chronic diseases, including RA, not only lead to the progressive deterioration of joints and a reduction in mobility but also result in a decreased quality of life for patients. The primary consequences of these conditions include chronic fatigue, sleep disturbances, and an increased risk of developing depressive states [14]. Patients suffering from RA often experience prolonged stress resulting from chronic pain and limitations in daily functioning, which leads to an increase in cortisol levels and dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, a system that plays a crucial role in the body's response to stress [15]. Balneotherapy, as one of the key components of spa therapy, has been shown to exert a beneficial effect on patients' mental well-being, particularly when combined with relaxation and rest. Mineral baths and treatments involving peat mud influence the nervous system through both thermal and chemical mechanisms, resulting in a reduction of sympathetic nervous system activity and an increase in parasympathetic nervous system activity, which promotes relaxation and enhances overall well-being [16]. The reduction of muscle tension and the decrease in pro-inflammatory cytokines, such as IL-6 and TNF-α, contribute to the alleviation of fatigue symptoms and the improvement of sleep quality in patients with rheumatoid arthritis, which is of crucial importance in the management of chronic pain [17]. An essential aspect of balneological therapy is its impact on patients' stress levels. Studies have demonstrated that patients undergoing spa therapy experience a significant reduction in serum cortisol levels, indicating a decrease in stress and an improvement in the body's neuroendocrine balance [15]. Additionally, balneological treatments support the regulation of the circadian rhythm, which contributes to an improvement in sleep quality and duration, a reduction in nocturnal awakenings, and an increase in the effectiveness of rest. As a result, patients experience reduced fatigue and an enhanced mood, which facilitates better functioning in daily life.

Moreover, spa therapy may aid in the treatment of depressive conditions in patients with rheumatic diseases. Studies have shown that regular exposure to natural environmental stimuli, such as mineral waters, the spa microclimate, and light therapy, contributes to an increase in serotonin and endorphin levels, leading to an improvement in mental well-being and a reduction in depressive symptoms [16]. In conclusion, balneotherapy serves not only as an effective support in the treatment of somatic symptoms of chronic diseases but also exerts a beneficial influence on patients' mental well-being by reducing stress, improving sleep quality, and alleviating depressive conditions. Its multidirectional effects make it a valuable component of comprehensive therapy for rheumatoid arthritis and other rheumatic diseases.

Certain mineral waters, particularly those rich in sulfur, exhibit a strong stimulating effect on regenerative processes within the body. Their therapeutic properties are derived from the presence of bioactive mineral components that support the rebuilding of damaged tissues, contribute to the reduction of oxidative stress, and influence repair processes at the cellular level [18]. In rheumatologic diseases, where chronic inflammation leads to the degeneration of joints, soft tissues, and ligaments, balneotherapy can serve as an important complement to pharmacological therapy and physical rehabilitation.

Sulfur exhibits anti-inflammatory and regenerative properties, which may be crucial for the protection and rebuilding of articular cartilage. Studies indicate that sulfur compounds can increase the production of proteoglycans and collagen, both of which are necessary for maintaining the proper structure and elasticity of cartilage [13].

Rheumatoid arthritis is a chronic autoimmune disease that leads to joint damage and the destruction of surrounding structures. Balneotherapy, through its anti-inflammatory and analgesic effects, can alleviate the symptoms of this disease. Clinical studies have demonstrated that sulfur baths can reduce joint swelling and improve their mobility, resulting in enhanced physical function for patients [8]. However, systematic reviews suggest that while many studies report positive effects of balneotherapy, some of them are plagued by methodological errors, making it difficult to make a definitive assessment of the therapy's effectiveness [16]. Balneotherapy is also used in the treatment of fibromyalgia, a chronic condition characterized by generalized musculoskeletal pain, fatigue, and sleep disturbances. Therapeutic waters affect several mechanisms that may provide relief to fibromyalgia patients. The relaxing effect of bathing in warm mineral waters helps reduce muscle tension and increases the production of endorphins, which naturally modulate pain perception [19]. Furthermore, improvements in microcirculation and the supply of mineral components to tissues contribute to the regeneration of muscle fibers and enhance the overall physical fitness of patients. Studies have shown that balneotherapy can improve sleep quality and reduce stress levels, a key factor in exacerbating the symptoms of fibromyalgia [16].

Although the benefits of balneotherapy are well-documented, its therapeutic effects are often short-term. Studies indicate that positive changes in terms of pain reduction, mobility improvement, and quality of life can persist from several weeks to several months after completing a treatment cycle. Therefore, it is recommended to repeat balneological therapy at regular intervals, which helps prolong the therapeutic effects and reduce disease progression. To obtain optimal approach involves applying therapy in repeated cycles several times a year, which can help maintain long-term improvements in motor function and reduce the need for pain-relieving and anti-inflammatory medications [2, 8, 19].

CONCLUSIONS

Balneotherapy is recognized as an effective and versatile method supporting the treatment of rheumatic diseases, which is why it is widely applied in rehabilitation medicine and spa therapy. By utilizing the natural properties of

mineral waters, peat mud, therapeutic mud, and medicinal gases such as carbon dioxide and hydrogen sulfide, it supports anti-inflammatory and analgesic processes, providing relief in chronic pain conditions. Although balneotherapy does not replace traditional pharmacological treatments, such as the use of anti-inflammatory and analgesic medications, it constitutes a highly valuable component in comprehensive therapy. Through its synergistic interaction with other treatment methods, it may contribute to the improvement of motor function, the reduction of muscle tension, and an overall increase in patients' quality of life. An increasing number of studies confirm the effectiveness of balneotherapy in the treatment of rheumatic diseases while also emphasizing the need for further development of this method. The introduction of standardized treatment protocols in rehabilitation medicine may not only enhance the efficacy of therapeutic procedures but also allow for better adaptation of therapy to the individual needs of patients. Balneotherapy serves as a valuable adjunct in the management of rheumatic diseases, particularly in supporting regenerative processes, reducing inflammation, and improving patients' quality of life. Its effectiveness has been documented in clinical studies; however, methodological limitations of research indicate the necessity for further investigations into its long-term effects. Regular repetition of therapeutic cycles may be crucial for maintaining health benefits, and future research will facilitate a better understanding of its mechanisms of action and the optimization of treatment protocols. Consequently, balneotherapy is becoming an indispensable tool in providing multidimensional care for individuals suffering from chronic rheumatic diseases.

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CONFLICT OF INTEREST
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REVIEW ARTICLE

The role of balneological resorts of Lviv region in modern rehabilitation

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ABSTRACT

Aim: Aim of the study is to analyze the current state and potential of balneological resorts of the Lviv region in the system of rehabilitation services, to determine their role in restoring the health of the population, and to outline development prospects in the context of growing demand for such services.

Materials and Methods: The criteria for including publications in the literature review were: proper scientific design in the form of original research articles or literature reviews and compliance with the specified search queries. Only peer-reviewed scientific publications containing theoretical or empirical research on the key concepts: balneology, balneological resorts, rehabilitation, sanatorium-resort treatment has been included into the analysis.

Conclusions: Balneological resorts of the Lviv region have significant prospects for further development, as this sphere is one of the main social institutions that solves the problem of improving the quality of population health (one of the most important indicators of assessing human potential as the basis for the development of the country's economy).

KEYWORDS: rehabilitation, balneology, resorts, sanatorium-resort facilities, natural therapeutic factors

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INTRODUCTION

The main task of the state is to preserve and improve the health of Ukrainians, increase life expectancy and rehabilitation. In highly developed countries of the world, the population health is a resource that requires careful care and preservation [1]. The imperative for increasing the average life expectancy of Ukrainians is to improve the functioning of the health services market, the leading place among which is occupied by those related to the development of the sanatorium and resort business in the rehabilitation process structure [2].

Modern rehabilitation is a set of measures aimed at restoring health and compensating for body functions that has been lost. An important role in modern rehabilitation is played by natural healing factors, which are represented by mineral waters of various compositions, healing muds and mild climatic conditions. Due to the variety of natural healing factors, balneological resorts of the L'viv region are a favorable place for the improvement and rehabilitation of patients with various diseases, such as cardiovascular, endocrine, respiratory, and musculoskeletal, and also digestive systems. On the example of balneological resorts of the region, including Truskavets, Skhidnytsia, Morshyn and Velykyi Liubin, we can trace the trends towards the optimal combination of sanatorium-resort treatment and modern rehabilitation programs. A significant role in the rehabilitation process belongs to sanatorium and resort institutions that combine natural healing factors and the latest medical technologies.

AIM

The aim of the study is to analyze the current state and potential of balneological resorts of the L'viv region in the system of rehabilitation services, to determine their role in restoring the health of the population, and to outline development prospects in the context of growing demand for such services.

MATERIALS AND METHODS

The literature analysis has been conducted on the basis of available scientific sources of recent years (2002-2024). The selection of scientific sources has been carried out in accordance with the established requirements for a comprehensive literature search, by using Google Scholar database. Publications have been selected for the review based on the following keywords: balneology, balneological resorts, rehabilitation, sanatorium and resort treatment.

The criteria for including publications in the literature review were: proper scientific design in the form of original research articles or literature reviews and compliance with the specified search queries. Only peer-reviewed scientific publications containing theoretical or empirical research on the key concepts: balneology, balneological resorts, rehabilitation, sanatorium-resort treatment has been included into the analysis.

REVIEW AND DISCUSSION

The balneological resorts of L'viv region are known not only in Ukraine, but also abroad, having been formed

on the basis of mineral waters in Velykyi Liubin (1778), Truskavets (1827), Morshyn (1877) and Skhidnytsia (1986).

Velykyi Liubin is one of the first balneological resorts in the Lviv region. The first written mentions of the healing properties of the Velykyi Liubin hydrogen sulfide springs dated back to the 15th century. The first hospital in the Velykyi Liubin has been built at the end of the 16th century, and a hiking sanatorium in the 18th century. However, the real flourishing of Velykyi Liubin as a resort has started since the 19th century, by the building of baths, sanatoriums and boarding houses began to be built. In a short time, Velykyi Liubin became a famous European resort. The number of guests of the resort has been increased significantly in 1903 after the construction of a railway branch from L'viv. In the period between the two world wars, the resort experienced significant prosperity. New hotels, boarding houses and sanatoriums were built. After the Second World War, the resort's infrastructure was modernized and new sanatoriums were built [3].

The resort Velykyi Liubin combining centuries-old traditions of using hydrogen sulfide water and peat with modern treatment methods. The resort specializes in the treatment of cardiovascular disorders, diseases of the nervous system, spine, muscles and joints, gynecological and dermatological diseases. In addition, Velykyi Liubin has a comprehensive space for the physical and mental rehabilitation of veterans «Galicia». The territory of thecomplex is divided into eight zones, including sectors for playing sports, jogging tracks, a walking area and a training ground with outdoor weight equipment [3].

Truskavets is one of the most famous balneological resorts in the L'viv region, the history of which dates back to the 19th century. The healing properties of Truskavets mineral waters have been described for the first time by the royal physician Wojciech Oczko back in 1578. At the beginning of the 19th century, a number of other mineral springs were discovered and their chemical analysis has been performed. The official foundation of the balneological resort took place back in 1827, when Józef Micewskihas built the first stationary wooden small house for bathing, which had 8 cabins and 4 houses for vacationers [4-7]. In 1835, Teodor Torosevych as studied the composition of the mineral water «Naftusya», thanks to which the resort began to develop rapidly. In 1892 a room for inhalations of the Vashmut system has been built, which helped Truskavets surpass all the famous resorts of the region and reach the level of such health resorts as Reichenhall and Wiesbaden. In 1913, for its successes in development, the resort was awarded by the Great Gold Medal. During the 1920s and 1930s, the resort was actively developing. In1952, Truskavets became a state-level resort. A new page in the development of the resort began with the acquisition of independence by Ukraine [7].

The resort is actively developing, offering not only sanatorium treatment, but also a wide range of services aimed at rehabilitation and restoration of health. A number of sanatoriums offer rehabilitation services, in particular orthopedic rehabilitation and rehabilitation after surgeries in combination with natural healing factors and modern medical technologies. In addition, Truskavets sanatoriums specialize in the treatment and prevention of a wide range of diseases, including urological, metabolic disorders, musculoskeletal, liver, biliary tract, cardiovascular, neurological and dermatological.

Morshyn (Fig. 1) is one of the oldest balneological resorts in the Lviv region. It isknown that as early as the 15th century,

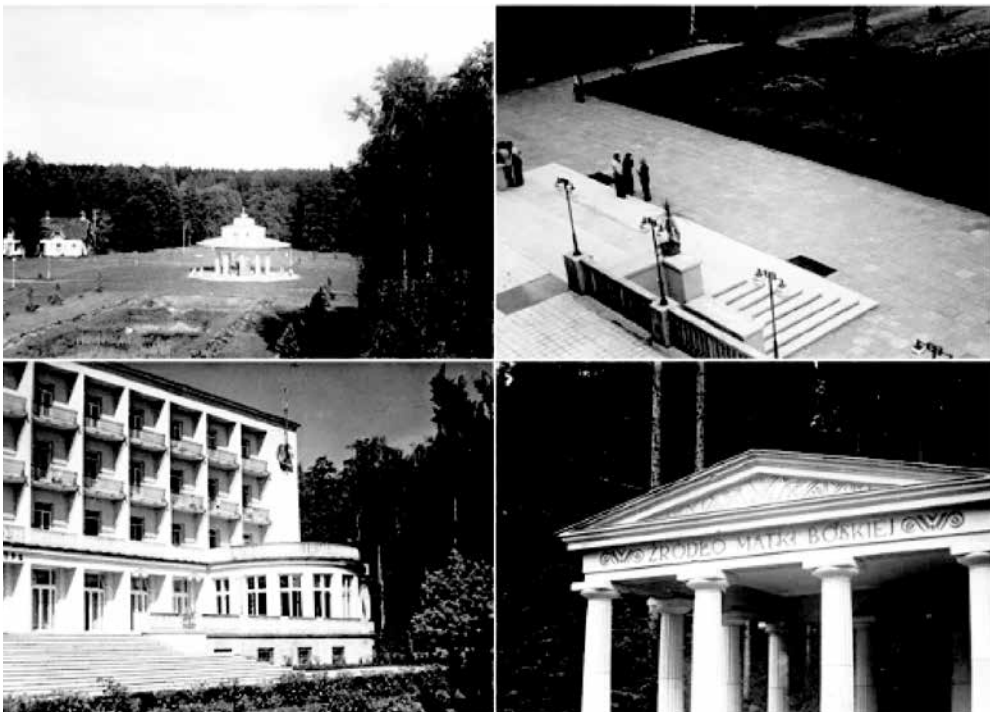

Fig. 1. Morshyn resort, 1950s

Source: compiled by the authors based on [Boris Vedernikov`s photo]

Morshyn residents drew attention to theunusual properties of natural mineral springs, but they began to use them for medicinal purposes only in the 19th century. In 1875, Lviv entrepreneur Boniface Shtiller has invited doctors to Morshyn to study the local mineral springs. In 1878, Morshyn began to develop as a resort, and the first sanatorium, baths, and boardinghouses were built. In 1880, mineral spring water began to be actively used for mineral baths, and peat mud for mud baths and applications. In the 20s and 30s of the 20th century, the resort was actively developed; new sanatoriums, hotel and resort complexes, and villas were opened. Later, an active construction of the new sanatoriums, medical complexes, and the spas began [6].

Morshyn is one of the leading balneological resorts in Ukraine, offering a number of rehabilitation programs and specializing in the treatment of diseases of the gastrointestinal tract, nervous system, respiratory system, musculoskeletal system and skin. In particular, the resort's sanatoriums and resorts offer rehabilitation programs in the following areas: neurological rehabilitation, musculoskeletal rehabilitation and rehabilitation for post-traumatic conditions.

Skhidnytsia is one of the youngest balneological resorts in the Lviv region. In the 50s of the 20th century, the unique mineral water sources of Skhidnytsia began to be actively explored. Their discoverer was Omelyan Stotsky, who laid the foundation for the development of the village as a medical resort. For more than 20 years, the scientist fought for the national recognition of Skhidnytsia healing springs, and thanks to his efforts, clinical and experimental studies based on mineral waters from local sources were carried out in the Skhidnytsia Hospital in the period from 1966 to 1968. In 1976, he was able to achieve his goal, and Skhidnytsia began to develop as a balneological resort [9]. Subsequently, active development of the resort began.

The main specialization of the Skhidnytsia health resorts are diseases of the gastrointestinal tract, skin, endocrine system, nervous system, respiratory system and circulatory system. Health resorts also offer individual rehabilitation programs that combine the use of mineral waters, physiotherapy, ozokerite therapy and balneotherapy, which helps to increase the effectiveness of treatment and rehabilitation.

The priority for the development of balneological resorts in the L'viv region is natural therapeutic factors, including mineral waters, therapeutic mud, and climatic conditions, which are used for the treatment, recovery, and rehabilitation of diseases.

The main natural mineral resources of the Lviv region are waters of various composition and properties, but the most common are waters without specific components, with an increased content of organic substances such as «Naftusya» and sulfide (hydrogen sulfide). Mineral groundwater of the Lviv region is an important element of regional resources, represented by about 60 deposits with balance reserves of 5.4 thousand m^3/day, of which 21 deposits are exploited. Mineral waters of the Precarpathian region (Truskavets and Morshyn) are especially intensively used [10]. The main mineral waters of the resorts include: «Naftusya», «Sofia», «Yuzya», «Bronislava», «Maria», weakly mineralized waters and alkaline (soda) mineral waters of the type «Borzhomi», «Boniface», «Magdalena», «Lyudmila» and «Morshynka».

It should be noted that for treatment and rehabilitation, resorts in the Lviv region also use peat therapeutic mud (peloids). Therapeutic mud has the appearance of a homogeneous finely dispersed mass with certain thermal and physicochemical properties. The largest deposit in the Lviv region is considered to be Morshyn, whose reserves of therapeutic mud are estimated at 239 thousand m^3. The peloids of this deposit are highly mineralized, with well-decomposed peat (specific gravity - 1.14 g/cm^3, moisture content - 71%) [8-10].

The climatic conditions of the region are diverse and enhance the special importance of certain recreational areas with unique microclimatic conditions.For example, the special air of the resorts in the mountainous part of the region is suitable for organizing aerotherapy (air baths and prolonged stay in the fresh air). The region's health resorts specialize in providing this type of health improvement in combination with other procedures [5].

The prolonged war in Ukraine has led to a significant increase in the number of people requiring treatment and rehabilitation due to physical and psychological war injuries. The country's health resort facilities are already becoming the basis for this type of rehabilitation [1]. The main advantage of sanatorium-resort treatment for rehabilitation is its orientation towards the broad use of the medical and recreational potential of resort areas. The use of natural therapeutic resources will allow reducing the costs of rehabilitation several times, compared to the use of pharmaceuticals [8].

This statement is consistent with the theoretical and empirical conclusions presented in the publications that have been analyzed, which were selected according to clearly defined criteria specified in the research methodology. The analysis included peer-reviewed scientific works that focus on issues of balneology, rehabilitation and sanatorium-resort treatment. The rehabilitation potential of balneological resorts of Ukraine has been substantiated on the basis of the peer-reviewed scientific works.

The main components of rehabilitation in sanatoriums and resorts can be medical and rehabilitation programs, which include various procedures, depending on the purpose: mineral water intake, mud therapy, physiotherapy [4], apitherapy, speleotherapy, aromatherapy, ozone therapy, ozokeritotherapy, climatotherapy. Sanatoriums and resorts offer opportunities for comprehensive recreation and treatment through the development of individual rehabilitation programs taking into account the characteristics of each patient: his physical condition, psychological problems and preferences. In sanatoriums, clients are under constant supervision of doctors and other specialists, which allows monitoring the effectiveness of treatment and timely making adjustments to the rehabilitation process [4].

The L'viv region has a developed sanatorium and resort infrastructure. Among the main balneological resorts are Truskavets, Morshyn, Skhidnytsia and Velykyi Liubin, on the

territory of which there are more than 200 sanatorium and resort facilities, including 55 sanatoriums, 7 boarding houses, 6 children's health facilities and more than 100 hotel complexes and private establishments (villas, estates, cottages) that provide medical, health and rehabilitation services.

Over the past few years, considerable changes have occurred in the activities of the sanatorium and resort economy of the L'viv region. Market analysis convincingly proves that today there is a gradual optimization of the activities of sanatorium and resort institutions. The full-scale war forced to adapt to modern realities and led to an increase in consumer interest in the services of Ukrainian balneological resorts and sanatorium and resort institutions. For example, in 2021, the Truskavets resort was visited by 183,444 people, in 2022 – 163,218 people, in 2023 – 183,160 people, in 2024 – 189,639 people, which indicates a positive trend towards an increase in the number of vacationers in the sanatorium and resort institutions of Truskavets.

It is worth noting that only a small number of sanatoriums and resorts in Lviv region have the latest material and technical base and can provide effective rehabilitation services. The creation of new rehabilitation centers on the basis of sanatoriums and resorts is especially necessary for a significant number of military and civilian populations of Ukraine. In the territory of Truskavets, Morshyn, Skhidnytsia and Velykyi Liubin, rehabilitation services are offered by the following sanatoriums and resorts: «Konvaliya», «Batkivshchyna», «Truskavetsky», «Dnipro-Beskyd», «Rixos-Prykarpattya», Rehabilitation Center «Modrychi», «Zeleny Bir», «Santa Maria», «Kyivska Rus», «Morshynkurort», « Velykyi Liubin» and others.

Despite the fact that the balneological resorts of the L'viv region have significant prerequisites for development, especially in the context of rehabilitation programs, they also face a number of problems:

- outdated material and technical base of sanatorium and resort facilities;
- wear and tear of medical equipment;
- intensive use of balneological resources;
- lack of qualified medical personnel;
- reduction of state funding;
- competition with European balneological resorts;
- increase in the cost of sanatorium and resort services;
- insufficient integration with public healthcare.

First of all, for the further development of these resorts it is necessary to:

- reconstruction of existing and construction of new sanatorium-resort facilities. The material and technical base plays an important role in the organization of sanatorium-resort treatment, recovery and rehabilitation. Reconstruction of facilities can affect the increase in work efficiency and their further development [5];
- the creation of modern rehabilitation centers today is an important direction of social integration of military personnel and civilians who need physical and psychological rehabilitation;
- in case of physical wear and tear of medical equipment – repair, replacement or purchase of new equipment;
- optimization of the use of balneological resources, which are the basis for the functioning of resorts. Within the framework of optimization, the following areas should be taken into account: monitoring the state of balneological resources, establishing maximum permissible recreational load standards, developing measures to protect resources, and implementing state control [5];
- improving the professional level of staff who will be able to provide high-quality and effective rehabilitation services;
- introduction of innovative treatment methods for the rapid and effective recovery of patients;
- development of individual rehabilitation programs and taking into account the characteristics of different categories of patients;
- popularization of the rehabilitation opportunities of balneological resorts through participation in forums and conferences to present the rehabilitation potential;
- expansion of state rehabilitation programs and increased funding.

CONCLUSIONS

Balneological resorts of the L'viv region have significant prospects for further development, as this sphere is one of the main social institutions that solves the problem of improving the quality of population health (one of the most important indicators of assessing human potential as the basis for the development of the country's economy).

The balneological resorts of Lviv region have significant potential for modern rehabilitation, which should be developed by improving rehabilitation programs and introducing the latest technologies. Further research will help expand the possibilities for using natural therapeutic factors for effective rehabilitation of diseases.

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REVIEW ARTICLE

The role of rehabilitation in the course of failed back surgery syndrome (FBSS)

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ABSTRACT

Aim: The purpose of this article is to discuss the role of rehabilitation in patients with failed back surgery syndrome (FBSS).

Materials and Methods: PubMed, Scopus and Google Scholar databases were searched to prepare the manuscript. Original papers, meta-analyses and review papers were included in the review, while conference proceedings, errata and letters to the editor were discarded.

Conclusions: The rehabilitation process is extremely important in the course of FBSS, but the therapy regimen should be individually tailored to the patient, with particular attention to the surgical method used previously and the time that has passed since the operation. Further research in this direction is needed.

KEYWORDS: physiotherapy, spine, spine surgery

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INTRODUCTION

Due to increasing life expectancy, there is an increasing demand for surgical procedures, including spine surgery [1, 2]. In some patients, despite the performance of surgery, complaints persist. Back pain syndrome after failed surgery (FBSS) is recognized [3]. FBSS is relatively common and affects 10-40% of operated patients [4, 5]. It is associated with a number of factors, including instability associated with the surgical procedure, especially if it is an extensive open technique procedure, such as poster lumbar interbody fusion (PLIF) [6-8], the patient's predisposition, such as a tendency to bleed more, a tendency to wound healing due to, for example, interventional comorbidities (diabetes, atherosclerosis) [9].

An important factor affecting the incidence of FBSS is overweight and obesity [10]. Another important factor is tissue scarring; the more invasive the procedure, the higher the risk [11]. An organic cause of pain is found in 90% of patients. Pathologic factors in the syndrome include scarring of the epidural and subarachnoid spaces, nerve ischemia, and local inflammation, which can become apparent on imaging studies [12]. Interestingly, the etiology of FBSS is usually surgical, but it can also be non-surgical. Slipman et al. [12] cite intervertebral foraminal stenosis (25-29%), discogenic pain (20-22%), pseudarthrosis (14%), neuropathic pain (10%), recurrent disc prolapse syndrome (7-12%), iatrogenic spinal instability (5%), intervertebral joint pain syndrome (3%) and sacroiliac joint pain syndrome (2%) as causes of FBSS. Therefore, medicine is looking for new, less invasive surgical techniques, such as endoscopic procedures to minimize the risk of FBSS [13].

Treatment of musculoskeletal pathologies, including the spine, is multidirectional. Increasingly, there is talk of the so-called three-stage concept of treatment of spinal pathology. This concept is based on the assessment and modification of risk factors, the implementation of medical therapy (in this case - surgical treatment of the spine), and then the timely implementation of the physiotherapy process. Depending on the surgical technique, the timing of physiotherapy implementation will vary [14]. The less invasive the surgical procedure, the shorter the time to start rehabilitation after spine surgery will be. Nevertheless, it should be remembered that the minimum period is 4-6 weeks. This is due to the healing time of the soft tissues [15]. In the case of herniated nucleus pulposus repair, taking physiotherapy too soon may result in a recurrent hernia [16]. Whether this is done by endoscopic technique, microdiscectomy or open hemilaminectomy technique. In each of these cases, there is a risk of recurrent hernia formation. Therefore, it is essential to implement a process of targeted physiotherapy for the operated spinal segment in a timely manner [16]. Table 1 presents the optimal time for implementing rehabilitation after spine surgery in the course of various pathologies.

Following surgery immediately, a number of improvement procedures are performed, learning to walk with/without orthopedic supplies, learning to sit up, implementing anticoagulation or breathing exercises, but exercises that load the operated spinal segment are not introduced [17]. The situation is similar in patients after stabilization procedures, such as PLIF, the time for targeted physiotherapy begins even 2-3 months after surgery, because too rapid

Table 1. Optimal time for implementation of rehabilitation after spine surgery in the course of various pathologies

Spine pathology	Surgical technique	Time of implementation of physiotherapy after surgery
Facet syndome	Radiofrequency (RF)	1-2 weeks
Cervical disc herniation (CDH)	Anterior cervical decompression and fusion (ACDF)	6-12 weeks
Lumbar disc herniation (LDH)	Endoscopic / microdiscectomy / classic herniectomy	6-12 weeks
Lumbar stenosis	Posterior lumbar decompression and fusion (PLDF)	2-3 months
Lumbar spondylolisthesis	Posterior lumbar decompression and fusion (PLDF) Extreme lateral interbody fusion (XLIF)	2-3 months

Source: compiled by the authors based on [14]

loading of the operated spinal segments is associated with the risk of implant loosening, and this is associated with reoperation [15].

The key in diagnosing FBSS is to determine the reason for the lack of improvement after surgery. Whether the pain is root in nature and reoperation is needed to decompress nerve structures, or whether the pain is of muscular origin, such as due to soft tissue scarring that has developed, and the patient can be treated minimally invasively, such as with pharmacotherapy, physiotherapy, spinal mesotherapy or spinal cord stimulation (SCS) [18,19,20]. Conventional treatment options typically include drug therapy, physiotherapy and neuromodulation, while bariatric surgery appears to be a potential adjunctive therapy for obese patients with refractory pain, as the factor causing the pain (obesity) is not eliminated in neurosurgery [12].

It is also important to keep in mind the greater trochanteric pain syndrome (GTPS), which may have been present before surgery and may be a major component of pain after surgery [21]. Steroid injections are an alternative in this case; nevertheless, medicine is looking for safer solutions such as injectable collagen therapy, especially in the group of geriatric patients with multimorbidity, and it is in this group of patients that most spinal surgeries are currently reported [1, 22-24] The right approach to treating FBSS is a broadly comprehensive treatment. Such an opportunity is offered to patients by rehabilitation, including spa treatment [25].

AIM

The purpose of this article is to discuss the role of rehabilitation in patients with failed back surgery syndrome (FBSS).

MATERIALS AND METHODS

PubMed, Scopus and Google Scholar databases were searched to prepare the manuscript. Original papers, meta-analyses and review papers were included in the review, while conference proceedings, errata and letters to the editor were discarded.

REVIEW AND DISCUSSION

THE ROLE OF REHABILITATION IN FBSS

As mentioned above, rehabilitation plays a very important role in FBSS but should be implemented taking into account many factors. The effectiveness of the treatment of a patient with FBSS is increased by the simultaneous use of pharmacotherapy, physiotherapy, interventional techniques and psychotherapy. Such management is part of the idea of multidisciplinary treatment of chronic pain. Rehabilitation programs should include a biopsychosocial approach that takes into account the biological, psychological and social aspects of the disease [12].

As we know from available studies in the literature, for example, gender does not affect the rehabilitation process in patients treated surgically and conservatively for discopathy [26]. However, it is known that smoking negatively affects the rehabilitation process and the level of pain intensity in patients after surgery for discopathy [27]. Timm KE, in 1994, published the results of a study showing the active approaches of low- and high-tech exercises provided the best results for FBSS patients, with low-tech exercise providing more sustained, cost-effective improvements [28]. Intensive physiotherapy and exercise programs are commonly prescribed for FBSS patients. Generally, authors agree that physical rehabilitation, in general, can help maintain or increase patient function [12, 19].

During the Covid-19 pandemic, access to the rehabilitation process was severely limited, and patients reported complaints of back pain despite surgery. This problem was solved by using telerehabilitation, that is, introducing the use of an online platform to provide exercise-related care [29].

The main goal of physiotherapy is to improve circulation to the affected tissues, relaxing them, since their key defense (compensatory) mechanism is their increased tension. The physical methods used have an anti-inflammatory, analgesic, myorelaxant effect and accelerate scar remodeling, as does injection collagen therapy [12]. Consequently, it is essential to strengthen the musculo-fascial corset that will stabilize the spine.

An individual program of comprehensive rehabilitation includes activating the patient, increasing the ability to cope with pain and its consequences, including a patient with an implanted spinal cord stimulator [30], educational and cognitive-behavioral therapy. Important is the identification of unresolved medical problems and their therapy, successively eliminating inappropriate medications and reducing their use as much as possible, alleviating symptoms, including depressive symptoms, setting realistic therapeutic and life goals, maintaining the effects of therapy, and finally social reintegration and return to work. The main components of multimodal programs are physical and kinesitherapy and psychotherapy. Gymnastics provides an opportunity for active cooperation and participation in pain control, improves overall mobility, quality of life for the patient, reduces pain intensity and level of disability [12].

It is also worth mentioning that physical therapy has limited therapeutic options in FBSS. The literature shows that transcutaneous electrical nerve stimulation (TENS) has documented effectiveness. It is of great importance especially after spinal stabilization procedures with muscle damage [31, 32].

Also, balneotherapy, as a treatment modality, can be helpful in relieving pain associated with the polyaminectomy syndrome (FBSS) [25].

The topic of FBSS treatment still remains difficult and requires the involvement of many specialists in various medical fields. As is well known, each subsequent spinal surgery increases the risk of postoperative complications. Therefore, solutions that are as minimally invasive as possible are being sought [33].

One method is epiduroscopy, which involves releasing adhesions inside the spinal canal, administering analgesics (such as bupivacaine) and anti-inflammatory drugs (such as dexamethasone). This method is minimally invasive, does not require general anesthesia and can reduce pain for 6-12 months [34].

Some patients develop spondyloarthrosis above or below the operated spinal segment, especially after the stabilization procedure. Facet syndrome develops. An alternative is the use of thermoablation, a radiofrequency technique. This is a safe and effective treatment method and can even be performed on an outpatient basis, usually under fluoroscopy [35].

In some patients, spinal surgery is of no benefit in the course of root pain. Therefore, in this group of patients, a procedure in the nature of neuromodulation of the previously compressed nerve root should be considered. For example, the pulsed radiofrequency (PRF) technique is used [36].

The mental and emotional state of FBSS patients is also an important consideration. Avila L. E et al. presented the results of a randomized trial comparing the effects of cognitive functional therapy (CFT) with core training exercise (CTE) [37], proving the effectiveness of functional cognitive therapy compared to the method used by physiotherapists.

To address the challenges and barriers to clinical treatment of FBSS, an international panel of physicians with a special interest in FBSS formed the Chronic Back and Leg Pain (CBLP) network with the primary intent of providing medical recommendations. A multidisciplinary approach to treating FBSS is now being promoted [32].

A limitation of this review article is the lack of citation of original randomized studies, with a long follow-up period, on large groups of patients. In addition, there is no consensus in the medical world on the precise timing of the inclusion of physiotherapy after spinal surgery and in the course of FBSS, although the authors' experience indicates the practical possibility of early inclusion of physical modalities such as low-intensity magnetotherapy or laser therapy and low-intensity exercises such as breathing exercises, adopting correct posture and isometric exercise.

CONCLUSIONS

The rehabilitation process is extremely important in the course of FBSS, but the therapy regimen should be individually tailored to the patient, with particular attention to the surgical method used previously and the time that has passed since the operation. Further research in this direction is needed.

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REVIEW ARTICLE

Analysis of indicators of providing sanatorium treatment for tuberculosis patients in Ukraine

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ABSTRACT

Aim: To examine the resource provision of anti-tuberculosis sanatoriums, which are subordinated to the Ministry of Health of Ukraine.

Materials and Methods: The materials were statistical data of the Ministry of Health, the Center for Public Health and the Center for Medical Statistics of the Ministry of Health of Ukraine. A statistical method was used to analyze the performance indicators of sanatorium treatment facilities for tuberculosis patients, and systematic, analytical and descriptive methods were used in the study of scientific works.

Conclusions: The number of sanatoriums for the treatment of tuberculosis patients for the period from 2015 to 2023 decreased, the rate of reduction amounted to 73.3% . As of 2023, there are 12 sanatoriums for tuberculosis patients under the jurisdiction of the Ministry of Health of Ukraine. The reduction in tuberculosis sanatoriums led to a decrease in hospital beds (rate of reduction -74.9%). In 2023, treatment and rehabilitation in tuberculosis sanatoriums could only pass 1009 patients (the rate of reduction -88.5%). The main problems in developing a network of sanatoriums for tuberculosis patients are insufficient funding, obsolete equipment and insufficient attention by the state to the comprehensive development of sanatoriums.

Sanatorium treatment is an important stage in the comprehensive treatment of tuberculosis patients. The organizational and economic mechanism for the development of tuberculosis sanatoria should be based on the mobilization of all available financial, material and human resources, with mandatory state support and responsibility of all participants in the process.

KEYWORDS: tuberculosis, sanatorium treatment, rehabilitation, tuberculosis sanatorium

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INTRODUCTION

The state and development of the medical industry affects the health indicators and quality of life of the population [1]. According to statistics, the health status of the population of Ukraine is unsatisfactory, the country has a, high level of morbidity and mortality among the population [2].

One of the current problems of the public health system of Ukraine and the world is the morbidity of the population tuberculosis [3-10]. World Health Organization data show that in 2023, the total number of people with tuberculosis was 10.8 million and 1.6 million people died from this disease [11].

According to the monitoring of the epidemic situation on tuberculosis in Ukraine, in 2023, the incidence of tuberculosis increased compared with 2022, and amounted to 48.4 per 100000 population against 45.1 per 100000 population. The highest incidence of tuberculosis per 100,000 population is observed in the Dnepropetrovsk (86.1), Kirovograd (92.1) and Odessa (99.6) regions; the lowest – in Kherson (15.2) and Donetsk (16.1). In Ukraine, the mortality rate from tuberculosis remains consistently high, in 2023 – 6.9 per 100.000 population. The number of children with tuberculosis has increased, in 2023 it was diagnosed in 835 children, compared to 577 in 2022. The total incidence of tuberculosis per 100.000 children is 11.4 in 2023, compared to 7.9 in 2021 [12].

Measures to monitor, diagnose, treat and prevent tuberculosis in the population are one of the main components of public health policy.

An important part of providing health services, along with prevention and treatment, is sanatorium treatment. Sanatorium treatment is an important step in the comprehensive therapy of tuberculosis patients and aims to restore and improve health [13, 14]. Adults and children with diagnosed tuberculos without bacterial infection after an acute phase or surgery may undergo rehabilitation in sanatoriums. Sanatorium rehabilitation of tuberculosis patients reduces the progression of the disease, prevents recurrence of the disease and improves the patient's ability to work [15, 16].

The reform that is currently being implemented in the health care system of Ukraine has also affected the establishment of sanatorium treatment. Inadequate funding of health system and problems of sanatoriums from the state budget led to a decrease in their number [16]. Scientists, investigating the problems of development and provision of sanatorium-resort treatment to the population, propose various approaches to improving the management system

and financing of sanatorium treatment institutions [13, 14, 16, 17]. However, there is little work devoted to the study and development of sanatorium treatment of tuberculosis patients. Therefore, it is necessary to conduct an analysis of the activities of tuberculosis sanatoriums in Ukraine, to determine the problems of developing the tuberculosis service.

AIM

To examine the resource provision of anti-tuberculosis sanatoriums, which are subordinated to the Ministry of Health of Ukraine.

MATERIALS AND METHODS

The materials were statistical and information data of the Ministry of Health, the Center for Public Health and the Center for Medical Statistics of the Ministry of Health of Ukraine. A statistical method was used to analyze the performance indicators of sanatorium treatment facilities for tuberculosis patients, and systematic, analytical and descriptive methods were used in the study of scientific works

REVIEW

Sanatorium treatment is an important component of the health care system, including medical, social, preventive and other measures aimed at restoring human capacity to function, eliminating or reducing manifestations of the pathological process; prevention of disability and preservation of human health [19, 20]. Sanatorium-resort treatment is medical assistance carried out with a preventive, curative or rehabilitative purpose using natural therapeutic means in the conditions of stay at the resort or health resort and in sanatorium-resort institutions [21].

The reduction of sanatoriums has brought changes in the provision of sanatorium treatment to the population. The epidemiological situation in the country due to COVID-19 also affected the provision of sanatorium treatment to the population [9]. The work of the sanatoriums was suspended, as a result of which there was a significant reduction in the number of days spent by patients in the sanatoriums. During the war, part of the sanatoriums remained in the occupied territories, some were destroyed, some moved to territory under the control of Ukraine [13].

There are problems in the financial support of sanatoriums. Sanatoriums that do not have funding under the agreement with the National Health Service of Ukraine, can be financed from the regional or local budget; transferred to a concession or merged with medical institutions, if these institutions can finance sanatorium treatment [16-22].

During the period 2019-2023, the number of sanatoriums subordinate to the Ministry of Health of Ukraine decreased from 104 to 31. As of 2023, the Ministry of Health of Ukraine is responsible for 31 sanatoriums, including 12 tuberculosis sanatoriums and 19 somatic profiles. Number of sanatoriums for the treatment of tuberculosis patients decreased by 33 (reduction rate -73.3%), number of sanatoriums with somatic profile – by 40 (reduction rate -67.8%) (Table 1) [23].

Tuberculosis treatment is a long-term process. One of the main goals in the treatment of tuberculosis is not only the recovery of the patient, but full body recovery during the sanatorium treatment. Sanatorium treatment of tuberculosis patients is carried out in anti-tuberculosis sanatoriums – institutions that carry out the prevention and rehabilitation of tuberculosis patients [13, 14].

The reform of the health system affected the TB sanatoriums of the Ministry of Health of Ukraine. These sanatoriums have been transferred to local government. However, due to the inability of local authorities' budgets to hold the sanatoriums financially, they faced the risk of closing and providing resources for these establishments became centralized again [13, 16].

Analyzing the dynamics of the work of tuberculosis sanatoriums of the Ministry of Health of Ukraine, it should be noted that their number in 2023 has decreased significantly compared to 2015 (the rate of reduction -76.9%) [23]. In 2023, the Ministry of Health of Ukraine manages 12 anti-tuberculosis sanatoriums (compared to 52 in 2015), of which 8 are for adults and 4 for children. Sanatoriums for tuberculosis patients for adults remained in Zhitomir (1), Ivano-Frankivsk (1), Kirovograd (1) and Kharkiv regions (5). There has been a significant decrease in the number of tuberculosis sanatoriums for children: 4 in 2023 compared to 33 in 2015 (-87.9%). Anti-tuberculosis sanatoriums for children remained in Kirovograd, Cherkasy and Kharkov regions (Table 2)

During the period from 2015 to 2025 there was a significant reduction of staff in tuberculosis sanatoriums of Ukraine. The reduction and closure of tuberculosis sanatoriums has led to a decrease in the number of staff. The decrease in the number of staff in the sanatoriums was faster than the overall decrease in the sanatoriums. With a 70.2% reduction in the number of tuberculosis sanatoriums (2019-2023), the number of individuals decreased by 89% in 2023 [23].

The reduction of TB sanatoriums of the Ministry of Health of Ukraine, led to a reduction in beds in sanatoriums (reduction

Table 1. Sanatoriums of the Ministry of Health of Ukraine

Sanatoriums population	2019	2020	2021	2022	2023	Rate of growth
All the sanatoriums	104	70	58	51	31	-70.2%
Tuberculosis	45	28	22	15	12	-73.3%
Somatic profile	59	42	36	36	19	-67.8%

Source: compiled by the authors of this study

Table 2. Number of tuberculosis sanatoriums of the Ministry of Health of Ukraine (2015-2023)

Regions	All sanatoriums			Sanatoriums for adults			Sanatoriums for children		
	2015	2023	rate of growth	2015	2023	rate of growth	2015	2023	rate of growth
Total in Ukraine	52	12	-76.9%	19	8	-57.9%	33	4	-87.9%
Vinnytsia	5	0	-100.0%	2	0	-100.0%	3	0	-100.0%
Volyn	2	0	-100.0%	1	0	-1000%	1	0	-100.0%
Dnipropetrovsk	7	0	-100.0%	2	0	-100.0%	5	0	-100.0%
Donetsk	2	2	0.0%	1	1	0.0%	1	1	0.0%
Zhytomyr	2	1	-50.0%	1	1	0.0%	1	0	-100.0%
Transcarpathian	1	0	-100.0%	0	0	0	1	0	-100.0%
Zaporizhzhya	1	0	-100.0%	0	0	0	1	0	-100.0%
Ivano-Frankivsk	1	1	0.0%	1	1	0.0%	0	0	0
Kyiv	0	0	0	0	0	0	0	0	0
Kirovograd	2	2	0.0%	1	1	0.0%	1	1	0.0%
Lugansk	1	0	-100.0%	0	0	0	1	0	-100.0%
Lviv	3	0	-100.0%	1	0	-100.0%	2	0	-100.0%
Nikolaev	1	0	-100.0%	0	0	0	1	0	-100.0%
Odessa	1	0	-100.0%	0	0	0	1	0	-100.0%
Poltava	3	0	-100,0%	2	0	-100.0%	1	0	-100.0%
Rivne	2	0	-100.0%	1	0	-100.0%	1	0	-100.0%
Sumy	1	0	-100.0%	0	0	0	1	0	-100.0%
Ternopil	2	0	-100.0%	1	0	-100.0%	1	0	-100.0%
Kharkiv	6	5	-16.7%	4	4	0.0%	2	1	-50.0%
Kherson	1	0	-100.0%	0	0	0	1	0	-100.0%
Khmelnitsky	2	0	-100.0%	0	0	0	2	0	-100.0%
Cherkasy	1	1	0.0%	0	0	0	1	1	0.0%
Chernivtsi	2	0	-100.0%	1	0	-100.0%	1	0	-100.0%
Chernihiv	1	0	-100.0%	0	0	0	1	0	-100.0%
city Kyiv	2	0	-100.0%	0	0	0	2	0	-100.0%

Source: compiled by the authors of this study

rate -74.9%). Most reduced beds in tuberculosis sanatoriums for children (reduction rate -81.4%) (Table 3) [23].

Reduction of the number of tuberculosis sanatoriums in the Ministry of Health of Ukraine, led to a decrease in the number of adults and children who could undergo treatment in sanatoriums (Table 4).

Among 19,000 adult tuberculosis patients, 1,009 people were able to receive treatment in sanatoriums in 2023 (rate of reduction is -88.5%). Among 835 tuberculosis patients of children 0-17 years old, in 2023 were able to undergo treatment in sanatoriums 332 children (rate of reduction -98.4%) (Table 4) [23].

DISCUSSION

After analysing the performance of the sanatorium service for tuberculosis patients, it should be noted that there has been a significant reduction in the number of tuberculosis sanatoriums, a decrease in staff resources, a decrease in the number of beds and the number of treated patients in sanatoriums.

The tuberculosis sanatoriums today face a number of problems that negatively affect their development. This is insufficient funding, wear and tear of the capital stock, lack of investment, insufficient attention and control of the state to the comprehensive development of sanatoriums [16, 17].

One of the reasons for the decrease in the number of sanatorium institutions is the imperfect financing system. The bulk of the financial resources of sanatoriums, which come from the state budget, are used to pay for the salaries of sanatorium workers and to pay for utilities. Insufficient financing of tuberculosis sanatoriums does not allow them to work at full capacity [14]. In a market economy, one of the important shortcomings of the management process and organization of the sanatorium is the lack of effective marketing policy, which has a great influence on the competitiveness of the sanatorium [22, 24].

Table 3. Number of beds in tuberculosis sanatoriums of the Ministry of Health of Ukraine

	2015	2023	Rate of growth
Total beds	5553	1 395	-74.9%
Adult beds	1767	690	-61 %
Beds for children	3786	705	-81.4%
Average number of days a bed is working per year	260.6	64,0	-75.4%
Average length of stay in bed	49.6	66.5	34.1%

Source: compiled by the authors of this study

Table 4. Number of patients in tuberculosis sanatoriums

	2015	2023	Rate of growth
Incoming patients (total)	29150	1341	-95.4%
Adults received	8784	1009	-88.5%
Children received	20366	332	-98.4%

Source: compiled by the authors of this study

Development of market relations, competition, introduction of new medical, rehabilitation and information technologies, Necessitate new approaches to the development of an economic mechanism for managing limited resources and require a new system of relations between the state and the health service, ensuring the treatment of tuberculosis patients [16].

In Ukraine, the main areas of the state in the fight against tuberculosis are medical and organizational. However, the development and improvement of activities aimed at prevention and recovery after tuberculosis treatment. Sanatorium treatment should be a stand-alone supplement in the system of combating tuberculosis. When implementing the reorganization and optimization of the tuberculosis service, it is necessary to take into account the status of the tuberculosis service of the specific regional center [18].

CONCLUSIONS

Sanatorium treatment is an important step in the comprehensive treatment of tuberculosis patients and in the prevention of tuberculosis among persons at risk. Proper planning and comprehensive application of rehabilitation measures and sanatorium treatment significantly improves physical health, functional state of organs and systems and has a positive impact on the quality of life of tuberculosis patients.

Insufficient financing of tuberculosis sanatoriums does not allow them to fully perform their functions. An unfavorable epidemiological situation with tuberculosis requires the development of an effective organizational and economic mechanism for regulating the sphere of sanatorium treatment of patients with tuberculosis.

The mechanism should be based on the mobilization of all available financial, material and human resources, mandatory government support, public awareness and responsibility of all participants in the process. Established rules, norms, standards should be an integral part of the system of economic relations that will influence the creation of optimal conditions for improving the efficiency of work of tuberculosis sanatoriums, and to contribute to the achievement of public policy objectives in the field of tuberculosis.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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REVIEW ARTICLE

Micro- and nanoplastic in the human digestive and urinary system

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ABSTRACT

Aim: To present the potential risks of introducing micro and nanoplastics into the human body through the digestive tract.

Materials and Methods: To compile this review, currently available scientific studies, other reviews, and meta-analyses on the topic of MNP, the digestive system, and the urinary system were analyzed. Available articles were analyzed in databases such as PubMed and Scopus. The databases were filtered using the terms: «microplastics»; «nanoplastics»; «food»; «intestines»; «stomach», «kidneys»; «liver»; «human». The most relevant literature sources were included in this review. The most recent articles were given priority.

Conclusions: The following work allows us to clearly state that MNP particles have a negative impact on the proper functioning of these organs. During the preparation of the review, scientific studies were analyzed on the basis of which similarities were observed in the effect of MNP particles on cells, tissues, and organs. The most frequently observed effect was the production of reactive oxygen species leading to inflammation in the tissue subjected to MNP. This similarity was observed regardless of whether the study was conducted on in-vitro cells or on living organisms. Many other individual effects were observed for the specificity of a given section of the digestive system. The current state of scientific knowledge on the influence of MNP particles on cells, tissues, and organs of the digestive and urinary systems of animal and human organisms is not sufficient. Further studies should be conducted to allow conclusions to be drawn on how MNP particles act on human and animal organisms.

KEYWORDS: plastic, microplastic, urology, stomach, food

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INTRODUCTION

Plastic is a general term for plastics. These materials are also called polymers because they are made of many mers, or small particles of the same compound. This structure allows them to create compounds with a higher molecular weight and appropriate physical and chemical properties. Plastic fragments are divided depending on their size, so nanoplastics are particles with sizes ≤ 100 nm, microplastics ≤ 5 mm, mesoplastics ≤ 25 mm and macroplastics > 25 mm [1].

Micro and nanoplastic particles are one of the problems of the modern world. The problem began when glass, paper, wood, and other raw materials started to be replaced with plastic. After the invention of plastic in 1862, many years had to pass before humanity began to notice the negative effects of this ubiquitous material. It was not until 2004 that the essence of this problem was realized when scientists began to present scientific studies confirming the presence of microplastics in the oceans. This publication showed the presence of plastic fragments smaller than 5 mm. Since then, plastic has continued to be used in production, but humanity has begun to ask itself many questions about the impact of MNP on the environment in which it lives and on its own body [1].

Science has been interested in it more deeply for less than ten years. Each year, the number of scientific papers on the subject of microplastics is higher than in the previous year. In recent years, the number of papers has increased by more than 100 times. In order to facilitate work with this material, a division is used into primary and secondary microplastics [1]. Primary microplastics are MP particles that are an element of manufactured products, such as personal hygiene products. These may be residues of toothpaste, hair gel, cleansing balm and air fresheners in the form of solid particles. They usually enter the environment along with discharged municipal sewage. Secondary microplastics are created as a result of subjecting fragments of plastics to chemical, biological, and mechanical processes. This happens, for example, with a plastic bottle lying on the beach for many years. Under the influence of rubbing against sand particles, water, MP particles crumble from it and end up in the environment. The crumbled fragments are secondary microplastics [1].

The statement that microplastics are a ubiquitous material is true. This is confirmed by studies that have shown the presence of MPs in seafood, mussels, oysters, table salt, sea salt, lake salt, rock salt, crustaceans and many species of fish [1], honey [2], poultry meat, plants [1], fruits and vegetables [3]. In the case of vegetables and fruits, there are currently not many studies that would give a broader picture of the content of MNPs in them. However, it is

believed that the way they are grown and transported has an impact on MPs in fruits. It is also found in drinking water - bottled water, tap water, white wine, milk, energy drinks and soft drinks, plastic cups, tea bags. Water from reusable bottles has a higher content of MPs than water from a single-use plastic bottle. This was due to the fact that the reusable bottle was subjected to mechanical processes such as washing, which led to the exfoliation of the plastic and the penetration of MNP particles into the water [1]. In addition to the penetration of MP from the living environment of food, for example the ocean to fish, it also gets into it during transport in containers made of plastic. Mechanical damage to such a container causes the penetration of MP into the food transported in it [1]. Scientists have also observed the presence of MP in everyday objects. Such as fabrics, low-quality clothes, household appliances, cups, caps, baby pacifiers, carpets, and floor coverings.

The main routes of entry of this material into the body are the digestive, olfactory and percutaneous routes [1, 4]. Micro and nanoplastic particles in the human body are an effect that can be reduced by introducing appropriate recycling or replacing this material with another. Contact with MNP is inevitable through the use of objects made of it, such as a keyboard, bottle, bag or notebook cover. We will not get rid of this source of MNP quickly due to the low cost and durability of plastic. However, we can try to eliminate it from food. The route of plastic absorption through food is more efficient than the percutaneous route. This means that this route poses a higher risk of MNP entering the body. MNP that enters this route is particularly dangerous to human health due to the fact that it can easily pass from the intestine into the circulatory system and with the blood can pass to all organs of the body [5, 6].

AIM

To present the potential risks of introducing micro and nanoplastics into the human body through the digestive tract.

MATERIALS AND METHODS

To compile this review, currently available scientific studies, other reviews, and meta-analyses on the topic of MNP, the digestive system, and the urinary system were analyzed. Available articles were analyzed in databases such as PubMed and Scopus. The databases were filtered using the terms: «microplastics»; «nanoplastics»; «food»; «intestines»; «stomach», «kidneys»; «liver»; «human». The most relevant literature sources were included in this review. The most recent articles were given priority.

REVIEW AND DISCUSSION

BOWELS. WAYS OF ENTRY OF MICROPLASTIC PARTICLES INTO THE HUMAN BODY THROUGH THE INTESTINAL TRACT

Not all MNP particles are absorbed into the body. This is evidenced by the presence of these particles in feces. According to the study [7], from 1 to 36 MNP parts/g of fecal mass were identified in human feces. These particles had sizes from 20 to 500 μm. MNP concentrations in the feces of infants were higher than in adults. Unexcreted MNP particles can be absorbed via enterococytes into the circulatory system. According to the analysis [8], this can occur by endocytosis, crossing the intestinal barrier by MNPs or through pores of intestinal epithelial cells formed by exfoliation of intestinal epithelium. In vitro studies analyzing the uptake of polystyrene MNPs in the epithelium of the small intestine [9] have drawn conclusions according to which NMP most likely enters by passive diffusion but also by active pathways such as phagocytosis.

THE IMPACT OF MICROPLASTICS ON THE HUMAN GUT MICROBIOME

So far, studies on this topic have been conducted mainly on animal organisms. They allow for the development of probable hypotheses as to how MNP will affect the human microbiome. Studies confirm that MNP molecules cause intestinal dysbiosis [10, 11]. Administration of MNP to mice, regardless of the dose, always causes intestinal dysbiosis. In the tested samples, a significant increase in *Firmicutes* and *Bacteroidetes bacteria* was observed, as well as a decrease in the ratio between *Firmicutes* and *Bacteroidetes bacteria*. Contact of the mouse intestinal microbiome and MNP results in the growth of harmful bacteria such as *Escherichia-Shigella*, *Enterobacteriaceae* and *Erysipelotrichales*. The longer the time, 14 days of contact of the mouse intestinal microbiome with MNP, the greater the increase in the content of these bacteria. Bacteria responsible for maintaining the stability of the intestinal microbiome, *Lachnospiraceae* and *Clostridia*, showed a significant increase compared to control organisms. After 28 days of exposure of mice to MNP, a decrease in *Lachnospiraceae* and *Clostridia bacteria* was observed. This gives rise to dysbiosis of the mouse gut microbiome. This study result allows us to conclude that MNP has a negative effect on the mouse gut microbiome, dysbiosis of the gut microbiome, which gives rise to inflammation [12].

Human intestinal cells isolated in the laboratory using the in vitro method were stimulated with PE MP and the intestinal microbiome of an infant and an adult was observed to behave [13]. These studies gave the same effect as in mice, i.e. PE MP caused intestinal dysbiosis. The intestinal microbiome of a child changes its composition after contact with PE MP. There was an increase in the population of *Nterobacteriaceae*, *Oscillospiraceae*, *Dethiosulfovibrionaceae* and *Moraxellaceae bacteria* relative to the population of *Monoglobaceae*. In the adult organism model, these changes concerned other intestinal pathobionts because there was an increase in *Desulfovibrionaceae*, *Dethiosulfovibrionaceae* and *Enterobacteriaceae*, as well as a decrease in the population of *Akkermansiaceae* and *Christensenellaceae*, considered indicators of a healthy intestinal state. This study also allowed the identification of a biomarker of the presence of PET MP in the intestinal microbiome. These include *Proteobacteria* and *Synergistetes* from the *Dethiosulfovibrionaceae* class because the presence of MP in the intestine was associated with an increase in their numbers [13].

PENETRATION OF MNP PARTICLES THROUGH THE INTESTINAL BARRIER

Animal studies [10, 14, 15] confirm that MNP particles disrupt the functioning of the intestinal barrier, penetrate it and are transported to the liver. The intestinal barrier is formed by tightly adherent enterocytes. Its task is to regulate the passage of nutrients and substances from the intestinal lumen to the interior of the enterocytes. At the same time, it protects against the penetration of toxins and pathogens. MNP, which is located in the intestinal lumen, affects the tightness of the barrier because it causes oxidative stress, which causes a higher level of mitochondrial depolarization, and this increases the permeability of the intestinal barrier [8]. This allows MNP to penetrate deep into the body and allows it to have a systemic effect. Whether the particle penetrates the intestinal barrier and in what quantity depends on the material it is made of [14]. The absorption of the tested particles ranged from 4% to 15%, and in the case of PLA2000 microparticles, 20 - 70%, and in the case of PLA250 and MF366 submicroparticles. In the case of PMMA25 nanoparticle, almost no cellular interaction was detected. All types of particles that were taken up by intestinal epithelial cells were also identified in hepatocytes. The most numerous were PLA250 particles.

THE INFLUENCE OF ALCOHOL PRESENCE IN THE INTESTINES ON THE ABSORPTION OF MICROPLASTICS

The presence of ethanol in the intestine affects the absorption of MP. This was confirmed in mice [16]. MP particles that bound to ethanol after penetrating the intestinal wall were transported to the liver. The liver of mice given MP with ethanol was in worse condition than those given MP alone. The liver in these mice was enlarged, contained more lipid droplets and showed a higher pattern of liver contusion. In the histopathological analysis of the liver of both mice, both those given MP alone and those given MP with ethanol, the presence of MP was observed, however the amount of MP in the liver tissue of mice given ethanol and MP was higher. The accumulation of microplastics in the spleen was three times higher in mice given MP with ethanol than in those given MP alone.

INTESTINAL INFLAMMATION CAUSED BY CONTACT WITH MNP PARTICLES

NMP particles affect the intestinal immune system. They activate macrophages and dendritic cells in the intestines. Activated cells secrete cytokines and chemokines that generate inflammation in enterocytes. MNP particles in enterocytes are received by the body as reactive oxygen species or activate the production of reactive oxygen species after entering the intestine. Therefore, MNP disturbs the balance between oxidants and antioxidants, causing oxidative stress. Oxidative stress contributes to local damage to intestinal tissue, the production of inflammation and intestinal barrier dysfunction [15]. All these effects of MNP presence in the intestines contribute to the occurrence of inflammatory bowel disease (IBD), Crohn's disease (CD), ulcerative colitis (UC) and colorectal cancer (CRC). The number of people in society with intestinal inflammation is increasing. This is observed especially in newly industrialized and developing countries where environmental pollution is higher. People with intestinal inflammation are more susceptible to MNP penetration into the tissues because the integrity of their enterococci is lower than in healthy individuals, which allows for easier penetration of MNP into the tissues [13].

STOMACH

The study that most clearly illustrates the problem of microplastics in the human body and stomach is the one conducted on human bodies. Samples from the stomachs of 26 corpses were used. The bodies came from 20 men and 6 women aged 18 to 72. The median age was 46.8 years. MP was identified in all samples from 26 different people. A total of 97 MP particles were extracted. From 1 to 14 MP particles were identified in each body sample. After averaging, it was shown that there were 9.4 +/- 10.4 MP particles per person. The dominant form was fibers, then fragments, and the least common was the purple form. MP fragments were mainly blue, red or transparent [17]. Currently, there is even less data analyzing the effect of MP on stomach cells than on intestinal cells. Based on the study conducted on SNU-1 stomach cells, it can be concluded that the absorption of MP particles by stomach cells depends on their size and the material from which they were made. Amine MP particles of 50nm are absorbed more frequently than 100nm particles, and the latter more frequently than 1000nm. There is no difference between the absorption of carboxylic and non-functional MP particles of 50nm and 100nm, but their absorption is still greater than that of 1000nm. Amine particles were absorbed most easily, carboxylic and non-functional particles were absorbed worse. More MP particles of 50 and 100nm, regardless of type, were observed in the cytoplasm of cells and on the cell membrane compared to those of 1000nm, which were present only on the cell membrane. Death of stomach cells was the most frequent and fastest in samples with amine MP particles of 50nm. It occurred more slowly in samples with carboxylic and non-functional particles due to the slower absorption process of these particles [18].

Microplastics irritate the gastric mucosa. PMMA MNP particles [19] cause aging of gastric epithelial cells by stimulating the production of reactive oxygen species and damaging the DNA repair mechanism. The main reason for this is damage to the NHEJ pathway. Gastric cells (GES-1) stopped multiplying and forming a colony at an appropriate concentration. This was more visible the higher the concentration of PMMA MNP used. This was noticed after exposure to 4 μg/ml PMMA NP. Similar results were obtained using gastric NGEC cells. Contact of PMMA particles with gastric cells contributes to a natural immune response, which results in inflammation of the stomach [19].

KIDNEYS

In the study of MP in urine and kidneys [20] 10 healthy individuals were included. Urine samples were collected from them. Samples from 10 kidneys were collected from kidneys removed due to tumors ranging in size from 1 to 4 g.

A total of 66 MP fragments were detected in the study. 23 were from urine samples and 43 from kidney tissue. Most of the identified fragments were smaller than 10 µm. Polyethylene and polystyrene were the types of MP that accounted for the majority of detected MP. Other forms of MP that were detected most frequently in the samples but were in the minority were Cu-phthalocyanine and hematite. In the study [21] polystyrene MP particles were also detected in kidney cells. Renal cells in contact with 1 µm MP particles reduce their metabolic and proliferation rates. These cells stopped forming a tightly adherent cluster but started to move away from each other, becoming more and more dispersed. An increase in reactive oxygen species was also observed. The effect of MP was also studied in mice [22] and confirmed that MP accumulates in the kidneys and causes histopathological damage to the mouse kidney. An increase in markers of endoplasmic reticulum stress, inflammation and neurotoxicity was observed. Another analysis [23] showed that NP polystyrene disrupts lipopolysaccharide-induced apoptosis in mouse kidney cells via the oxidative stress pathway – endoplasmic reticulum. NP particles induce inflammation, oxidative stress and lipid disorders. Long-term exposure of NP to kidney cells caused renal tubule atrophy, glomerular collapse and inflammatory cell infiltration. As for the effect of polystyrene MP particles on mouse kidney cells, it is similar to the effect of polystyrene NP on the studied kidney cells. It causes an increase in reactive oxygen species, proteins associated with cell stress, biomarkers of inflammation and autophagy. Accumulating polystyrene MP particles in the studies caused an increase in mortality, loss of mouse body weight and histological damage to the mouse kidneys [23].

LIVER

In the study [24] the effect of NP particles on the metabolism of human liver cells from the line (L02) was examined. Liver cells were exposed to NP particles at various low concentrations (0.006, 0.0125, 0.0312 mg/ml) and high concentrations of NP (0.125 and 0.25 mg/ml). Mitochondrial damage was demonstrated by the overproduction of mitochondrial reactive oxygen species (mROS) and the suppression of mitochondrial membrane potential (MMP) and mitochondrial respiration. It was shown that low NP concentrations stimulate cells to activity. This is due to the fact that hepatocytes try to fight NP particles. The higher the NP concentrations used, the more the viability of the tested cells decreased. The tested cells absorbed NP into the cytoplasm. The higher the NP dose the cells were exposed to, the more intensive their absorption was. This resulted in an increase in mitochondrial reactive oxygen species. The production of mROS in liver cells always occurred regardless of the dose of NP absorbed. The release of additional mROS in cells disrupts the mitochondrial membrane, thus affecting the mitochondrial membrane potential. It increases mitochondrial damage and slows down the intensity of ATP production [24].

Oral administration of MNP was used in mice [10]. The tested mice were given MNP orally through food and pathological changes in hepatocytes were observed. These changes included punctate necrosis, edema, vacuolization and karyopyknosis in liver cells. In the groups that were given MNP through air, vacuolization and karyopyknosis were also observed, but to a lesser extent. NP has worse effects on the body than MP. Oral administration of MNP resulted in a change in the activity of hepatic pathways. Oral administration of NP particles resulted in increased activity of nine pathways. The most active pathway was the one associated with the circadian rhythm of mice. Oral administration of MP particles resulted in increased activity of hepatic pathways such as «pancreatic secretion», «protein digestion and absorption» and «digestion and absorption of fats» [10].

MNP MAY CONTRIBUTE TO FOOD ALLERGIES

The current studies collected in the analysis [15] allow us to conclude that NP absorbed by intestinal cells promotes allergic diseases. A positive relationship was found between exposure in late pregnancy to chemicals that are used as plasticizers in plastic products and atopic dermatitis and allergic respiratory inflammation. Mice exposed to oral bisphenol A exacerbate inflammatory allergies of the digestive system. In addition, it was observed that MP in the intestines can suppress the immune system and increase the likelihood of gastrointestinal diseases, such as nonspecific bowel disease and increase the risk of food allergy. Enterocytes in contact with MP release cytokines such as IL-33, IL-25 and TSLP, which expand group 2 innate lymphoid cells, which produce IL-4, IL-5 and IL-13.30,31 These cytokines stimulate dendritic cells to induce a Th2 phenotype on T lymphocytes, and also directly stimulate adaptive Th2 immunity and subsequent allergic response. Intestinal dysbiosis, which is the effect of MNP in the intestines, also contributes to the occurrence of gastrointestinal allergies [15].

MICROPLASTICS AS A SOURCE OF MECHANICAL AND CHEMICAL MICRODAMAGE IN THE DIGESTIVE TRACT

MP particles absorbed with food can cause mechanical and chemical damage in the digestive tract. This damage may result from fragments of plastics rubbing against the tissue of the digestive tract and from the reaction of the cells of the digestive tract and hydrochloric acid interacting with chemicals that are used to give the appropriate properties to plastics [25].

POTENTIAL DISEASES AS EFFECTS OF MNP IN THE BODY

Currently, we do not have enough data to clearly state how MP will affect human health. However, certain conclusions can be drawn based on how other animal organisms react to the presence of MP in their bodies. Scientists have found that MP in the human body can cause inflammation associated with RA, nonspecific bowel disease, cancer, heart disease, genotoxicity, chronic diseases such as diabetes, atherosclerosis and autoimmune diseases, neurodevelopmental diseases, reproductive problems, and asthma [26]. It is also known that children's organisms cope worse with MNP particles than

adults. However, at present there is not enough research to indicate the long-term and generational effects of the body's contact with MNP particles [15].

CONCLUSIONS

Micro and nanoplastics are a serious issue because their presence in water and food poses a threat to human health. The penetration of MNP into human tissues depends on the material from which it comes. Regardless of where it occurs in the digestive system, it always contributes to the growth of reactive oxygen species and the creation of inflammation. This is a serious problem because the inflammation caused by MNP will not be easy to remove due to the currently unavailable methods of removing these particles from the body. MNP also contributes to faster mortality and separation of cells that build the tissue of the organ. This weakens the regenerative capacity of the organ. Such an organ will cope worse in the event of a disease. Weaker regeneration capacity may contribute to tissue death. MNP also disrupts the mechanisms of repairing damaged DNA. This may negatively affect the body's defense against cancer cells.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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REVIEW ARTICLE

Whole-body cryotherapy for mental health and cognitive function: A potential therapy for CFS and long COVID?

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ABSTRACT

Aim: To present the potential role of whole-body cryotherapy (WBC) in improving mental health and cognitive function in patients with Chronic Fatigue Syndrome (CFS) and Long COVID Syndrome (LCS), based on current scientific evidence.

Materials and Methods: A review of international literature from the last decade concerning the application of WBC in patients with CFS and LCS was conducted. Sources included randomized controlled trials, clinical case reports, and systematic reviews focusing on mental health, cognitive outcomes, and physiological mechanisms associated with whole-body cryotherapy. Emphasis was placed on mechanisms involving neuroinflammation, oxidative stress, and autonomic regulation.

Conclusions: WBC shows promise as an adjunctive, non-pharmacological intervention for reducing fatigue, alleviating depressive symptoms, and improving cognitive function in CFS and LCS. Its therapeutic potential is linked to autonomic and neuroendocrine modulation, reduction of inflammation, and enhanced antioxidant capacity. While existing studies support WBC's safety and short-term efficacy, further clinical trials are necessary to standardize treatment protocols and assess long-term benefits across diverse patient populations.

KEYWORDS: chronic fatigue syndrome, long COVID syndrome, cold therapy, mental health

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INTRODUCTION

Chronic Fatigue Syndrome (CFS) is defined by persistent and unexplained fatigue that does not improve with rest and is often worsened by physical or mental activity. This condition is believed to involve complex interactions among immunological, psychological, and neurological factors [1, 2]. In contrast, Long COVID Syndrome (LCS) refers to a spectrum of symptoms that manifest following the resolution of acute COVID-19 infection, typically persisting for over four weeks or 3 months after infection, for at least 2 months and which cannot be explained by other causes and include fatigue, cognitive impairment and various neuropsychiatric symptoms [3-5]. CFS and LCS have emerged as significant health concerns, characterized by debilitating fatigue and cognitive dysfunction.

CFS and LCS exhibit significant overlap in their presentations, specifically concerning chronic fatigue and cognitive impairments. These conditions are characterized by debilitating fatigue that persists over time and is often exacerbated by physical or mental exertion, leading to substantial reductions in daily functioning. Research highlights that cognitive dysfunction, frequently referred to as "brain fog" is a prominent symptom in both CFS and LCS, affecting memory and attention [6, 7]. Furthermore, the chronic nature of these conditions and the absence of effective cure underline the necessity for holistic approaches to management.

Whole-body cryotherapy is a therapeutic technique that exposes the entire body to extremely low temperatures, usually in the range of -100°C to -140°C, for short periods of time, usually one to four minutes [8]. The procedure is carried out in specially designed cryochambers, where patients experience the effects of the cold, which trigger various physiological responses designed to facilitate recovery, reduce inflammation and improve overall health. The range of temperatures in cryochambers can vary depending on the country in which the study is performed [8]. Furthermore, WBC is purported to exert antiinflammatory effects through the suppression of pro-inflammatory cytokine synthesis. Additionally, the intervention is known to stimulate the autonomic nervous system, with potential ramifications for the enhancement of cardiovascular function. Emerging evidence further suggests that WBC modulates systemic antioxidant capacity, potentially mitigating oxidative stress and fostering redox homeostasis [9]. These physiological mechanisms collectively support pain alleviation, attenuation of inflammatory responses, and enhancement of musculoskeletal function. WBC is currently under investigation as a potential therapeutic approach for various pathological conditions, including, e.g. rheumatoid arthritis, ME/CFS, fibromyalgia, long-COVID syndrome, multiple sclerosis, obesity, and musculoskeletal injuries related to sports activity. Nevertheless, the comprehensive spectrum of its benefits, as well as possible adverse effects,

remains an area of ongoing scientific inquiry [10]. Research indicates that WBC may contribute to an increase in parasympathetic activity, thereby reducing stress and anxiety, which are commonly associated with conditions such as depression [11]. Multiple studies suggest that WBC can alleviate depressive symptoms. For instance, the stimulation induced by cryotherapy sessions promotes the release of endorphins, which can improve mood and help manage conditions such as depression and anxiety [12]. Similar conclusions were shown in a randomized controlled trial by Rymaszewska et al., who investigated the effects of WBC as an add-on treatment for depression, demonstrating significant improvements in patients' mental health outcomes when combined with standard pharmacological treatments [13]. Moreover, studies suggest that WBC may enhance neuroplastic adaptations, leading to more resilient neuronal pathways, which could offset cognitive deficits often observed in neurodegenerative conditions or post-viral syndromes [14].

AIM

The purpose of this review is to highlight the beneficial effects of Whole-Body Cryotherapy on mental health and the enhancement of cognitive functions in both healthy individuals and patients with LCS and CFS.

MATERIALS AND METHODS

A review of international literature from the last decade concerning the application of WBC in patients with CFS and LCS was conducted. Sources included randomized controlled trials, clinical case reports, and systematic reviews focusing on mental health, cognitive outcomes, and physiological mechanisms associated with whole-body cryotherapy. Emphasis was placed on mechanisms involving neuroinflammation, oxidative stress, and autonomic regulation.

REVIEW AND DISCUSSION

WHOLE BODY CRYOTHERAPY IN HEALTHY INDIVIDUALS

Whole-body cryotherapy is extensively employed as a post-exertional recovery strategy among healthy people, often as a biological rejuvenation, as in the case of elite athletes [15]. In recent years, WBC has been increasingly utilized in healthy individuals as a strategy to enhance overall well-being. Preliminary research suggests potential benefits of WBC at -130 °C in the domain of mental health, including improvements in quality of life, attenuation of depressive symptoms, and enhancement of cognitive functions, as well as the reduction of oxidative stress and inflammatory biomarkers [16]. Research indicates that WBC can have significant physiological effects, including alterations in blood parameters and antioxidant profiles. For instance, a study by Stanek et al. demonstrated that healthy individuals exposed to WBC at -120°C showed a decrease in oxidative stress levels, suggesting an improvement in the antioxidant capacity of the body [17]. WBC is also postulated to exert a modulatory influence on selected immune parameters. Consequently, regular exposure to cryogenic conditions following SARS-CoV-2 infection may facilitate immune system recovery in convalescent individuals, potentially contributing to the enhancement of their overall well-being [18]. Augustyńska et al. indicate that WBC at -120°C to the final -145°C may enhance cognitive functions among healthy individuals, particularly following structured interventions like training camps, where athletes not only engage in physical activities but also undergo multiple sessions of cryotherapy. Such exposure is posited to foster improvements in neural transduction, evidenced by relationships drawn between enhanced blood parameters and cognitive health [19]. Furthermore, studies suggest that WBC influences levels of pro-inflammatory cytokines and oxidative stress markers, potentially leading to physiological responses that may enhance cognitive acuity and mood states. Research conducted by Lubkowska et al. noted the immune modulation effects of WBC at -130°C, which could also have ramifications for mental health. The enhancement of noradrenaline release among other neurotransmitters might underline the psychological benefits attributed to WBC, making it a plausible candidate for alleviating depressive symptoms in healthy individuals [20]. The relationship between physical recovery and psychological well-being has been partially addressed by Hausswirth et al., who demonstrated that WBC at -110 °C significantly influence autonomic nervous system activity. Following a single session, a marked increase in parasympathetic tone and a substantial rise in circulating catecholamine were observed. Given the role of these neurophysiological mechanisms not only in physical stress regulation but also in mood and emotional processing, the findings suggest that cryostimulation may indirectly contribute to psychological benefits, such as reduced anxiety and improved mental recovery [21] (Fig. 1).

WHOLE BODY CRYOTHERAPY *VS* LCS

The effects of WBC on cognitive function and mental health, particularly in patients suffering from Long COVID Syndrome (LCS), are gradually gaining attention in the scientific literature. While research specifically targeting LCS patients is still limited, various studies exploring the general benefits of WBC on psychological well-being and cognitive performance provide valuable insights. One significant study by Rymaszewska et al. evaluated the impact of WBC at temperatures from -110 °C to -160 °C on cognitive deficits in subjects with Mild Cognitive Impairment (MCI). In randomized controlled trial it was found that WBC is associated with improvements in mood, which was detected in self-reported depressive symptoms level in World Health Organization Quality-of-Life Scale (WHOQoL-26). Moreover, the same research showed improvement in cognitive function, suggesting a potential avenue for alleviating symptoms prevalent in patients with fatigue syndromes, because it has been shown that WBC can regulate brain-derived neurotrophic factor (BDNF) levels [22]. The relationship between LCS and Multiple Sclerosis (MS) is a subject of increasing research interest. In MS

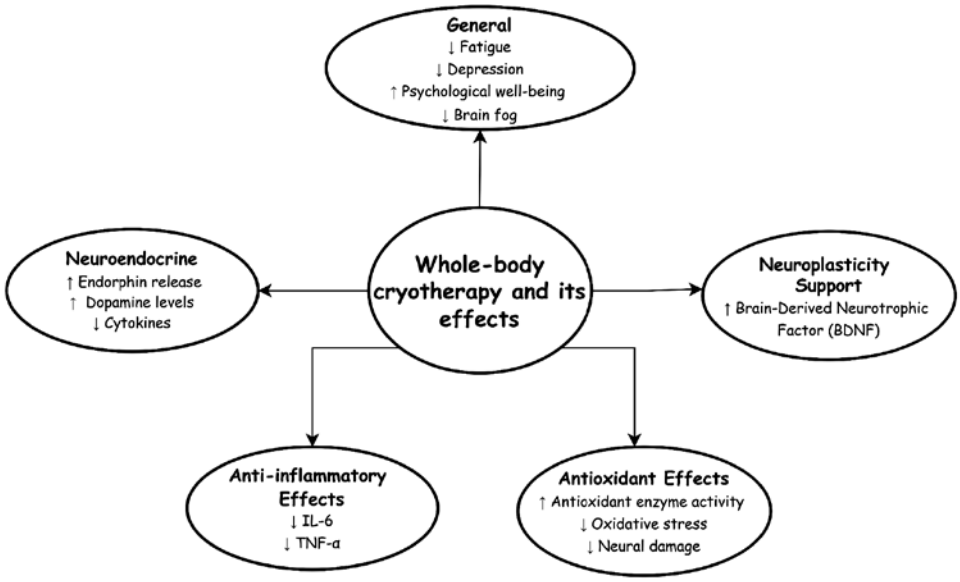

Fig. 1. Effects of Whole-body cryotherapy on mental health and cognitive function according to the latest literature sources

Source: compiled by the authors of this study

patients, an impairment in IFN-I response has been widely described at the genetic and transcriptional levels and is confirmed by three decades of successful treatment with IFN-1B formulations. Studies on severe COVID-19 patients highlighted a defective IFN-I production, with a consequent delayed and unrestrained T cell response, enhancing both viral spread and cytokine release that predispose to multiorgan failure. Bellucci et al. discuss the interplay between SARS-CoV-2 and multiple sclerosis, specifically identifying the potential for COVID-19 to trigger neuroinflammatory responses, which could lead to symptoms reminiscent of those seen in MS. They suggest that the mechanisms by which COVID-19 affects the central nervous system (CNS) might extend our understanding of the etiology of MS and related conditions. This highlights the possibility that viral infections may contribute to the manifestation of autoimmune symptoms in susceptible individuals [23]. Moreover, research by Pawik et al. demonstrated the beneficial psychological effects of WBC at -110 °C on patients with multiple sclerosis, indicating that cryotherapy can alleviate depression and enhance overall psychological well-being [14]. Their findings highlight the potential parallels in mood enhancement and improved functional status that could be beneficial for LCS patients suffering from depression or anxiety. Furthermore, investigations into oxidative stress suggest that WBC at temperatures from -60 °C to -140 °C can positively modify oxidative markers, which may influence neuroinflammatory processes often exacerbated in chronic conditions [24]. Stanek et al. also observed beneficial effects of WBC at -120 °C on oxidative stress parameters, which can contribute to broader implications for cognitive and psychological improvements in patients [25]. The modulation of systemic inflammation through cryotherapy could reduce neuroinflammation, a characteristic involved in many post-viral syndromes, thus offering potential therapeutic pathways for individuals dealing with LCS. Additionally, a broader review by Krzystanek et al. discusses various studies indicating improved depressive symptoms and cognitive enhancement through WBC at temperatures from -110 °C to -160 °C, suggesting that extreme physical stimuli like cryotherapy could evoke significant therapeutic effects in patients with chronic health conditions, potentially applicable to those with LCS [11].

WHOLE BODY CRYOTHERAPY *VS* CFS

Whole-Body Cryotherapy is being studied for its potential effects on cognitive function, depression, and mental health, particularly in patients suffering from Myalgic Encephalomyelitis (ME), also called Chronic Fatigue Syndrome (CFS). Recent literature suggests that WBC may help alleviate symptoms related to cognitive dysfunction and mood disturbances common in CFS patients. In the pivotal study, Kujawski et al. examined the effects of combining WBC at -110 °C with static stretching exercises [26]. The findings indicated a significant reduction in fatigue levels among CFS patients who underwent this combined treatment. Notably, cognitive improvements were also reported, specifically in the speed of processing visual information and set-shifting capabilities. The study concluded that the combination of these therapies is well tolerated and can lead to positive changes in cardiovascular and autonomic functioning [26]. These results suggest that WBC may help mitigate some of the cognitive difficulties often experienced in CFS by addressing both physical fatigue and associated cognitive deficits. In another study published in 2021, Kujawski et al. investigated how WBC at -110 °C and static stretching affected the allostatic response, a term referring to the body's ability to maintain stability through change of CFS patients compared to healthy individuals [27]. This comparative analysis involved measuring fatigue, cognitive function, cardiovascular metrics, and autonomic nervous system responses before and after completing a 10-session program

of WBC combined with static stretching. The results showed that CFS patients displayed significant changes in fatigue levels and cognitive performance after the interventions, reinforcing the hypothesis that WBC may enhance both physical and cognitive resilience in individuals with CFS [27]. Miller et al. studied the benefits of WBC at -120 °C in different patient populations, including multiple sclerosis, which shares characteristics with CFS, such as fatigue and cognitive impairments. Their findings indicated that WBC is effective in reducing fatigue levels and improving functional status, suggesting its potential application in managing CFS symptoms [28]. Diving into the biochemical effects, Dziedzic et al. highlighted that WBC at -120 °C might target neuroinflammation and oxidative stress, factors known to contribute to cognitive deficits observed in chronic fatigue syndromes [29]. By potentially modulating these pathways, WBC could lead to improvements in both cognitive function and emotional well-being.

CONCLUSIONS

WBC appears to be a promising non-pharmacological intervention with beneficial effects on mental health and cognitive function in both healthy individuals and patients suffering from CFS and LCS. Evidence suggests that WBC may alleviate depressive symptoms, enhance cognitive performance, and support autonomic balance, potentially through mechanisms involving neuroinflammation reduction, oxidative stress modulation, and neuroendocrine stimulation, as shown in Figure 1. These effects are particularly relevant for conditions characterized by fatigue, cognitive impairments, and mood disturbances, where conventional treatments offer limited efficacy. The reviewed studies underscore the therapeutic potential of WBC as part of a multidisciplinary approach to managing chronic fatigue-related disorders. However, while initial findings are encouraging, the heterogeneity of study designs and patient populations highlights the need for further well-designed, randomized controlled trials to confirm efficacy, establish optimal treatment parameters, and evaluate long-term outcomes. Future research should also explore the integration of WBC with other rehabilitation strategies to enhance recovery and quality of life in individuals affected by CFS and LCS.

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CASE STUDY

Comprehensive rehabilitation of a child with organic pathology, own clinical experience

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ABSTRACT

A girl M., 17 years old, was a patient under observation. The diagnosis was cerebral palsy, right spastic hemiplegia (consequences of perinatal lesion of the central nervous system); psychomotor and communicative retardation; condition after birth trauma (intraventricular hemorrhage) with hypoxia and coma during the neonatal period. The medical records of an inpatient undergoing a rehabilitation cycle were analyzed on the base of the Municipal Institution «Zalishchyky Children's Medical Rehabilitation Center» in Ternopil region.

The rehabilitation course lasted 14 days and included realization of an individual program of physical therapy developed according to the patient's clinical condition and regulations of the individual rehabilitation program.

The results of the rehabilitation course are indicative of a significant positive dynamics of the patient's clinical condition. Muscle spasticity reduced, postural control improved, walking pattern became stable and general motor activity increased.

Organic lesions of the central nervous system in childhood remain one of the most serious medical and social issues of current medicine. Movement disorders attract special attention of specialists, certain forms of cerebral palsy in particular, such as spastic hemiplegia. Such conditions are often associated with functional disorders of the muscular-skeletal system, speaking, and cognitive development, requiring early, systemic and comprehensive approach to rehabilitation.

KEYWORDS: rehabilitation, children, cerebral palsy

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INTRODUCTION

In previous years, the World Health Organization (WHO) has estimated that approximately 2,4 billion people in the world need rehabilitation aid to improve their quality of life and health [1]. Currently, this amount is growing continuously due to survival of children with organic neurological pathology. Therefore, rehabilitation aid is an integral part of health care combining preventive, curative or therapeutic, and palliative services. The WHO defines rehabilitation as a set of interventions designed to optimize functioning and reduce disability in individuals with health conditions in interaction with their environment [2]. One of the priorities of the WHO is a universal health coverage [3].

In 2019, the WHO Rehabilitation 2030 Initiative emphasized that cerebral palsy is the most severe global burden among all the non-communicable chronic diseases due to its occurrence [4]. Cerebral palsy is a neurological non-progressive disease occurring due to brain damage. Its onset is very early during the antenatal or intranatal periods of development. The prevalence of cerebral palsy ranges from 2 to 2,5 cases per 1,000 live births [5]. Cerebral palsy significantly limits activity, and its signs even can deteriorate during the life span [6]. The disease is associated with communication and speaking difficulties, poor fine motor skills due to psychomotor disorders, excessive salivation, sleep disorders, changes of the psychic condition and pain syndrome caused by spasticity. Cerebral palsy is not only the most common motor disorder of children associated with lifelong disability and multiple disorders, but with multiple morphological clinical manifestations. Clinical signs of cerebral palsy are different in children. Since this organic disabling pathology is accompanied by a wide range of problems. All these require development and implementation of an effective health care system that should significantly influence upon everyday functioning and quality of life [7]. Developing new intervention strategies, sharing experience, and a systematic approach to improvement and optimization are key points in rehabilitation of children suffering from cerebral palsy [8]. Timely and correct diagnostics assuming categories of clinical subtypes of cerebral palsy, assessment of motor function, and directed to identification of concomitant diseases, is crucial for early intervention and further observation and rehabilitation [9]. Early rehabilitation programs should meet the age and functional status of children with cerebral palsy.

An early comprehensive effect on various functional systems of the body is the most balanced approach to rehabilitation of children with cerebral palsy. Thus, in particular, successful kinesitherapy [10] extracorporeal shock wave therapy [11] used alone or in combination with pharmacological therapy [12], have obviously promising results for children with cerebral palsy [13].

CASE REPORT

A girl M., 17 years old, was a patient under observation. The diagnosis was cerebral palsy, right spastic hemiplegia (consequences of perinatal lesion of the central nervous system); psychomotor and communicative retardation; condition after birth trauma (intraventricular hemorrhage) with hypoxia and coma during the neonatal period.

Rehabilitation care was given on the base of the Municipal Institution «Zalishchyky Children's Medical Rehabilitation Center» in Ternopil region.

From the medical and life history, it is known that the child was born from a complicated pregnancy with gestosis and the threat of premature birth. The childbirth was rapid followed by newborn asphyxia, Apgar score 3/5 points. Neonatal diagnosis included severe hypoxic-ischemic lesion of the central nervous system (II degree coma (7 days), convulsive syndrome), birth trauma (intraventricular hemorrhage). During the first years of life, formation of motor, communicative and cognitive skills was retarded.

At the time of the last visit to the doctor, there is a restriction of active movements in the right limbs with muscle hypertonicity. When assessing with the modified Ashworth scale – 2 points [14]. The gait is unsteady with support on the outer edge of the foot. There are disorders of fine motor skills of the right hand and retarded speech development. Assessment of pain intensity is 2 points.

The neurological status includes right spastic hemiparesis manifested in increased muscle tone, contractures in the right limbs, and pathological foot reflexes. The patient's gait is with elements of "mower's foot", instability when standing on the right leg, right-sided weakness in the upper limb, and limited fine motor skills. Significant decline in cognitive functions includes impaired ability for abstract thinking, learning difficulties in particular. Speech characteristics: severe dysarthria, limited vocabulary, difficulty in constructing complex sentences.

Social status. The child studies according to an individual program in inclusive education. She needs help in performing complicated routine skills. Nevertheless, self-care is partially acquired due to early rehabilitation treatment, and the patient has been undergoing rehabilitation courses at this institution since the age of three. Psychological-emotional state is characterized by emotional lability. The girl gets exhausted easily, needs constant psychological support. Her family (legal representative) takes an active part in the rehabilitation process.

Considering the history data, objective examination, age, nature of the disease, degree of disorders, and social-economic conditions of the family, a multidisciplinary team was involved consisting of a pediatrician, neuropathologist, orthopedist, psychologist, speech therapist, physical therapist, and an individual plan of rehabilitation care was made.

The current rehabilitation plan consisted of:

1. Physical therapy:
   – kinesitherapy, postisometric relaxation, Bobath elements (reduction of spasticity, neurodevelopmental approach);
   – training with an occupational therapist (improvement of the right hand functions, self-care training);
   – individual training in exercise therapy 5 times a week (exercises for stretching, coordination, balance, muscle strengthening);
   – hydrorehabilitation (training in the pool twice a week) [15];
   – therapeutic massage;
   – the use of orthopedic correctors or orthoses;
   – hippotherapy.
2. Physiotherapy:
   – magnetic therapy on the lumbar-sacral region to reduce spasticity;
   – paraffin applications on the right hand;
   – electric stimulation of muscles-antagonists.
3. Cognitive-speech correction:
   – speech therapy (work with a speech therapist-pathologist to improve articulation, expand vocabulary and verbal understanding);
   – work with a neuropsychologist focused on the development of memory, attention, and logical thinking;
   – support of social communication skills.
4. Pharmacological therapy:
   – muscle relaxants;
   – neurometabolic therapy;
   – symptomatic treatment of anxiety and sleep disorders.
5. Psychological support:
   – ogical-educational work, participation in lessons).
6. Socialization and education:
   – inclusive education according to adapted program;
   – preparing for the transition to adulthood;
   – training with a social worker.

Considering the current plan of the rehabilitation care we have determined the tasks and aims for the period of the rehabilitation course. They included hypertonicity reduction of the adductor and flexor muscles, strengthening of the weakened muscles, improvement of mobility in joints, stabilization of a correct posture, and improvement of walking and balance.

Rehabilitation prognosis was partially favorable. The course of the rehabilitation treatment: On admission, the patient's condition was of moderate severity. She complained of postural disturbances, unstable gait, uncontrolled movements, retarded psychic and communicative development (Fig. 1).

In the first days of the rehabilitation course, the patient undergoes training using an active suspension system. Physical therapy training uses the system of partial unloading of body weight. The figure shows a fragment of the rehabilitation session. The patient is fixed in the suspension system providing her support in the vertical

Fig. 1. The initial stage of gait restoration using a suspension system

Picture taken by the authors

Fig. 2. Restoring independent walking skills using support rails

Picture taken by the authors

position and partial unloading of the lower limbs while walking. Under supervision of a physical therapy specialist, the patient trains her movement skills and restoration of walking function. There is special rehabilitation equipment in the room: balancing platforms, sensory hemispheres, balls and exercise devices for developing coordination, proprioception and general motor skills (Fig. 2).

The patient is doing exercises in a vertical position with a partial support of the parallel rails. Postural control, walking stability and reducing the need in external assistance are seen. The specialists correct the position of the upper limbs and control her walking. This stage in rehabilitation is indicative of gradual adaptation to self-locomotion.

The patient's general condition became better on the 9th day of the rehabilitation course. The child is able to maintain a correct body position (posture) during 2 minutes. She walks twenty meters independently without any aids of support or assistance from outside (Fig. 3).

The patient continues doing exercises along the rails with minimal support from therapists. She is more confident in

Fig. 3. The stage of walking training with support

Picture taken by the authors

Fig. 4. The final stage of the rehabilitation course – restoration of walking with minimal external assistance

Picture taken by the authors

performing movements, and her coordination and stability with loading become better too. Such dynamics is indicative of a high effectiveness of an individual rehabilitation course and achieving goals defined within the limits of the individual rehabilitation program (Fig. 4).

On the 13th day of the rehabilitation course, the patient's general condition is satisfactory. The girl maintains a correct posture during 7 minutes. She walks the distance of 50 meters independently without any aids and support. Her functional state is significantly better. Her posture is stable, steps are symmetrical, and the upper and lower limbs take an active part in walking, which is indicative of the formation of a stable walking stereotype and improvement of the quality of locomotion.

The rehabilitation course includes:

1. Physiotherapy – 180 min;
2. Stimulating therapy – 100 min;
3. Therapeutic exercises – 360 min;
4. Ultrasound therapy – 100 min;
5. Therapeutic manipulations or therapeutic massage – 240 min;
6. Hydrotherapy – 360 min;
7. Thermotherapy – 360 min;
8. Training skills of self-care – 180 min;
9. Training skills of maintaining the posture (mobility) of the body movements – 180 min;
10. Training skills of maintaining health – 180 min.

The rehabilitation course lasted 14 days and included realization of an individual program of physical therapy developed according to the patient's clinical condition and regulations of the individual rehabilitation program.

The principal tasks of the program were:

- Optimization of trophic and functional state of tissues;
- Gradual increase in load on the cardiovascular system;
- Increase in static and kinematic load on the muscular-skeletal system focusing on the muscles of the back and lower limbs;
- Activation of proprioceptive sensitivity by means of special sensory-motor exercises;
- Doing exercises in open and closed kinematic chains;

- Correction of the posture and improvement of walking patterns;
- Training coordination and speed of changing direction.

The results of the rehabilitation course are indicative of a significant positive dynamics of the patient's clinical condition. Muscle spasticity reduced, postural control improved, walking pattern became stable and general motor activity increased. According to the modified Ashworth scale, muscle tone decreased to 1+ point, which is indicative of a moderate spasticity compared to the state on admission (it was 2 points). According to the visual analog pain scale (VAS), the degree of pain was 1 point, which corresponds to insignificant discomfort or its absence. It is also indicative of a positive dynamics of treatment, since on admission the assessment according to this scale was 2 points.

The goals defined by the individual rehabilitation program are achieved. Assessing the effectiveness of rehabilitation intervention – "improvement". Considering the dynamics of the functional state and the potential for further development, repeated rehabilitation courses during a year according to individually determined intervals are recommended.

CONCLUSIONS

Rehabilitation of children with organic pathology, cerebral palsy etc. is an important and at the same time complicated process requiring a comprehensive approach and individual plan. Rehabilitation helps restore or improve physical health, stabilize psychological condition of a child and its social adaptation, which is an important issue in achieving a positive effect from the rehabilitation process.

It is valuable that the rehabilitation process is ongoing and includes the involvement of a multidisciplinary team as well as support from the family or legal representatives. Only in this case, can maximum results be achieved in restoring children's health.

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VARIA

Summary of the 2nd National Scientific Conference 'Complementary Disciplines of Physiotherapy' John Paul II University in Biala Podlaska, 22nd and 23rd May 2025

Joanna Baj-Korpak, Monika Kadłubowska, Kamil Zaworski, Dominika Wysokińska

On 22nd and 23rd May 2025, the 2nd National Scientific Conference 'Complementary Disciplines of Physiotherapy' took place in Biala Podlaska. The organiser of this event was Department of Physiotherapy of John Paul II University in Biala Podlaska. The conference was held under the honorary patronage of the Rector of John Paul II University in Biala Podlaska, Prof. Jerzy Nitychoruk, PhD, and the President of the National Council of the Polish Society of Physiotherapy, Prof. Andrzej Myśliwiec, PhD. The event was organised under the media patronage of the journal "Acta Balneologica".

Scientific Committee:

President:
associate prof. Elżbieta Rutkowska, PhD – John Paul II University in Biala Podlaska

Members:
prof. Andrzej Myśliwiec, PhD – President of Polish Society of Physiotherapy
prof. Krystyna Chmiel, PhD – John Paul II University in Biala Podlaska
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Elżbieta Horoszewicz, PhD Eng. – University of Siedlce
Marian Stelmach, PhD – John Paul II University in Biala Podlaska

Organising Committee

President:

Joanna Baj-Korpak, PhD – John Paul II University in Biala Podlaska

Members:

Dominika Wysokińska, PhD – John Paul II University in Biala Podlaska
Kamil Zaworski, PhD – John Paul II University in Biala Podlaska
Monika Kadłubowska, MA – John Paul II University in Biala Podlaska
Justyna Chmiel, PhD – Medical University of Lublin
Kamil Chołuj, PhD – Medical University of Lublin
Renata Rzeczkowska, MA – secretary – John Paul II University in Biala Podlaska

The conference was opened with an introductory word by the President of the Scientific Committee, associate prof. Elżbieta Rutkowska, PhD, together with the Rector, Prof. Jerzy Nitychoruk, PhD.

The proceedings began with a plenary session, which included three presentations.

- associate prof. Beata Jurkiewicz, PhD, MD – Head of the Department of Paediatric Surgery and Urology, Centre of Postgraduate Medical Education, Warsaw
  'Urolithiasis in children as a civilisation disease. The latest minimally invasive treatment techniques',
- Anna Morawska-Borowiec, MA – President of the Board of the 'Faces of Depression' Foundation
  'Faces of depression. I do not judge. I accept',
- Krzysztof Robaczyński, MA – 'Fuga Mundi' Foundation
  'Selected professional aspects of activating people with disabilities'.

On the first day, papers were presented in two scientific sessions in which the authors covered a range of topics, including communication with a patient, medical-legal aspects of professional confidentiality, psychological mechanisms in the activation of people with disabilities, the role of rehabilitation in the process of returning consciousness to comatose patients, social attitudes of Polish and Ukrainian students towards wheelchair users, motor activation, contemporary trends in rehabilitation, including robotics in rehabilitation and other issues. After each scientific session, there was time for discussion and talks during which the participants highlighted the high level of the papers presented.

Following the scientific sessions, the conference participants had the opportunity to take part in one of the two offered workshops:

- *Low Pressure Fitness – a form of core muscle training using specific breathing techniques,*
- *Augmentative and Alternative Communication (AAC).*

At the end of the first day of the conference, the conference participants were invited to a dinner. This social gathering was an opportunity to engage in an exchange of ideas and strengthen inter-university ties.

The next day's proceedings consisted of three sessions – including one poster session aimed at young scientists (students and PhD students). The scientific session covered topics in animal-assisted therapy and physiotherapy of animals, oncological prehabilitation, implementation of mobile rehabilitation teams in Ukraine, technical/engineering support for physiotherapy and many other topics.

During the poster session, 20 posters were presented, whose authors discussed therapeutic problems in their selected cases. The session included a competition with prizes. The competition committee distinguished the poster 'The influence of complex rehabilitation with the use of modern technology on step length and TUG test results in patients after ischaemic stroke' by Marek Piela and Maciej Tomik.

Representatives of Medical Universities, University of Szczecin, University of Warmia and Mazury in Olsztyn, University of Siedlce, University of Lower Silesia in Wroclaw, University of Bialystok, Jerzy Kukuczka Academy of Physical Education in Katowice, International Academy of Applied Sciences in Lomza, East European Academy of Applied Sciences in Bialystok, Ivan Horbachevsky Ternopil National Medical University, Lesya Ukrainka Volyn National University, Clinic for Adults 'Budzik' in Warsaw, Centre of Postgraduate Medical Education in Warsaw, St. Jadwiga Queen Clinical Regional Hospital No. 2 in Rzeszow, 'Fuga Mundi' Foundation, 'Faces of Depression' Foundation, and practitioners from Poland and abroad participated in the exchange of views and experiences in the field of physiotherapy, animal assisted therapy, psychology and pedagogy.

The official summary and conclusion of the proceedings was made by the President of the Scientific Committee, associate prof. Elżbieta Rutkowska, PhD, together with the President of the Organising Committee, Joanna Baj-Korpak, PhD.

It should be noted that the 2nd National Scientific Conference 'Complementary Disciplines of Physiotherapy' was organised as part of a project subsidised by the state budget, awarded by the Minister of Science within the framework of the Excellent Science II Programme. Amount of funding: PLN 58,410.00, total value of the project: PLN 65,010.00 – in accordance with the agreement number KONF/SP/0105/2024/02.

The exhibitors, journals and publishers promoting the conference were also a huge support of the event: Indiba, FizjoActiv, MedenInmed, BTL, Astar, MÓWik, Publishing House of John Paul II University in Biala Podlaska, ALUNA Publishing House.

On behalf of the conference organisers, we would like to thank all the speakers and numerous participants.

We warmly invite you to participate in future editions of the conference.

Wielka Księga Balneologii, Medycyny Fizykalnej i Uzdrowiskowej

Tom I Część ogólna

Tom II Część kliniczna

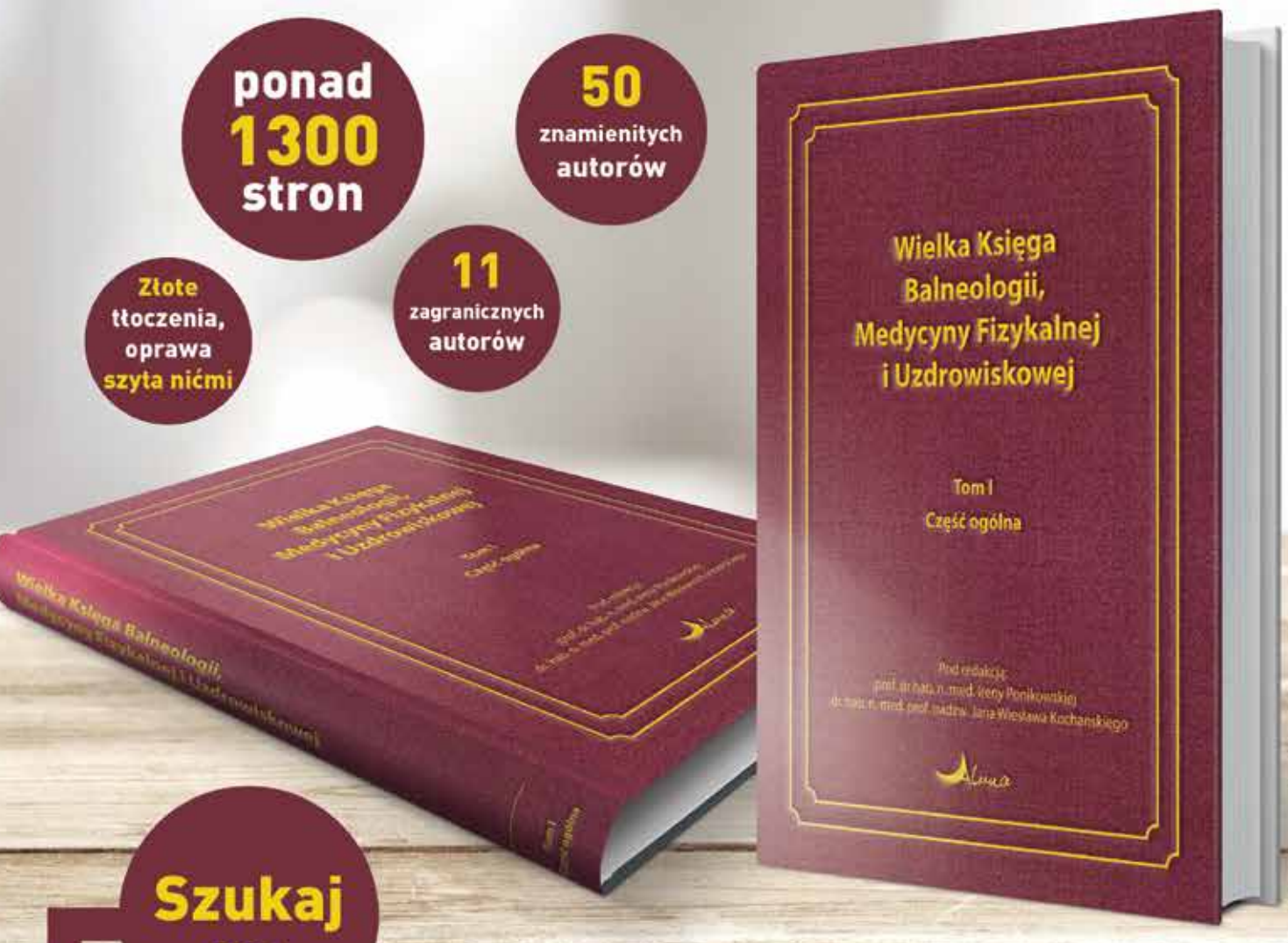
Pod redakcją:
prof. dr hab. n. med. Ireny Ponikowskiej
dr. hab. n. med. prof. nadzw. Jana Wiesława Kochańskiego

ponad 1300 stron

50 znamienitych autorów

11 zagranicznych autorów

Złote tłoczenia, oprawa szyta nićmi



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